Australian Government
Great Barrier Reef Marine Park Authority

Sea snakes

Information valid as of Feb 2012

Summary

Diversity

Sixteen species from the subfamily Hydrophiinae but only 14 species maintain permanent breeding populations in the Great Barrier Reef Marine Park (the Marine Park).

Susceptibility

High mortality from trawl by-catch.

Major pressures

Commercial fishing, climate change, coastal development and declining water quality.

Cumulative pressures

Sea snakes associated with inshore habitats are exposed to cumulative pressures resulting from climate change, coastal development, declining water quality and in some locations incidental by-catch from the trawl fishery. These pressures are likely to impact on sea snakes directly and the habitats and prey species they rely on.

Management in the Great Barrier Reef and adjacent areas in Queensland

Legislative management tools for the conservation of sea snakes in the Great Barrier Reef World Heritage Area (the World Heritage Area) include the *Environment Protection and Biodiversity Conservation Act 1999*; *Great Barrier Reef Marine Park Act 1975*; *Fisheries Act 1994* (Qld); *Nature Conservation Act 1992* (Qld).

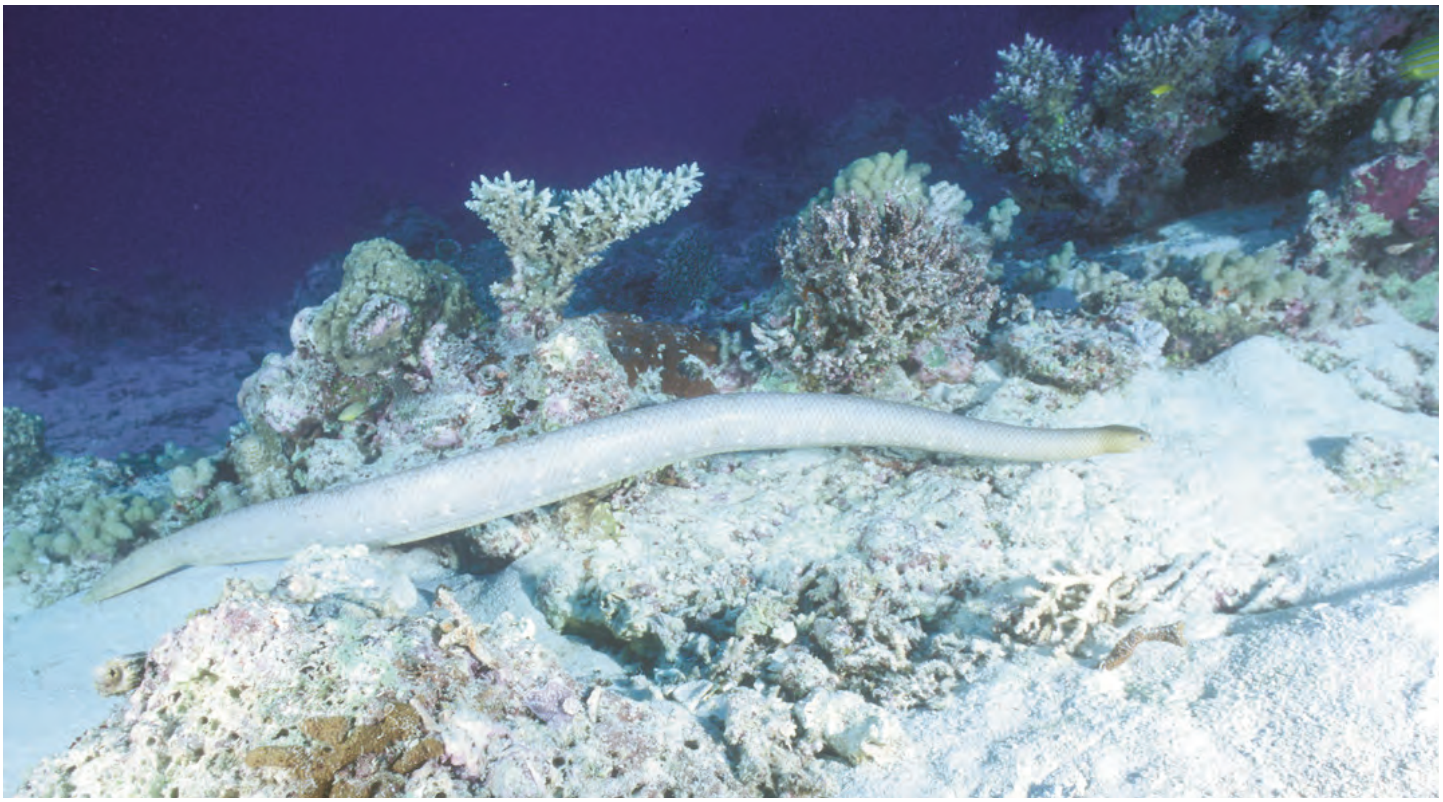
Existing management actions

A number of management arrangements are in place in the World Heritage Area that 'operationalise' legislative management tools and provide additional guidance and/or strategic direction to Marine Park management operations. These include:

- The joint Great Barrier Reef Marine Park Authority (GBRMPA) and Queensland Government Field Management Program that enforces spatial protection provided by the *Great Barrier Reef Marine Park Zoning Plan 2003* (only 34 per cent of the Marine Park open to otter trawling)
- Queensland Government management arrangements under the East Coast Trawl Fishery (introduction of certain by-catch reduction devices in trawl apparatus to help reduce sea snake by-catch and mortality).

Great Barrier Reef Outlook Report 2009 assessment

Poor, with little information available on which to base the assessment grade.



Olive sea snake (*Aipysurus laevis*) in its reefal habitat

Vulnerability assessment: High, particularly in trawl grounds of the Marine Park.

