Understanding the Environmental Risks of Unplanned Discharges – the Australian Context: Social Values

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Abstract

This paper summarises the current state of knowledge regarding social consequences of unplanned hydrocarbon releases in Australia, with specific objectives to: a) describe the key social values which are potentially susceptible to impact from unplanned discharges; b) discuss potential consequences of impacts from unplanned discharges on social values, and capacity to recover; and, c) describe the broad aspects of each social value, which may affect their susceptibility to impacts from unplanned discharges.

The key social values and their attributes of relevance to unplanned discharges have been identified as:

- fisheries and aquaculture
  - provision of edible seafood, including value of commercial and recreational fishing and contribution to livelihoods and community
- recreation and aesthetic
  - coastal and marine tourism, including enjoyment of coastal environment and importance to coastal tourism
  - public health, including direct and indirect effects of exposure; physical and mental health
- cultural and spiritual
  - coastal and marine species and places of significance to indigenous or non-indigenous peoples
- industrial uses
  - industrial water use, including use of seawater for desalination and cooling water
  - oil and gas producing assets
  - ports, harbours and shipping.

Commercial fisheries and aquaculture operations in Australian waters provide a high level of contribution to the economy, through their generation of revenues and employment. Together with recreational and traditional fisheries, they also make a substantial contribution to livelihoods and the social and cultural values of coastal communities. Aspects of fish biology that may affect potential impact and recovery of populations upon exposure to hydrocarbons and hence the consequences for human well being include: direct toxicity and physical effects, whether the species is demersal or pelagic, the timing and sensitivity of the species life stages, and potential changes in habitat. The most pronounced effects of unplanned discharges suffered by fisheries and aquaculture operations are not necessarily loss of stock or closure of fisheries, but rather the contamination of seafood leading to tainting and subsequent loss of market demand. Consumer confidence that fisheries and aquaculture products are no longer tainted (brand reputation) may be just as important to industry recovery as replenishment of stock.

Similarly, coastal tourism is a major business sector of the Australian economy driven by visitation to attractive natural resources of the Australian coastline (e.g. beaches, reefs). Human use values associated with coastal tourism and recreational activities involve both the intrinsic gratification of those participating in the activity, and the employment of those supporting the activity (for example charter or tour operators). Impacts on the natural resources driving visitation - either loss of access, aesthetics, reputation or loss of the resource itself - can lead to a loss of visitors and associated business activity. The proximity of tourism areas or 'hubs' in Australia, as well as the timing or seasonality of tourist activities, and availability of substitute sites (or activities), are key factors in assessing the potential impact of unplanned hydrocarbon discharges. Recovery of tourism and recreational activities depends on the success and timing

of cleanup activities and restoration of natural assets that draw visitors, as well as brand reputation of the impacted area.

Public health considerations in the impact assessment of unplanned hydrocarbon discharges include both direct effects (such as skin contact irritation, inhalation of vapours, and ingestion of contaminated water or seafood) and indirect effects (such as impacts on the mental health of those impacted, or involved in the cleanup or suffering consequential losses, e.g. fishers who lose access to a livelihood). This paper provides reference to Australian guidelines that are useful to the assessment of public health risk associated with contaminated water and seafood.

Cultural and spiritual values must be considered in the social impact assessment of unplanned hydrocarbon discharges; and may relate to a range of uses and issues including animals and plants associated with water, spiritual relationships, customary use, recreational activities and significant sites in the landscape. Identification and assessment of Australian Indigenous traditional fisheries (including fishes, turtles, crocodiles, dugong and other species) in a hydrocarbon spill area is very important from the perspective of potential impacts not only on food sources, but also the traditional fishing knowledge systems.

Other human activities and uses of the services provided by the marine environment may be affected by unplanned hydrocarbon discharges, such as those associated with port and harbour facilities or the industrial use of seawater. The level of impact will be determined by the hydrocarbon plume trajectory in terms of proximity to ports or industrial seawater intakes, as well as the particular seawater quality specifications required by the affected industry. The consequences of industrial impacts are typically financial and economic losses associated with loss of operability.

Recovery and/or mitigation of impact will be influenced by the duration of persistence of the hydrocarbon plume, as well the ability of the individuals, businesses and industry to adapt to the changed environment.

1. Introduction

1.1 Background

Most of Australia's oil and gas production comes from offshore fields where extraction, processing and shipment of product either remains entirely offshore or is connected to onshore or island facilities via pipelines. The risk of unplanned discharges from Australian petroleum production and associated infrastructure is mitigated by strong regulation and industry engineering and process standards. Management and preparedness planning for accidental petroleum discharges focuses on potential impacts on ecological receptors; however, the effects on human wellbeing of such changes in the marine and coastal environment also require consideration.

The offshore petroleum industry operates within a complex and uncertain, linked socio-ecological marine system, in which understanding human impacts and behaviour can be as important as understanding natural processes (Liu et al. 2007; Österblom et al. 2013). While the importance of understanding and managing human dimension impacts from major spill events is globally well-recognised, they receive little systematic attention in oil spill contingency plans or in determining the allocation of resources to initial response efforts to alleviate impacts (Lord et al. 2012, Hayward Walker 2014). The aim of this paper is to provide a current state of knowledge review of the social consequences of oil spills within the Australian context.