- Species of sea snake likely to be impacted by climate change, coastal development and reduced water quality due to poor land-use practices are those dependent on shallow coastal habitats and coral reefs
- Various species of sea snake occupy shallow nearshore habitats, many of which are being degraded due to direct or indirect anthropogenic impacts
- There is some evidence to suggest that sea snake abundance has declined on some reefs in Australian waters, possibly due to habitat degradation[1]
- Commercial fishing logbooks substantially underestimate incidental catch (and subsequent mortality) of sea snakes
- Results from a joint Fisheries Research and Development Corporation/Department of Employment, Economic Development and Innovation (FRDC/DEEDI) funded research project (FRDC 2005/053) indicate that an estimated 105,000 sea snakes are caught as by-catch each year in the East Coast Trawl Fishery
- Sea snakes are air-breathers, so being captured in trawl nets can lead to significant mortality (as high as 37 per cent [2]). The level of mortality of sea snakes within trawls also depends on the depth of the trawl and weight and size of the catch (both of individual species and combined)
- The low reproductive output of sea snakes limits their potential for population recovery once they have been reduced
- Low dispersal capability of sea snakes reduces potential for re-colonisation of previously impacted areas
- Genetic analysis indicates that sea snakes exist as discrete meta-populations, such that heavy fishing pressure may have the potential to cause local depletions[3,4,5]
- A lot of our knowledge about sea snakes comes from fisheries research conducted using trawling as the capture method. This means there is very limited data for those species not captured by trawling, such as those species that are highly coral reef habitat-specific
- Very little information is available to determine the impacts of climate change on sea snakes in the World Heritage Area.

Suggested actions to address vulnerabilities

- Develop programs to better understand the cumulative impacts affecting sea snakes in inshore habitats
- Support and facilitate additional research on the life-history, reproduction, population stucture, distribution, abundance and habitat use of sea snakes to inform management of these species in the World Heritage Area. Attention needs to be placed on species determined to be at high risk to otter trawling in the Marine Park and on coral reef specific species for which there is a particular paucity of information
- Work with the Queensland Government, QSIA, commercial fishers and other stakeholder groups to develop and implement management arrangements that reduce the mortality of sea snakes while maximising catch. Such arrangements would include:
  - regularly review the proportion of the east coast trawl fleet fitted with the types of by-catch reduction devices (BRDs) that have been demonstrated to reduce sea snake by-catch and mortality. Consider means for increasing the uptake levels of these devices if levels are low (for example, the use of extension officers)
  - continue research to determine the most effective location for placement of BRDs
  - research the impact of short trawl times as a mechanism to further reduce sea snake mortality
  - consider measures to mitigate the impacts of trawling in areas that are known to yield high capture and mortality rates of sea snakes as determined by the Ecological Risk Assessment of the East Coast Otter Trawl Fishery[a] (for example, fishing effort controls,guided by accepable sustainable levels of fishery interaction with sea snakes and effective BRDs installed at appropriate distances within nets)
  - review the effectiveness of arrangements implemented to improve logbook reporting of sea snake by-catch
- Develop programs that investigate the impacts of climate change on sea snakes.

[a] This ERA process has been undertaken by GBRMPA, fishing industry representatives and the former Queensland Department of Employment Economic Development and Innovation (Fisheries Queensland) and is currently being finalised (as at April 2012).

Background

Brief description of sea snakes

Sea snakes, like other reptiles, have lungs to breath air. They also have all the attributes normally associated with terrestrial snakes, including a forked tongue and an integument of scales that are periodically shed.

There are two groups of sea snakes found in Australia – true sea snakes and sea kraits. The true sea snakes are the only group to have breeding populations in the Marine Park. The sea kraits (Genus *Laticauda*) occur as breeding populations in New Guinea, but there has been no verification of breeding populations in Australia: all records of *Laticauda* from the Marine Park seem to be of vagrant individuals.[6] True sea snakes are entirely marine in habit and never voluntarily leave the water, whereas the sea kraits regularly venture onto land to rest, hide on the shore and to breed.[7]

Most species of sea snakes are benthic foragers, feeding on crabs, fish eggs and demersal fish.[8] One species, *Pelamis platurus*, feeds predominantly on small pelagic fish towards the surface.[6]

Sea snakes are extraordinary divers, able to descend to depths of 100 metres and remain submerged for two hours or more. They surface to breathe air but supplement their oxygen and carbon dioxide exchange by cutaneous respiration while submerged.[1]

Sea snakes have low potential to produce young (i.e. low fecundity) compared to many marine animals and even compared to many terrestrial snakes. For example, the viviparous (live bearing) olive sea snake (*Aipysurus laevis*) attains sexual maturity at 4 - 5 years of age (three years for males) and reproduction probably only occurs every second year. In addition, gestation period is long (11 months) and clutch size is small (mean = 2.6).[6] In general, sea snakes court and mate in winter and give birth in summer.

Most sea snake species average between half a metre and a metre in total length when adult, but maximum sizes often exceed a metre. There is little data on the growth of sea snakes, but values of 0.1 – 0.5 mm per day seem likely.[6] Due to the cryptic behaviour of juvenile sea snakes, the apparent size structure of individuals in an area is not a good indicator of population status.

The Marine Park is situated within the global hotspot of sea snake diversity, which centres on the Indo-Australian Archipelago.[6] The high diversity of sea snake species within the Marine Park reflects a high diversity of micro-habitats that are used by the group. Some species occupy a range of habitats, while other species are restricted to particular habitats such as coral reefs, shoals, and muddy areas.[1]

Some reef dwelling sea snakes, such as *A. laevis*, have a definite home range (0.15 – 0.18 hectares) and appear not to move across narrow 'barriers' of unsuitable habitat.[3,6]

This indicates that unoccupied or previously depleted reefs may remain unpopulated by this species for a long time, being colonised only by the action of a storm or other infrequent event that transport sea snakes from a nearby inhabited reef.[3,9]

Olive sea snake (*Aipysurus laevis*). Note the nostril valves that open inwards and close to prevent sea water entering the lung while diving

Diets and habitats of sea snake fauna of the Great Barrier Reef and Coral Sea.[b]

Species	Habitat	Diet	Water depth	
Acalyptophis peronii - horned sea snake	Inter-reefal	Principally gobi fish; family *Gobiidae*	Deep	30 - 64 m
Aipysurus duboisii – Dubois' sea snake	Coral reefs, over seagrass or sandy habitats	Generalist feeder on various fish (may take occassional invertebrate)	Variable	2 - 10 m direct observation 18 - 55 m trawl by-catch
Aipysurus eydouxii – spine-tailed sea snake	Muddy bottoms; also in rivers and estuaries	Highly specialised; fish eggs only	Shallow	
Aipysurus laevis – olive sea snake	Coral reefs, rocky coasts and soft sediments	Generalist feeder on various fish (may take occassional invertebrate)	Variable	1 - 55 m
Astrotia stokesii – Stokes' sea snake	Eurytopic	Poorly known	Variable	
Disteira kingii – spectacled sea snake	Inter-reefal	Generalist feeder on various fish (may take occassional invertebrate)	Deep	
Disteira major – olive-headed sea snake	Inter-reefal over sandy and muddy habitats	Generalist feeder on various fish (may take occassional invertebrate)	Variable	1 - 43 m
Emydocephalus annulatus – turtle-headed sea snake	Coral reefs	Highly specialised; fish eggs only	Shallow	
Enhydrina schistosa – beaked sea snake	Muddy and sandy habitats; estuaries and creeks	Generalist feeder on various fish (may take occassional invertebrate)	Shallow	
*Hydrophis elegans** - elegant sea snake	Sandy and muddy habitats; also in estuaries	May be an eel-specialist	Shallow	1 - 18 m
*Hydrophis ornatus** - ornate reef sea snake	-	Poorly known (may feed principally on eels)	Deep	18 - 55 m
Hydrophis mcdowelli – small-headed sea snake	Sandy habitats	Poorly known (may feed principally on eels)	Deep	15 - 40 m
Lapemis curtus (synomous with *L. hardwickii*) – spine-bellied sea snake	Muddy and sandy habitats in turbid waters	Generalist feeder on various fish (may take occassional invertebrate)	Variable	1 - 40 m
Hydrophis pacificus – large-headed sea snake	Northern Great Barrier Reef soft benthic habitat	-	Variable	to 50 m
Pelamis platurus – yellow-bellied sea snake	Pelagic (may be a vagrant inhabitant of inter-tidal habitats)	Generalist feeder on various fish (may take occassional invertebrate)	Water surface	

* Two species identified as being at high risk to the impacts of otter trawling in the Marine Park

[b] Adapted from Heatwole and Lukoschek 2008.[1]

Geographical distribution

Australia has a rich diversity of sea snakes. They have a distribution which generally extends from southern Queensland northward around to the central coast of Western Australia.[6] Of the 32 species of true sea snakes found in Australian waters, 14 species maintain permanent breeding populations in the Great Barrier Reef Region.[1]

In general, species richness declines from north to south; all 14 species of Hydrophiines that breed in the Marine Park are known to occur in the northern Great Barrier Reef while only eight of these species are known to occur in the Swain Reefs (southern Great Barrier Reef).[2]

Some sea snakes are true reefal species, whereas others occur in deeper inter-reefal areas, or on rocky or muddy substrates between the Great Barrier Reef and the Queensland coast.

In the Marine Park, two species of sea snake are closely associated with coral reef habitats (*Aipysurus duboisii* and *Emydocephalus annulatus*) and two species are associated with coral reefs but are also found in other habitats (*Aipysurus laevis* and *Astrotia stokesii*); three species are found in inter-reefal areas (*Acalyptophis peronii*, *Disteira kingii* and *Disteira major*); five species are mainly from muddy or rocky coastal habitats; and one species, *Pelamis platurus*, is a pelagic surface-water species that is closely associated with oceanic convergence zones.[1,2,6]

Population status in the Great Barrier Reef Marine Park

No species of sea snake found in Australian waters is currently listed as threatened under Queensland or Australian legislation, but two species from the Ashmore/Hibernia Reef area in Western Australia (*Aipysurus foliosquama and A. apraefrontalis*) are currently nominated for listing as 'Critically Endangered' under the *Environment Protection and Biodiversity Conservation Act 1999*. All species of sea snakes are considered a 'listed marine species' under the *Environment Protection and Biodiversity Conservation Act 1999* and are 'protected species' under the *Nature Conservation Act 1992* and the *Great Barrier Reef Marine Park Act 1975*. Therefore, the direct harvest of sea snakes is prohibited.

While the broad distributions of most of the species have been documented, abundance estimates are only available for a few species, or for small parts of the Marine Park,[2] and there are relatively limited data on which to base population status assessments. This is partly due to logistical difficulties associated with directly counting sea snakes, and also because trawl by-catch studies provide little information on sea snake species that are closely associated with coral reef habitats.[2]

According to the *Great Barrier Reef Outlook Report 2009,*[10] there are 'serious concerns about the status of some species', although considerable uncertainty exists.

An ecological risk assessment of the East Coast Otter Trawl Fishery in the Great Barrier Reef Marine Park has identified two species of sea snakes of the genus *Hydrophis* (*H. ornatus*, the ornate reef sea snake and *H. elegans*, the elegant sea snake) as being at high risk to the impacts of otter trawling.

Ecosystem role/function

Most sea snakes species in the Marine Park are benthic foragers that inhabit shallow coastal habitats and coral reefs.[1] In some locations they are relatively abundant. However, data relating to their ecological role and to their influence on other components of marine ecosystems are lacking.

Ecosystem goods and services

Ecosystem goods and services category	Services provided by the species, taxa or habitat
Provisioning services (e.g. food, fibre, genetic resources, bio-chemicals, fresh water)	Sea snakes are used for food, leather and medicine in parts of southeast Asia, but they do not provide any direct provisioning services to humans in the Marine Park. In Queensland in the 1970s-1980s there was a leather fishery for sea snakes based on trawl by-catch. This included areas within the Great Barrier Reef Marine Park.
Cultural services (e.g. spiritual values, knowledge system, education and inspiration, recreation and aesthetic values, sense of place)	Sea snakes have significant cultural value to some coastal communities. For example, sea snakes are regarded as iconic marine wildlife at the Keppel Islands, and many tourist divers actually seek (and pay for) interactions with sea snakes. In some Indigenous communities, sea snakes are regarded as totems; they represent contemporary descendants of 'dreamtime' beings.[11] Sea snakes also contribute to the overall biodiversity of the Marine Park.
Supporting services (e.g. primary production, provision of habitat, nutrient cycling, soil formation and retention, production of atmospheric oxygen, water cycling)	While there are limited data on the ecological role of sea snakes, they are likely to provide nutrient cycling as secondary and tertiary level predators.
Regulating services (e.g. invasion resistance, herbivory, seed dispersal, climate regulation, pest regulation, disease regulation, natural hazard protection, erosion regulation, water purification)	The regulating services of sea snakes within marine ecosystems are unknown.