1.2 Objectives and scope

The objectives of this white paper are to:

a) Describe the key Australian social values (e.g. fisheries, aquaculture, tourism, recreation, industrial water use) which are potentially susceptible to impacts from unplanned discharges.
b) Discuss potential consequences of impacts from unplanned discharges on social values, and capacity to recover (including reference to lessons learned from recent unplanned discharges in Australia and elsewhere).
c) Describe the broad aspects of each social value, which may affect their susceptibility to impacts from unplanned discharges (e.g. seasonality or important constituents of fisheries/aquaculture/tourism/recreation).

This white paper forms part of the Australian Petroleum Production and Exploration Association (APPEA) project *Understanding the Environmental Risks of Unplanned Discharges – the Australian Context,* which is part of an update to the Blue Book series (Swan et al. 1994). The focus of this white paper on social rather than environmental considerations of unplanned hydrocarbon releases is unique in the series and reflects the importance of embedding management of the human dimension of the marine and coastal socioecological system in sectoral risk assessment and response plans.

The APPEA project is primarily concerned with better understanding the consequences of unplanned discharges from oil and gas infrastructure. Compared to ship-sourced spill events, unplanned petroleum discharges from oil and gas installations in Australia are infrequent and typically comprise relatively low volumes (< 1000 L; May 1992, AMSA 2015). Of the 44 major oil spill events recorded in or near Australian waters since 1970 (release amounts ranged from ~1 to 17 280 tonnes), only the 2009 Montara wellhead release (~4750 tonnes) originated from an oil platform wellhead blowout, while the majority of others (38) occurred as a result of shipping incidents (AMSA 2015). Literature concerning impacts on Australian social values from ship-sourced spill events is sparse, and from oil and gas installations is mainly limited to the 2009 Montara event (which occurred in the Timor Sea off the northern coast of Western Australia, and

did not impact upon the Australian mainland coastline; APASA 2010). This white paper therefore largely draws from the international literature on the potential consequences of unplanned discharges on human use and on social values, and theorises how these may relate to the Australian context. The potential for social values of neighbouring countries (e.g. Indonesia, East Timor) or within international waters are not discussed, but may feasibly need to be considered in relation to the zone of influence of some unplanned petroleum discharge scenarios. Further, while Australia is expected to become the world's chief exporter of gas, very little is known about the environmental fate or impacts of gas condensate, and therefore this paper does not address this question.

Social values are highly subjective to the person or group of people holding them, and may vary in geography and over time (Ogier and Macleod 2013). It is not the intent of this paper to attempt to detail social values across all Australian jurisdictions from all perspectives now and into the future. Nor does this paper describe the consultation process required to determine whose values should be given standing or priority. Rather, the paper provides key considerations of social values to assist the locally-specific decision-making required in the assessment of, and response to, unplanned discharges.

The economic consequences of unplanned discharges in terms of direct cleanup costs, fines, damages, compensations and litigation expenses have purposely been excluded from the scope of this paper. Environmental accounting and ecosystem services approaches may usefully inform consequential effects on social values (e.g. as applied to the Deepwater Horizon incident, NRC 2013; and in general by Chang et al. 2014); however it is beyond the remit of this paper to detail these methods. Also, this paper does not directly discuss issues of 'social licence to operate' within Australian waters of the oil and gas industry, which generally requires demonstration of adequate custodianship within or adjacent to environmentally or socially sensitive areas (such as the Great Australian Bight, Great Barrier Reef or Ningaloo Marine Park). In this respect, the influence of public media (including social media) may be very important to consider. Demonstration of oil spill preparedness planning to protect sensitive environmental and social values will assist operators' social licence.

1.3 Key social values

A useful framework for defining the social values of marine and coastal environments is provided by the National Water Quality Management Strategy (ARMCANZ & ANZECC 1998), which is the main mechanism for water quality management in Australia. Environmental agencies and other stakeholders use the National Water Quality Management Strategy to protect agreed environmental values (ANZECC and ARMCANZ 2000a) that include the inherent value of a healthy ecosystem, as well as the social values of:

- fisheries and aquaculture
- recreation and aesthetics
- industrial water use
- cultural and spiritual.

This paper discusses the attributes of each social value that are of relevance to the assessment of potential consequences of impact from unplanned discharges, as outlined in Table 1.1.

Table 1.1 Social value attributes of relevance to unplanned discharges evaluated in this paper

Key social values	Attributes of relevance to unplanned discharges	Section of paper
Fisheries and aquaculture	Provision of edible seafood – including value of commercial and recreational fishing and contribution to livelihoods and community	Section 2
Recreation and aesthetic	Coastal and marine tourism, including enjoyment of coastal environment and importance to coastal tourism	Section 3
	Public health, including direct and indirect effects of exposure; physical and mental health	Section 4
Industrial uses	Uses of seawater, e.g. for desalination and cooling water	Section 5
	Allocation of coastal waters to ports, harbours and shipping; oil and gas producing assets	Section 6
Cultural and spiritual	Coastal and marine species and places of significance to indigenous or non-indigenous peoples	Section 7

2. Australian Fisheries and Aquaculture

2.1 Key fisheries and aquaculture operations

Key fisheries and aquaculture operations in Australia are potentially susceptible to unplanned hydrocarbon discharges from neighbouring petroleum production activities. For detailed information on all reportable fisheries and aquaculture operations in Australia, the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) Australian fisheries and aquaculture statistics (ABARES 2014) provides a useful source and is updated regularly. Commonwealth and State fisheries departments also provide publicly available information on the geography and stock assessment of fisheries and aquaculture operations.