Dubois' sea snake (*Aipysurus duboisii*)

Pressures influencing sea snakes in the Great Barrier Reef Marine Park

Pressures

Sea snakes in the Marine Park are exposed to a range of pressures including fishing, coastal development, declining water quality and climate change. These pressures act on a range of different life history stages. A more detailed description of the range of pressures that impact on sea snakes in the Marine Park is provided in the vulnerability assessment matrix at Appendix 1.

Vulnerability assessment matrix

The *Great Barrier Reef Outlook Report 2009*[10] identified a number of commercial and non-commercial uses of the Marine Park, along with habitat loss and degradation as a result of climate change, coastal development and declining water quality due to catchment run-off as the key pressures reducing the resilience of the ecosystem.

From the *Great Barrier Reef Outlook Report 2009*[10] it was considered that pressures such as climate change, coastal development, catchment run-off and direct use are the key factors that influence the current and projected future environmental, economic and social values of the Great Barrier Reef. These pressures can impact directly and/or indirectly on habitats, species and groups of species to reduce their resilience. Using the vulnerability assessment framework adapted by Wachenfeld and colleagues,[12] this Vulnerability Assessment aims to provide an integrated assessment of social, ecological, economic and governance information. For each key pressure in the Marine Park, exposure and sensitivity is assessed in relation to each other to reach a level of potential impact. The potential impact is then reassessed having considered the level of natural adaptive capacity that sea snakes have to respond to the pressure and the adaptive capacity that management has, or can apply, to reduce the potential impact from the pressure.

This provides managers and stakeholders with an understanding of the key elements that each pressure can impose on the species group to reach a final assessment of the overall residual vulnerability of sea snakes to that particular pressure. This allows for the formulation of suggested actions to minimise the impact of the pressures which sea snakes are most vulnerable to.

A summary of the assessment of impacts is listed below, however, for the detailed assessment and explanatory notes refer to Appendix 1.

Vulnerability assessment matrix summary for sea snakes

		Exposed to source of pressure (yes/no)	Degree of exposure to source of pressure (low, medium, high, very high)	Sensitivity to source of pressure (low, medium, high, very high)	Adaptive capacity – natural (poor, moderate, good)	Adaptive capacity – management (poor, moderate, good)	Residual vulnerability (low, medium, high)	Level of confidence in supporting evidence (poor, moderate, good)
Pressures	**Commercial marine tourism**	No	Low	Low	Moderate	Good	Low	Poor
	Defence activities	Yes; locally	Low	Low	Moderate	Good	Low	Poor
	Commercial fishing	Yes; inter-reefal species	High*	High*	Poor	Moderate	High	Good
	Recreational fishing	Yes; developing coast	Low	Low	Moderate	Moderate	Low	Poor
	Ports and shipping	Yes; locally	Medium	Medium	Moderate	Moderate	Medium	Poor
	Recreation (not fishing)	Yes; developing coast	Low	Low	Moderate	Good	Low	Poor
	Traditional use of marine resources	Yes; locally	Low	Low	Good	Good	Low	Good
	Climate change	Yes	High	Medium	Poor	Moderate	Medium	Poor
	Coastal development	Yes; developing coast	Medium	Medium; predominantly nearshore species	Poor	Moderate	Medium; predominantly nearshore species	Poor
	Declining water quality due to catchment runoff	Yes; developing coast	Medium	Medium	Poor	Moderate	Medium	Poor

*The assessment of pressure on sea snakes from commercial fishing is specifically related here to the East Coast Otter Trawl Fishery. Although 34 per cent of the Great Barrier Reef Region is open to otter trawling, only a relatively small percentage of this is trawled more than once a year.[13] The level of impact with regard to the extent of trawling is little understood.

Key concerns

- Given that many sea snake species inhabit shallow coastal areas, these sea snake populations are most likely to be influenced by habitat degradation which results from coastal development, declining water quality and climate change.[14,15] Little is known about the biology and ecology of sea snakes. In particular, there is considerable uncertainty regarding the population status (including distribution and abundance) of sea snakes in the Marine Park. Such knowledge gaps make it difficult to quantify the extent of these impacts on sea snakes and to make informed management decisions with regard to them.
- Concern has been raised about the number of sea snakes taken as by-catch by the Queensland East Coast Trawl Fishery.[2,16] Although the Queensland Government monitors interactions between commercial fishers and protected species (including sea snakes) through mandatory logbooks, analysis of these logbooks indicate that fisher's under-report the catch and mortality of sea snakes by a factor of 30-40 times.[2]
- Results from a joint Fisheries Research Development Corporation / Queensland Department of Employment, Economic Development and Innovation funded research project (FRDC 2005/053) estimated that approximately 105,000 sea snakes are incidentally captured each year by the Queensland East Coast Trawl Fishery.[2] The red-spot king prawn sector accounted for 59 per cent of all sea snake catches and 85 per cent of all mortalities.
- Approximately 26 per cent of sea snakes that are caught in the fishery die, either in the nets, or in the hours and days after release.[2] Within the red-spot king prawn sector, which accounts for the greatest sea snake mortality within the East Coast Trawl Fishery, the combined within-trawl and post-trawl mortality is 37 per cent.[2] Despite relatively high annual catch rates, the beam trawl sector imposed no direct incidental fishing mortality, probably due to short trawl times.[2] This may indicate the effectiveness of reduced trawl times as a management tool.
- Results from the recently conducted ecological risk-assessment of the East Coast Trawl Fishery found that two species of sea snake, the elegant sea snake (*Hydrophis elegans*) and the ornate reef sea snake (*H. ornatus*) were at high risk to trawl activities in the Marine Park. The high risk status of these two species was assessed due to life history traits (long lived/low natural mortality, low fecundity-give birth to live young) that afforded them very little resilience to fishery impact factors such as the high level at which they interact with the fishery, low survival after interaction and the limited effectiveness of exclusion devices or by-catch reduction devices to increase their survival after interaction.
- Given the low reproductive potential of some sea snakes, it is likely that trawling-induced mortality may lead to (or has already caused) declines in abundance. In addition, given that current research indicates that sea snakes maintain discrete meta-populations, it is unlikely that areas where sea snakes have been depleted will recover quickly or be re-colonised from other areas.[9]
- There is concern that the rate of uptake of by-catch reduction devices which are effective at reducing the mortality of sea snakes may be low and that the positioning of those that are installed may have reduced effectiveness due to their positioning within the net which is critical.

Mitigation

- Additional research on the biology, ecology, population structure and habitat requirements of sea snakes is required.
- Courtney and colleagues[2] investigated the utility of BRDs for reducing catches of sea snakes by the trawl fishery. Results indicate that the fisheye BRD and the square mesh codend BRD reduce the catch rate of sea snakes by 63 per cent and 60 per cent respectively, with no significant reduction in the catch rate of marketable prawns. These two devices also significantly reduce the catch rates of other by-catch by 33 per cent and 31 per cent respectively. Although there was no significant difference between them, the fisheye BRD is likely to be more effective at excluding sea snakes because the small mesh size of the square mesh codend BRD will almost certainly prevent large sea snakes from escaping.
- Courtney and colleagues[2] recommend that the fisheye BRD be made mandatory in those sectors of the East Coast Trawl Fishery associated with high sea snake mortalities, particularly the red-spot king prawn sector. However, for the fisheye BRD to be effective, it must be installed close to the rear of the codend (i.e. within 50 meshes of the drawstring).[2] There is also evident utility in using square-mesh cod ends in the scallop trawling sector or even a combination of both fisheye and square-mesh cod ends in those sectors which would benefit from such devices. Roy and Jebreen[17] highlight the value of extension work on by-catch reduction (including for protected species) within the trawl fishery and recognise this as a priority that would benefit from continued support.

- Incidental capture of sea snakes in trawls is spatially variable. Therefore, a suggested action is for the impact of trawling in areas that are known to yield high capture rates of sea snakes be reviewed in line with an ecological risk-assessment (ERA) of this activity.[2c]
- Because the within-trawl mortality rate of sea snakes is directly related to the duration of the trawl,[18] it is also suggested that trawl times be minimised in areas where significant numbers of sea snakes are incidentally captured.

Management of sea snakes in the Great Barrier Reef Marine Park

Management agencies with responsibilities for managing these species or impacts on these species within the Great Barrier Reef World Heritage Area and the statutory and non-statutory tools that influence the conservation management of these species.

Legislation or policy	Object as it applies to the species	Tools for conservation	Who administers it
World Heritage Convention	• Four natural heritage criteria with associated conditions of integrity. Criteria focus on (i) geological processes and phenomena, including the evolution of the earth; (ii) ongoing ecological and biological processes; (iii) linked aesthetic components of the natural world; (iv) the biological diversity and habitats of threatened species • Natural heritage Criteria iv states that the natural heritage asset must contain the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.	• Provides State Parties to the Convention with definitions of natural and cultural heritage, measures for the protection of natural and cultural heritage; the means of administration and obligations of the Convention; funding arrangements, educational programs and reporting obligations.	United Nations Educational, Scientific and Cultural Organization (UNESCO)

Convention on Biological Diversity (CBD)	• The three main objectives of the CBD are:
	  • The conservation of biological diversity
	  • The sustainable use of the components of biological diversity
	  • The fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.
		• Provides State Parties to the Convention with global principles, objectives and obligations for the conservation of biodiversity
		• Guides Australia's strategic planning to achieve national priority actions for biodiversity conservation through a range of objectives and targets for each.
			United Nations Environment Programme (UNEP) – CBD Secretariat

Environment Protection and Biodiversity Conservation Act 1999 and *Environment Protection and Biodiversity Conservation Regulations 2000*	• Legislative framework for environmental protection in Australia • Provides means of assessment of 'actions' within Australian marine and terrestrial environments • Legislative role includes the listing and regulation of threatened and protected species and communities, the preparation	• Application of 'controlled action' regulation for Matters of National Environmental Significance as required • Assessment and export approval processes for all fisheries with an export component (or Wildlife Trade Operation) • Penalties for non-compliance	Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC)

[c] This ERA process has been undertaken by GBRMPA, fishing industry representatives and the former Queensland Department of Employment Economic Development and Innovation (Fisheries Queensland) and is currently being finalised (as at April 2012).