In 2012–13, the gross value of Australian commercial fisheries was $1.4 billion and aquaculture production was $1 billion (ABARES 2014). A high level overview of employment in fisheries and aquaculture operations, together with the most valuable species in each Australian jurisdiction, is provided in Appendix A. Salmon aquaculture in Tasmania is the most valuable operation in Australia ($489 million during 2012–13), followed by the western rock lobster fishery in Western Australia ($237 million) and southern bluefin tuna aquaculture in South Australia ($153 million; Appendix A). When all other commercial operations in these three states are included, together they comprised two thirds of Australian gross production in 2012–13. The combined value of fisheries and aquaculture in New South Wales, Victoria and the Northern Territory ($257 million) accounted for < 10% of Australian production.

While changes in production net revenue is one measure of potential loss to fisheries or aquaculture from an oil spill, production net revenue does not always correlate to other measures of economic and social value, such as indirect and flow-on economic value, employment or contribution to livelihoods and community. For example, Queensland is estimated to employ 20% of fisheries and aquaculture workers in Australia, yet only produces 12% of the country's commercial value in the sector (Appendix A). The ratio of commercial production value to employment participation will depend on factors such as relative profitability (i.e. some species require less catch or production effort per dollar profit), and whether seafood processing occurs in Australia or receiving markets. Whether being assessed by production or employment, it is essential to note that locally-important commercial fisheries of lesser value than those included in Appendix A occur in each jurisdiction.

In addition to potentially disrupting commercial fishing and aquaculture, hydrocarbon spills may also affect recreational and customary fishing activities. In Australia, recreational fishing carries considerable societal and economic benefits, contributing ~$1.8 billion to the economy in 2005 (ABARES 2014). A large part of this estimate was derived from the recreational boating and coastal tourism industries that derive benefit from recreational fishing activities, such as charter tours (see Section 3); however, the retail purchase of bait and tackle also contributed 10–30% of the economic value of recreational fishing (ABARES 2014). Beyond the economic value and employment associated with recreational fishing, each year the activity provides a leisurely pastime to an estimated 3.4 million Australians, which must be considered as a very important social value (ABARES 2014). Furthermore, many Indigenous Australians consider customary fishery species to hold significant cultural and spiritual value, in addition to providing a food source (ABARES 2014); and this concept extends to all communities whose way of life helps define their identity (Webler and Lord 2010) (further discussed in Section 7).

2.2 Aspects affecting potential impact and recovery of fisheries and aquaculture operations

Aspects of fish biology that may affect potential impact and recovery of populations following exposure to hydrocarbons are important to understand, and are detailed in a separate project white paper (Westera & Babcock 2015). In summary, the key aspects include (Westera & Babcock 2015):

- Direct impacts of hydrocarbon exposure – toxicity of various oils and dispersed oil mixtures on fishes, and physical exposure leading to acute (e.g. fish kills) or chronic (e.g. fish tainting) impacts.
- Demersal versus pelagic fisheries – due to the comparative persistence of hydrocarbons in the benthic environment compared to overlying waters, demersal fisheries (associated with the seabed) may be more susceptible to ongoing exposure and impact from unplanned discharges than pelagic fisheries. Further, site-attached demersal fishery species may be more susceptible than mobile demersal species that may be able to avoid impacted areas.
- Sensitivity of life stages – the timing of a spill event in relation to the reproductive stage of a fishery or aquaculture species may be important in determining impact. The sensitivity to hydrocarbon compounds of a fish species' different life-stages can vary.
- Changes in habitat due to hydrocarbon exposure – modification or loss of habitat supporting fisheries or aquaculture operations.

The following discussion considers the potential implications of unplanned hydrocarbon discharges on the human use values of fisheries and aquaculture operations.

2.2.1 Loss of stock

Direct exposure and acute toxicity of hydrocarbons to fish can cause mortalities and loss of fisheries and aquaculture stock (ANZECC and ARMCANZ 2000b, Westera & Babcock 2015). The Australian experience of fish stock losses from unplanned hydrocarbon discharges is limited. The 2009 Montara unplanned discharge event occurred in the vicinity of the Commonwealth's Northern Demersal Scalefish Managed Fishery (including goldband snapper, red emperor, and other high-value fish), the Mackerel Interim Managed Fishery, the Northern Shark Fishery, and a recreational sailfish fishery (Burns et al. 2011). While a number of sensitive animals were known to have been directly killed by the released oil (DSEWPAC 2011), widespread fish kills were not reported and it was presumed that stock losses were minimal (the impact assessment instead focussed on potential chronic impacts and tainting; see Section 2.2.2). Internationally, there is variability among study findings regarding fish stock response to large scale hydrocarbon releases. For example, acute catastrophic losses were largely avoided following the 2010

Deepwater Horizon incident in the Gulf of Mexico, whereas the 1989 Exxon Valdez incident off the coast of Alaska triggered a 5 year collapse of the local herring fishery (summarised in Westera & Babcock 2016).

2.2.2 Loss of condition – seafood tainting

The most pronounced effects of unplanned discharges suffered by fisheries and aquaculture operations are not necessarily the immediate short-term mortality events (loss of stock), but rather the contamination of seafood leading to tainting (ANZECC & ARMCANZ 2000b, ITOPF 2011). Tainting is described as the off-odour/flavour of seafood flesh from exposure to some components of oil including phenols, BTEX components and some metals (ANZECC & ARMCANZ 2000b). Seafood tainting may be caused by direct exposure to hydrocarbons, or indirectly from the contamination of fishing or aquaculture equipment. Tainting of fish flesh was tested following the Montara discharge event, and olfactory analysis did not identify any differences in species collected from areas exposed to hydrocarbons compared to non-exposed areas (with the exception of red emperor sampled immediately following capping of the well, but not thereafter; Rawson et al. 2011).

Moreover, seafood may be 'safe to eat' but not necessarily taint-free (see Section 4). The public are typically highly cautious in consuming seafood that does not look or smell 'right', and ITOPF (2011) notes that:

- seafood being taint-free is widely considered by the public to be the default criteria for being safe to eat (since contaminant levels at which humans detect oil taint are very low)
- the repercussions of public perception of contaminated seafood can be serious, unless the issues of market confidence and public health are well managed.

Closure or suspension of fisheries and aquaculture operations are more likely to be associated with precautionary food safety management and preservation of seafood brands, than direct product mortality (Chang et al. 2014). Similarly, the avoidance of recreational or traditional fisheries may be more likely due to perceived or real tainting of seafood. Following the 2009 Montara event, the commercial fishing fleet were advised by regulators to avoid fishing in oil-affected waters, and commercial fishers voluntarily undertook operations outside the affected area (Burns et al. 2011). Unless catches in unaffected areas are able to offset 'closed' fishery areas, the associated seafood processing and wholesaling industries may suffer from lower production (Chang et al. 2014). Potential disruption to the supply chain and upstream processing of fisheries and aquaculture products should also be considered. Replenishment of aquaculture operations with untainted stock, or a switch to a less-preferred species, will likely be associated with commercial impact.

2.2.3 Geographic considerations

Geographically, the risk of unplanned petroleum exposure to individual fisheries or aquaculture operations will need to be assessed on a case-by-case basis within the predicted zone of influence from source discharges. Aquaculture operations are more geographically concentrated than wild fisheries, which may reduce the likelihood, but increase the consequence, of exposure to unplanned petroleum discharges. For example, most southern bluefin tuna in Australia are caught in the Great Australian Bight, and delivered to aquaculture farms off Port Lincoln in South Australia for fattening (ABARES 2014). The likelihood of a small portion of tuna being exposed to a moderate spill in the Bight may be high, but the commercial consequences on the overall population of tuna would be low – conversely, the likelihood of a spill affecting the exact location of aquaculture farms may be low, but the commercial consequences would be far greater. Similarly, fish stocks with limited geographic ranges (e.g. sheltered embayments) will be more

susceptible than those with larger ranges (e.g. open-ocean pelagic species) (Westera & Babcock 2015). Terrestrial-based aquaculture operations are obviously at negligible risk, unless clean seawater supply is required and affected (see Section 5).

2.2.4 Synergistic effects

Any assessment of fisheries or aquaculture stock abundance and condition following an unplanned hydrocarbon discharge event will need to consider synergistic effects such as (ITOPF 2011):

- natural spatiotemporal variability of the stock
- (over)fishing pressure prior to the event
- other sources of contamination such as industrial and stormwater inputs
- short-term climactic events and long-term climate change (Norman-López et al. 2011).

2.2.5 Recovery of fisheries and aquaculture

An account of the capacity for fish assemblages to recover following exposure to hydrocarbons is provided by Westera & Babcock (2015), who suggest:

- recovery of fish stocks will depend on the level of exposure to potential toxicants, as determined by the intensity and duration of an unplanned discharge, the composition of the discharge and whether dispersants were used
- small-scale impacts where adult fish can migrate into an adjacent area may recover in the short-term, unless habitat has been affected
- where larger areas are impacted and repopulation must take place via larval recruitment, recovery may take longer, depending on the life cycles of affected species
- species that are short-lived, highly fecund and abundant may recover rapidly
- less abundant, long lived, predatorial fish may take longer to recover
- recovery of site-attached demersal fishes may take longer than mobile demersal and pelagic fishes
- recovery may be delayed if there is residual oil in the sediment
- recovery would not be complete until fishes have re-established within a natural range of variation expected for that habitat
- timeframes for recovery vary significantly.