	of recovery plans for threatened and protected species, the identification of key threatening processes and, where appropriate, the development of threat abatement plans and recovery plans.	• Act is regularly reviewed.	
Guidelines for the ecologically sustainable management of fisheries -2007	• Provides guidance to the assessment of Australian fisheries that seek to operate with a Wildlife Trade Operation (WTO) accreditation under the *Environment Protection and Biodiversity Conservation Act 1999* • Sea snakes are protected species that are incidentally captured within the East Coast Trawl Fishery (ECTF), which is a fishery with a current WTO accreditation managed under the Queensland *Fisheries Act 1994*.	• Fisheries under *EPBC Act 1999* WTO assessment must demonstrate that they operate under a management regime that meets two principles. 1. A fishery must be conducted in a manner that does not lead to over-fishing, or for those stocks that are over-fished, the fishery must be conducted such that there is a high degree of probability the stock(s) will recover; and 2. Fishing operations should be managed to minimise their impact on the structure, productivity, function and biological diversity of the ecosystem.	DSEWPaC
Fisheries Act 1994 (Qld) and *Fisheries Regulation 2008*	• Provides the legislative framework and regulatory controls for managing fisheries in all Queensland waters and Commonwealth waters subject to the Offshore Constitutional Settlement for the state of Queensland.	• Prescribes authorised fishing gears and the way in which they may be used, including incorporation of exclusion devices and by-catch reduction devices • Prescribes the requirement for vessel movements to be monitored remotely • Provides temporal/seasonal regulation of fishing activities • Can potentially regulate on fishing practices such as trawl times • Compulsory logbook reporting for commercial fishers • Penalties for non-compliance.	Queensland Government
Great Barrier Reef Marine Park Act 1975 and *Great Barrier Reef Marine Park Regulations 1983*	• Legislative framework for the management of biodiversity conservation through zoning, issuing of permits and implementation of plans of management that collectively enable management of human activities.	• Regulation provides for the creation of Special Management Areas within the Marine Park • Regulation of scientific research in the Marine Park • Regulation of activities and development within the Marine Park • Regulation on the discharge of waste into the Marine Park • Penalties for non-compliance • Processes of review.	Great Barrier Reef Marine Park Authority (GBRMPA)
Great Barrier Reef Marine Park Zoning Plan 2003	• A multiple-use marine protected area management tool that protects biodiversity by the regulation of activities within the Great Barrier Reef Marine Park • The Representative Area Program that provided the basis for the Zoning Plan spatial planning decisions, described 70	• Spatial management of activities within the Great Barrier Reef based on protection of habitat type representative areas • Thirty three per cent of the Marine Park is dedicated as Marine National Park (green) zones in which no extractive	GBRMPA

	broad-scale habitats, or bioregions, and as such provides the basis for ecosystem-based management in the Marine Park.	activities are permitted • Trawling is only permitted in General Use (light blue) zones which cover 34 per cent of the Marine Park • Penalties for non-compliance • Processes of review.	
Marine Parks Act 2004 (Qld) *and Marine Parks Regulation 2006*	• The object of this Act is to provide for the conservation of the marine environment by: • declaring State marine parks • establishing zones, designated areas and highly protected areas within marine parks • developing zoning and management plans • recognising the cultural, economic, environmental and social relationships between marine parks and other areas • applying the precautionary principle.	• Aims to involve all stakeholders cooperatively • Coordination and integration with other conservation legislation • Penalties for non-compliance • Processes of review.	Queensland Government
Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004 (Qld)	• A multiple-use marine protected area management tool that protects biodiversity by the regulation of activities within the Great Barrier Reef Coast Marine Park • The Representative Area Program that provided the basis for the Zoning Plan spatial planning decisions, described 70 broad-scale habitats, or bioregions, and as such provides the basis for ecosystem-based management in the Great Barrier Reef Coast Marine Park.	• Spatial management of activities within State waters of the Great Barrier Reef based on protection of representative bioregions • Penalties for non-compliance • Complements spatial management zones and certain regulatory provisions established under the *Great Barrier Reef Marine Park Zoning Plan 2003.*	Queensland Government
Nature Conservation Act 1992 (Qld) and *Nature Conservation (Wildlife) Regulation 2006*	• Act provides for the conservation of nature, including wildlife, in Queensland jurisdiction • Sea snakes are listed protected wildlife under the Regulation.	• Prescribes protected native wildlife, their management principles and the management intent • Provides for the preparation of Conservation Plans for native wildlife and their habitat under Ministerial discretionary powers • No Conservation Plan for sea snakes currently exists • Penalties for non-compliance.	Queensland Government
Great Barrier Reef Biodiversity Conservation Strategy 2012	• Identifies sea snakes as a species 'at risk' in the Marine Park, particularly *Hydrophis ornatus* and *H. elegans* at high risk to otter trawling • Grades the level of risk experienced by sea snakes through a vulnerability assessment process.	• The Biodiversity Conservation Strategy outlines a Framework for Action with three strategic objectives aimed at building or maintaining ecosystem resilience and protecting biodiversity: 1. Engage communities and foster stewardship 2. Building ecosystem resilience in a changing climate 3. Improved knowledge • Objectives are comprised of	GBRMPA

		program-level outcomes with key actions and contain targets for measuring success • Implementation of the Strategy will be undertaken through a multi–agency, multi-stakeholder collaborative approach.	
Great Barrier Reef Climate Change Action Plan 2007-2012	• Identification of specific measures to enhance resilience of the Great Barrier Reef ecosystem and support adaptation by regional communities and industries that depend on it.	• Allocation of dedicated funding to implement actions to improve the resilience of the Great Barrier Reef ecosystem.	GBRMPA
Reef Water Quality Protection Plan 2009	• An overarching framework to achieve a sustainable future for the Great Barrier Reef and the industries in the Reef's catchment by improving water quality that flows into the Great Barrier Reef lagoon.	• Improve water quality that flows into the Reef by targeting priority outcomes, integrating industry and community initiatives and incorporating new policy and regulatory frameworks.	Joint Australian Government and State of Queensland initiative
Great Barrier Reef Protection Amendment Act 2009 (Qld)	• A framework for reducing the levels of dangerous pesticides and fertilisers found in the waters of the Great Barrier Reef by 50 per cent in four years.	• Mix of strict controls on farm chemicals and regulations to improve farming practices.	Queensland Government
Coastal Protection and Management Act 1995 (Qld) and *Coastal Protection and Management Regulation 2003*	• Provides the legislative framework and regulations for the coordinated management of the diverse range of coastal resources and values in the coastal zone. This framework includes provisions that establish the Queensland Coastal Plan.	• Queensland Coastal Plan outlines directions for effective protection and management of the coastal zone.	Queensland Government
Queensland Coastal Plan (prepared under the *Coastal Protection and Management Act 1995* and includes a state planning policy under the *Sustainable Planning Act 2009*)	• The Queensland Coastal Plan has two parts: State Policy for Coastal Management and the State Planning Policy 3/11: Coastal Protection (SPP).	• The State Policy for Coastal Management provides policy direction for natural resource management decision-makers about land on the coast, such as coastal reserves, beaches, esplanades and tidal areas • The SPP provides policy direction and assessment criteria to direct land-use planning and development assessment decision making under the *Sustainable Planning Act 2009*.	Queensland Government

Sustainable Planning Act 2009 (Qld) and *Sustainable Planning Regulation 2009*	• Establishes process for land-use planning and development assessments. Identifies state legislation that may be triggered by development assessments and the process by which developments must be assessed against each piece of legislation
	• Establishes the framework for the development of Regional Plans.
		• Regional plans operate in conjunction with other state planning instruments, usually taking precedence over them
		• Regional plans must conform to policies established within the Queensland Coastal Plan
		• Regional plans identify:
		  • desired regional outcomes
		  • policies and actions for achieving these desired regional outcomes
		  • the future regional land use pattern
		  • regional infrastructure
			Queensland Government

		provision to service the future regional land use pattern • key regional environmental, economic and cultural resources to be preserved, maintained or developed.	