While the above summary provides a good synopsis of the potential for recovery of fish stocks, the recovery of commercial, recreational or traditional fisheries and of their associated economic, social and cultural values may not follow the same trajectory. Further assessment of recovery in the sense of the human use value of fisheries and aquaculture needs to consider:

- whether contamination is reduced to a level of 'seafood safe to eat' and/or not tainted
- if aquaculture operations can and have been re-stocked
- consumer confidence and demand for the fisheries or aquaculture product has returned to pre-impact levels (which may not be immediately realised, even if the product is no longer tainted; ITOPF 2011).
- the ability to switch effort to alternate, non-impacted geographic locations and/or target species (Webler and Lord 2010).

3. Coastal Tourism and Business

3.1 Australian coastal tourism

The coastal tourism industry underpins key social values which must be considered when assessing the potential consequences of unplanned hydrocarbon discharges. Tourism is a major business sector of the Australian economy, contributing 2.7% to Gross Domestic Product and 4.6% (534 000 persons) to national employment in 2013/14 (ABS 2014). Annual expenditure by tourists during this period was estimated at $113 billion, of which 76% was derived from domestic tourism and recreation (ABS 2014). Research by Tourism Australia (2015a) indicates that the Australian coastline is a major driver of overall tourism activity, with two thirds of international visitors experiencing coastal environments in some way. Over 80% of the Australian population live within 50 km of the coast, and domestic tourism and recreation (including leisure activities, day trips and overnight stays) are similarly concentrated on coastal and marine activities (Pforr et al. 2007, ABS 2014, Tourism Australia 2015a,b).

The beaches and marine biodiversity along Australia's long coastline and associated marine wildlife experiences rank amongst the most appealing attractions to international and domestic visitors alike (Tourism Australia 2015a,b). Specific recreational activities of importance include fishing, surfing, diving, relaxing, nature appreciation, birdwatching, boating and camping. Specific areas of importance include beaches, marine reserves and coastal national parks (Kenchington 1993, Jones and Buckley 2001, Pforr et al. 2007, Tourism Australia 2015b).

3.2 Potential impacts of unplanned hydrocarbon discharges on coastal tourism and guidance for assessment

Human use values associated with coastal tourism and recreational activities involve both the intrinsic gratification of those participating in the activity and the employment of those supporting the activity. Unplanned hydrocarbon discharges thus have the potential to disrupt individual and societal use and enjoyment of the coast, as well as the livelihoods and economy derived by tourism operators, accommodation providers and retailers. Chang et al. (2014) suggest that loss of visitors and associated business revenue from oil spills is due to loss of:

- attractive natural resources (e.g. beach, reefs, coastline)
- access to attractive natural resources
- amenity or aesthetics of attractive natural resources
- reputation (brand damage) relevant to attractive natural resources.

For example, loss of beach access, amenity and/or perceived enjoyment may be a key reason for holiday-makers and recreational users alike to avoid an area impacted by hydrocarbons, with tourism operators and local business that partially or wholly rely on beach visitation suffering reduced revenue (Cirer-Costa 2015). The commercial impact may extend beyond the directly impacted zone of recreational use, and include transport operators and real estate value (Chang et al. 2014). The magnitude of impact may be dependent on the ability of those associated with the tourism industry to adapt to substitute activities or sites (Webler and Lord 2010).

Some guidance for the assessment of the aesthetic recreational use of marine water quality is provided by the Australian *Guidelines for Managing Risks in Recreational Water* (NHMRC 2008), which state that:

> *"Recreational water bodies should be aesthetically acceptable to recreational users. The water should be free from visible materials that may settle to form objectionable deposits;*

floating debris, oil, scum and other matter; substances producing objectionable colour, odour, taste or turbidity; and substances and conditions that produce undesirable aquatic life".

The guidelines advise that assessment of consumer complaints may be useful in determining the suitability of waters for recreational use (NHMRC 2008). Monitoring of complaints following an unplanned hydrocarbon discharge may also be useful in broader assessment of the impact on touristic values.

3.3 Factors affecting impact and recovery of coastal tourism

Coastal tourism, recreation and business is dependent on the aesthetics and quality of the natural resources that promote visitation (e.g. the beach, marine environment and water quality, reef ecosystems, 'charismatic megafauna', shorebird populations). These natural resources are typically susceptible to impact from unplanned hydrocarbon discharges. In determining potential impacts on tourism, it is important to determine which aspects of the coastal ecosystem are responsible for drawing visitors. Understanding the specific attraction/s of coastal areas facilitates a more considered assessment of their susceptibility to damage from hydrocarbon discharges, and subsequent effects to tourism, public recreation and associated businesses (i.e. known dive sites, surf spots, favoured swimming areas, popular fishing locations, walk trails, sightseeing locations etc).

The proximity of coastal tourism precincts to offshore oil and gas infrastructure is a key factor in determining susceptibility to impacts from unplanned hydrocarbon discharges. For example, the point of hydrocarbon release from the Montara wellhead was ~200 km offshore of the Australian coastline with 99% of the discharge estimated to remain within a radius of 82 km, such that the incident did not directly impact upon the mainland (APASA 2010). Notwithstanding, some impacts to tourism activity associated with recreational fishing and diving charters to the nearby Ashmore Reef and Scott Reef shoals may have occurred, and brand damage to regional tourism may also have occurred following domestic and international media coverage of the Montara event.