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Appendix 1. Vulnerability assessment matrix

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Declining water quality due to catchment runoff**
Exposed to source of pressure **(yes/no)**	Yes*; locally	Yes; locally	Yes*; ECOTF – inter-reefal areas	Yes*; regionally	Yes; locally	Yes; regionally	Yes; locally	Yes	Yes*; predominantly developing coast south of Port Douglas	Yes*; regionally
Degree of exposure to source of pressure **(low, medium, high, very high)**	Low. Potential exposure within certain high-use regions of the Marine Park is high. However, Great Barrier Reef-wide exposure is low.	Low. A limited number of defence activities take place in the Marine Park that would impact on sea snakes. Potential for localised impacts when live-firing or detonating explosives.	High. High exposure of sea snake species to impacts of commercial fishing in the East Coast Trawl Fishery. Trawling limited to 33 per cent of the Marine Park and only ~6 per cent of the marine park is actively trawled. Exposure is spatially and temporally variable, with higher catches of sea snakes in some trawl sectors (such as the redspot king prawn sector).	Low. Low risk of exposure for sea snake species to both existing and potential impacts of recreational fishing.	Medium. Degree of exposure around ports is likely to increase as the need for further shipping increases within the Great Barrier Reef. There may be exposure to risk in high-use shipping lanes, but sea snakes would need to be at or close to the surface to be exposed to this risk. Impacts of ports combine cumulatively with other pressures affecting inshore habitats.	Low. Recreational activities within the Marine Park have a low, indirect impact on sea snake populations	Low. Anecdotal reports indicate that sea snakes are not captured and used as a marine resource by Traditional Owners.	High. High degree of exposure to the impacts of climate change, particularly through the effects of ocean warming and acidification on reef habitats[14] and extreme weather, sea level rise and ocean warming on inshore habitats.	Medium. Many sea snakes are dependent on coastal habitats for survival. Exposure of sea snakes as a group to the impacts of coastal development at a reef-wide scale is medium and limited to developing areas south of Port Douglas.	Medium. Variable/altered catchment run-off has potential to impact sea snake populations via the effects of habitat loss and impacts to prey populations in inshore areas.
Sensitivity to source of pressure **(low, medium, high, very high)**	Low. There is little indication that sea snakes are (or will be) impacted by commercial tourism activities across Great	Low. Sea snakes would be sensitive to detonation of explosives, but the number of events each year is very limited and	High. Total catch of sea snakes in the East Coast Trawl Fishery is estimated to be 105,000 per year. Trawl mortality can be as high as 37	Low. Sea snakes will take live-baits bottom-set for fish species by recreational fishers. This can result in the sea snakes	Medium. Some sea snakes have sensitivity to impacts from ports and shipping because they face habitat loss and degradation, and impacts upon	Low. Potential exists for boat-strike on sea snakes by recreational (not fishing) vessels. This is unquantified though and	Low. Limited exposure to extractive traditional use.	Medium. Sea snakes are likely to be sensitive to changes in water temperature and indirectly via direct effects to reef species if the fish communities	Medium – inshore species on developing coast. Low – elsewhere. There are limited data on the distribution of sea snakes in the Great Barrier Reef, but	Medium. There are limited data on the distribution of sea snakes in the Great Barrier Reef, but trawl by-catch data indicate some species are closely associated with

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Declining water quality due to catchment runoff**
	Barrier Reef-wide scales.	restricted to a very limited number of locations within the Marine Park.	per cent in some trawl sectors. There is some post-capture mortality recorded, which increases the combined mortality for sea snakes.	becoming hooked. However, anecdotal records indicate incidence of capture is low and most fishers cut the line without handling the sea snake. Post-capture mortality data unknown.	prey from port developments and diffuse pollution. Oil spills from shipping incidents have the potential to have significant impacts at the regional scale. Ports and shipping activities are focused around geographically-discrete locations meaning impacts associated with this pressure are considered to effectively apply at the local scale. However, with the extent of planned port expansions and developments in the Marine Park, the cumulative effects on populations will require consideration. Potential exists for boat-strike of sea snakes around ports and in major shipping channels/ shipping lanes, but extent and outcome of impacts is unquantified.	likely to be low.		they rely on for food are impacted by sea level rise.[14]	trawl by-catch data indicate some species are closely associated with inshore areas[2] where they are likely to be more sensitive to the impacts of coastal development.	near-shore areas[2] where they are likely to be more sensitive to the impacts of catchment run-off. Species associated with habitats further offshore are also likely to experience declining water quality impacts on habitat and prey availability over longer timeframes.