The timing or seasonality of particular tourist activities (e.g. summer/winter, wet/dry season attractions) will also influence the severity of disruption from a hydrocarbon discharge event, as will the duration of discharge.

Recovery of tourism and recreational activities will depend on both the success of cleanup activities and restoration of natural assets that draw visitors, as well as brand reputation of the impacted area. Further, the overall impact and recovery of associated human wellbeing will be influenced by the ability of individuals, businesses and industry to adapt to the changed environment or switch to substitute tourism activities or sites.

4. Public Health

Public health considerations in the impact assessment of unplanned hydrocarbon discharges include the direct effects of skin contact irritation, ingestion of contaminated water or seafood and inhalation of vapours, as well as indirect effects such as impacts on the psychological health of those involved (Moore & Burns 2011, Chang et al. 2014). Consequential economic effects on health care costs may also need to be considered (Moore & Burns 2011, Chang et al. 2014).

4.1 Exposure to contaminated water

The National Water Quality Management Strategy recognises two types of recreational exposure pathways to potentially contaminated water (ANZECC & ARMCANZ 2000a):

- Primary contact recreation – activities such as swimming, bathing and other direct water-contact sports. Potential health effects from exposure may arise from ingestion or skin contact, but the visual clarity of water should also be sufficient to protect the safety of swimmers.
- Secondary contact recreation – activities such as boating and fishing where there is less body contact with the water. Potential health effects from exposure may arise from occasional skin contact. In practice, primary contact guidelines are often adopted as a conservative approach to management of secondary contact recreation.

Regardless of the exposure pathway, the *Guidelines for Managing Risks in Recreational Water* (NHMRC 2008), state that:

> "*Water contaminated with chemicals that are either toxic upon ingestion or irritating to the skin or mucous membranes are unsuitable for recreational purposes. The frequency, extent and likelihood of exposure are crucial parts of assessing the risk from a contaminant. If it is probable that contamination is occurring and there is significant exposure of users, chemical analysis will be required to support a quantitative risk assessment. The assessment should consider both the expected dose and the expected frequency of exposure*."

In terms of assessing risk to public health from ingestion of contaminated water arising from an unplanned hydrocarbon discharge, NHMRC (2008) recommends the Australian Drinking Water Guidelines for toxicant concentrations in water. The drinking water guideline values have recently been updated (NHMRC & NMMERC 2015), and are based on an assumption of 2 L consumed per day. Ingestion from primary and secondary contact recreation activities will be much lower than daily drinking water consumption, and NHMRC (2008) suggests dilution of the drinking water guideline levels may be appropriate for a determination of guideline toxicant concentrations in recreational water (e.g. based on water consumption of 100–200 mL per day).

A water quality risk assessment based on ingestion pathways and guidelines will likely be conservatively protective of health effects from skin contact and irritation. However, ANZECC & ARMCANZ (2000a) advise that special care must be taken in the assessment of toxicants that may be absorbed via the skin. Furthermore, while recreational users may avoid contaminated areas, workers involved in cleanup activities may be more at risk of skin exposure to hydrocarbon discharges and other chemicals used in the cleanup. In a review of the international literature on oil spill health effects on workers, Moore & Burns (2011) observed that unless this risk is appropriately managed, skin exposure to hydrocarbons and other chemicals used in the cleanup may result in skin reddening, swelling, burning, follicular rashes, drying of the skin, infections, dermatitis, folliculitis, eye irritation and other allergic reactions.

4.2 Inhalation of hydrocarbon vapours

Inhalation of vapours arising from hydrocarbon discharges can also affect human health and exacerbate pre-existing conditions (Moore & Burns 2011, Chang et al. 2014). Volatile organic compounds comprise irritants that can vaporise and cause chronic respiratory illnesses such as asthma, emphysema or chronic obstructive pulmonary disease (Moore & Burns 2011). Spill workers may again be particularly at risk, with several studies showing an increased prevalence of respiratory symptoms and persistent airway injury in response workers, indicating that inhalation of hydrocarbon vapours can be detrimental to public health (Moore & Burns 2011). Effective occupational health and safety procedures to manage risks to workers from hydrocarbon inhalation are imperative in any clean up response (e.g. ensuring the use of masks and/or breathing apparatus).

4.3 Ingestion of contaminated seafood

Tainting of seafood from hydrocarbon exposure was discussed in Section 2.2.2, where it was noted that even if seafood are safe to eat, a precautionary approach of 'no consumption' is usually applied by both consumers and managers of fisheries and aquaculture operations. Notwithstanding, Food Standards Australia New Zealand provide strong guidance on the safe consumption of seafood, including the specification of 'maximum residue limits' permissible for contaminants in seafood (FSANZ 2006). These guidelines may offer a useful tool in the assessment of potential impacts from unplanned hydrocarbon discharges on seafood safety.

Following the 2009 Montara event, Burns et al. (2011) monitored the tissue of fish for persistent polycylic aromatic hydrocarbons (PAHs) and concluded that the fish sampled probably would have been safe to eat, since petroleum hydrocarbons were not detected (with the analytical limit of reporting < 10 µg kg^{-1}). In comparison, they noted that the persistence of PAHs in fish tissue described within international literature following several ship grounding oil spills ranged from 1.3 to 14 000 µg kg^{-1}.

4.4 Mental health

The mental health of individuals involved in unplanned hydrocarbon discharge events may be impacted, with flow-on impacts to societal values (Moore & Burns 2011, Chang et al. 2004). Stress caused by loss of employment or income to affected parties (e.g. grounded fishers or local tourism operators), as well as trauma suffered by abatement workers, has been documented to lead to an increased prevalence of anxiety and depression disorders (Moore & Burns 2011). For example Gill et al. (2012) compared the mental health impacts of the 1989 *Exxon Valdez* oil spill and the 2010 Deep Horizon oil spill and found high levels of psychological stress associated with both disasters. Stress levels correlated with concerns for family health, the strength of commercial ties to renewable resources, and concern about economic future, economic loss, and exposure to the oil (Gill et al. 2012). Further, unhealthy responses to manage stress, anxiety or depression (e.g. alcohol consumption and/or drug abuse) may create further social impact (Chang et al. 2014).

5. Industrial Use of Seawater

Many industries rely on a supply of clean seawater for activities such as desalination and cooling water operations, including the mining, processing and manufacturing sectors, water and electrical utilities (for both domestic and industrial use), and the oil and gas sector itself. Solar salt production from seawater is also a significant industry in the warmer, high evaporation areas of South Australia and the northwest of Western Australia. The National Water Quality Management Strategy (ANZECC & ARMCANZ 2000a) recognises the industrial use of sea water as a key social value, with an objective to maintain water quality to be fit for industrial purpose. Unplanned hydrocarbon discharges may contaminate seawater inputs required for industrial use (Chang et al. 2014), but the level of impact will be determined by:

- the particular water quality specifications required by the affected industry, e.g. cooling water may require a lower level of water quality than desalination water intended for human consumption
- the anticipated hydrocarbon plume trajectory, both in relation to proximity of industry and the location of the intake within the water column.

The consequences of impact on industry are typically financial losses associated with shut down of operations, additional scrubbing or filtering of water, and/or cleaning of process equipment. However, for some industries there may also be impacts on brand and future sales. Recovery

and/or mitigation of impact will be influenced by the duration of persistence of the hydrocarbon plume, and whether an alternate water supply may be easily sourced.

6. Ports and Harbours

Ports and harbours represent coastal locations that have been allocated to service recreational and commercial marine transport activities and associated industries. Port closures associated with unplanned hydrocarbon discharge events are rare and mainly associated with loss of vessel containment, but may nevertheless cause disruption to marine transport activities such as shipping, pleasure cruising and ferry activities (Chang et al. 2014). Port and harbour siting and traffic throughput are important considerations when assessing potential consequences. It is noted that most working ports in Australia have dedicated oil spill contingency plans in place. Ports and harbours are often associated with recreational and tourism use, which are sensitive to impact from large unplanned hydrocarbon discharges (see Section 3).

In specific relation to unplanned hydrocarbon discharges from oil and gas infrastructure, perhaps the ports and harbours most susceptible to impact are those associated with the petroleum industry itself. The shipping of products to market and marine transport of supplies to support exploration and production activities often requires dedicated port and harbour facilities, located in close proximity to extractive and processing facilities. Impact assessment of unplanned discharges should therefore consider potential disruption to the supply chain and shipment to market.

Coastal and marine naval defence bases and infrastructure may also be considered a social value to be protected, although there is very little relevant literature on the potential consequences of unplanned spills. Potential disruption to defence activities and capabilities should also be considered.

7. Cultural and Spiritual Values

7.1 Indigenous values

Cultural and spiritual values of Indigenous Australians connected to marine and coastal environments may relate to a range of uses and issues including animals and plants associated with water, spiritual relationships, customary use, recreational activities and significant sites in the landscape (Collings 2012). Cultural and spiritual values must be considered in the social impact assessment of unplanned hydrocarbon discharges, and protection of these values is a key aim of the National Water Quality Management Strategy (ANZECC & ARMCANZ 2000a).

Identification and assessment of traditional fisheries (including fishes, turtles, crocodiles, dugong and other species) in a hydrocarbon spill area is important from the perspective of potential impacts not only on food sources, but also the traditional fishing knowledge systems that are central to many cultural, ceremonial and social events (ABARES 2014). Fishing is an important educational tool in Indigenous communities, enabling the inter-generational passing on and practice of traditional ways (ABARES 2014). Spiritual relationships with non-fished animals and plants are similarly important to identify, and require recognition in social impact assessment (Collings 2012).

Specific guidelines for marine and estuarine water quality to protect cultural and spiritual values of Indigenous Australians are yet to be developed. However, it is often deemed that the protection of ecosystem, recreational, fishing and aesthetic values of water bodies offers some assurance towards protecting the fauna, flora, habitats and recreation values of cultural and

spiritual importance (ANZECC & ARMCANZ 2000a). In this respect the ANZECC and ARMCANZ (2000a) Guidelines for Fresh and Marine Water Quality offer a useful tool in assessing 'acceptable' hydrocarbon associated contaminant levels in potentially impacted areas.

7.2 Non-indigenous values

Similar to Indigenous Australians, many non-indigenous Australians consider the coastal and marine environment to hold significant cultural and spiritual value; and their way of life of on the coastal fringe helps define their identity (Webler and Lord 2010). Further, the presence and protection of maritime heritage values, including shipwrecks and other archaeological or historic sites should be considered in any local assessment of the potential consequences of unplanned discharges from oil and gas producing infrastructure.

8. Conclusions

Unplanned hydrocarbon discharges associated with the offshore petroleum industry occur within a complex and uncertain, linked socio-ecological marine system, in which understanding human impacts and behaviour can be as important as understanding natural processes.

Commercial fisheries and aquaculture operations in Australian waters are valuable and provide a high level of employment. Recreational and traditional fisheries are also of substantive social value. Aspects of fish biology that may affect potential impact and recovery of populations upon exposure to hydrocarbons include direct toxicity and physical effects, whether the species is demersal or pelagic, the timing and sensitivity of the species life stages, and potential changes in habitat. Ultimately, potential impacts on stock volume and condition affect commercial production of fisheries and aquaculture operations. The most pronounced effects of unplanned discharges suffered by fisheries and aquaculture operations are not necessarily loss of stock, but rather the contamination of seafood leading to tainting. Consumer confidence that fisheries and aquaculture products are no longer tainted (brand reputation) is just as important to industry recovery as replenishment of stock.

Similarly, coastal tourism is a major business sector of the Australian economy. Human use values associated with coastal tourism and recreational activities involve both the intrinsic gratification of those participating in the activity and the employment of those supporting the activity. Attractive natural resources of the Australian coastline (e.g. beach, reefs, coastal parks) promote visitation, and impacts on those resources (loss of access, aesthetics, reputation or loss of the resource itself) can lead to a loss of visitors and associated business revenue. Recovery of tourism and recreational activities depends on the success of cleanup activities and restoration of natural assets that draw visitors, as well as brand reputation of the impacted area.

Public health considerations in the impact assessment of unplanned hydrocarbon discharges include both direct effects (such as skin contact irritation, inhalation of vapours, and ingestion of contaminated water or seafood) and indirect effects (such as impacts on the mental health of those involved).

Cultural and spiritual values must be considered in the social impact assessment of unplanned hydrocarbon discharges, and may relate to a range of uses and issues including animals and plants associated with water, spiritual relationships, customary use, recreational activities and significant sites in the landscape.

Other activities of human use value may be affected by unplanned hydrocarbon discharges, such as marine transport associated with port and harbour facilities, and industrial use of seawater.

Recovery and/or mitigation of impact to pertinent social values will be influenced by the duration of persistence of the hydrocarbon plume, as well the ability of the individuals, businesses and industry to adapt to the changed environment.

While this paper has provided an overview of possible social consequences of unplanned petroleum discharges, further work is needed to (i) better understand potential impact pathways on social values, (ii) identify appropriate indicators and methods to determine the magnitude of possible impacts to social values and (iii) actions to mitigate social impacts.

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Appendix A

2012/2013 commercial production value of fisheries and aquaculture operations, key species, and 2011 estimated employment value by Australia jurisdiction

Commercial value (m) of fisheries and aquaculture[1]	Estimated employment[2]	Key species by value[3]	Production value (m)
Tasmania			
$696 (29%)	2265 (16%)	salmonids (aquaculture)	$489
		abalone	$97
		southern rock lobster	$65
		oyster (aquaculture)	$23
South Australia			
$441 (19%)	2306 (17%)	southern bluefin tuna (aquaculture)	$153
		southern rock lobster	$86
		prawns	$30
		abalone	$30
		oysters (aquaculture)	$35
Western Australia			
$427 (18%)	1748 (13%)	western rock lobster	$237
		pearls (aquaculture)	$79
		prawns	$26
		tropical snapper	$13
		finfish (aquaculture)	$13
Commonwealth waters			
$320 (13%)	ND	prawns	$75
		tuna	$59
		flathead	$24
		tropical rock lobster	$20
		gummy shark	$16
		blue grenadier	$16
Queensland			
$277 (12%)	2790 (20%)	prawns	$64
		prawns (aquaculture)	$57
		coral trout	$25
		crabs	$30
		barramundi (aquaculture)	$20
		rock lobster / bugs	$18
New South Wales			
$124 (5%)	2700 (20%)	oysters (aquaculture)	$36
		prawns	$17
		sea mullet	$7
Victoria			
$75 (3%)	1700 (12%)	abalone	$26
		southern rock lobster	$17
		abalone (aquaculture)	$11
Northern Territory			
$58 (2%)	283 (2%)	pearls (aquaculture)	$21*
		mud crab	$6
		gold band snapper	$5
		barramundi	$4**

Notes:

1. Values in parentheses indicate percentage of Australian gross commercial production value
2. Values in parentheses indicate percentage of Australian estimated employment, including seafood processing and wholesaling
3. Key species are from fisheries operations unless otherwise indicated.
4. ND – not determined; * – 2010/11 value; ** – does not include barramundi production from aquaculture (estimated at $8m in 2011/12)

Source: ABARES (2014)