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Declining water quality due to catchment runoff**
Adaptive capacity – natural **(poor, moderate, good)**	Moderate. Data indicates low potential for sea snakes to disperse naturally. Therefore their capacity to adapt by avoiding or migrating out of high-use sites may be poor. However, limited exposure to this low impact pressure at Reef-wide scales provides a natural capacity for resilience against this pressure.	Moderate. Data indicates low potential for sea snakes to disperse naturally. Therefore their capacity to adapt by avoiding or migrating out of defence sites may be poor at localised scales. However, limited exposure to this pressure at Reef-wide scales provides a natural capacity for resilience against this pressure.	Poor. Data indicates low potential for sea snakes to disperse naturally. Therefore their capacity to adapt by avoiding or migrating out of commercial otter trawling may be poor. Sea snakes are relatively slow swimmers and seem to have limited capacity to avoid otter trawl nets. This makes them susceptable to incidental capture.	Moderate. Data indicates low potential for sea snakes to disperse naturally. Therefore their capacity to adapt by avoiding or migrating out of high-use recreational fishing sites may be poor. However, limited exposure to this low impact pressure at Reef-wide scales provides a natural capacity for resilience against this pressure.	Moderate. Data indicates low potential for sea snakes to disperse naturally. Therefore their capacity to adapt by avoiding or migrating out of port areas and major shipping channels/ shipping lanes may be low. Inshore species may be susceptible to habitat loss and degradation (noise, pollution, disturbance/ displacement, land reclamation, benthic degradation) as a result of expanded and new port developments. Although it must be considered cumulatively along with other impacts, limited exposure to this pressure at Reef-wide scales provides a natural capacity for resilience against the pressure.	Moderate. Limited exposure and sensitivity to this pressure but data indicates low potential for sea snakes to disperse naturally. Their capacity to adapt by avoiding or migrating out of high-use locations for boat traffic may be low.	Good. Limited exposure to extractive traditional use.	Poor. Sea snakes have a limited natural adaptive capacity to changes in sea temperature.[14] Many species are generalist feeders[8] so may be better able to adapt to changes in prey distribution and abundance. Specialist feeders with high habitat specificity (e.g. coral reefs) may have less adaptive capacity to climate change impacts on these ecological requirements. Otherwise there is limited information to address the natural adaptive capacity of sea snakes to climate change impacts.	Poor. There are no data on patterns of habitat use for sea snakes in the Great Barrier Reef. Some of the inshore associated species (such as *Enhydrina schistosa*) are specialist feeders[8] so are less likely to be able to exhibit natural adaptive capacity to coastal development. Other more generalist species found further offshore (such as *Lapemis curtus)*[8] are likely to be less impacted by coastal development.	Poor. There are no data on patterns of habitat use for sea snakes in the Great Barrier Reef. Some of the inshore associated species (such as *Enhydrina schistosa*) are specialist feeders[8] so are less likely to be able to exhibit natural adaptive capacity to the effects of catchment run-off. Other more generalist species found further offshore (such as *Lapemis curtus)*[8] may take longer to experience the impacts on trophic and habitat requirements due to poor water quality from catchment run-off, but may ultimately be as unable to adapt as inshore sea snake species.

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Declining water quality due to catchment runoff**
Adaptive capacity – management **(poor, moderate, good)**	Good. Management controls (e.g. spatial, temporal, and site-specific) could be considered if required and would be effective if sufficient support led to implementation	Good. Defence activities are well-managed and limited in extent, duration and geographic distribution. Could modify current practices should sea snakes become at risk from Defence activities.	Moderate. Different types of by-catch reduction device are being tested and financial incentives are offered for purchase and fitting of devices that have been tested and shown to be effective at reducing by-catch of sea snakes. Spatial and temporal closures could be considered as a management option should data become available that indicate that these would reduce the risk to sea snakes.	Moderate. Management controls (e.g. spatial, temporal, and site-specific) could be considered if required.	Moderate. Management controls (e.g. spatial, temporal, and site-specific) can be considered. However, the location of ports are difficult to change because of specific requirements. There is also a lack of information that can provide an understanding of how cumulative impacts from coastal development, including ports and shipping, are impacting populations of sea snakes and their supporting habitat in the Marine Park. This information is required to support decisions on the management of ports and shipping expansion in the World Heritage Area.	Moderate. Management controls (e.g. spatial, temporal, and site-specific) could be considered if required.	Good. Limited exposure to this source of pressure, therefore limited evidence to suggest management controls need to be considered.	Moderate. Limited capacity to address effects of climate change directly, but increasing the resilience of sea snake populations to effects of climate change (and other anthropogenic pressures) through adaptation planning may prove successful.	Moderate. The *Great Barrier Reef Marine Park Act 1975* provides limited scope to manage activities outside the Marine Park. To achieve good water quality and coastal ecosystem outcomes for the Great Barrier Reef, the GBRMPA facilitates the development of partnerships with industry, community, local and state governments and other Australian government agencies. Through these partnerships the GBRMPA is able to influence the management and planning of catchment and coastal pressures bydeveloping and maintaining a culture of mutual obligation. This is undertaken by providing input into the Queensland Coastal Plan policies and statutory Regional Plans which plan for coastal development in Queensland. The *Sustainable Planning Act 2009* (Qld) legislates on state planning	Moderate. The *Great Barrier Reef Marine Park Act 1975* provides limited scope to manage activities outside the Marine Park. To achieve good water quality and coastal ecosystem outcomes for the Great Barrier Reef, the GBRMPA facilitates the development of partnerships with industry, community, local and state governments and other Australian Government agencies. Through these partnerships the GBRMPA is able to influence the management and planning of catchment and coastal pressures by developing and maintaining a culture of mutual obligation. This is undertaken by fostering partnerships through the *Reef Water Quality Protection Plan 2009* and *Reef Rescue* Program. There is a critical need for better

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Declining water quality due to catchment runoff**
									approval processes and requires triggered proposals to be assessed under considerations such as the *Fisheries Act 1994* habitat management capabilities. The GBRMPA also provides input into environmental assessments for projects referred under the EPBC Act. There is a critical need for better information on the distribution and abundance of sea snakes in the near-shore areas to inform management.	information on the distribution and abundance of sea snakes in the near-shore areas to inform management.
Residual vulnerability **(low, medium, high)**	Low	Low	High (for some trawl sectors)	Low	Medium (around high-use ports)	Low	Low	Medium	Medium (predominantly inshore species along the developing coast)	Medium (along the developing coast)
Level of confidence in supporting evidence **(poor, moderate, good)**	Poor.	Poor.	Good . Stobutzki *et.al.* 2000;[8] Courtney *et al.* 2007;[16] Courtney *et al.* 2010[2]	Poor.	Poor.	Poor.	Good. Through Indigenous partnerships and liaison, anecdotal information is considered reliable	Poor. Hamann *et.al.* 2007;[14] Fuentes et.al. 2009[15]	Poor.	Poor. Hamann *et.al.* 2007[14]

The pressures addressed in this Vulnerability Assessment were identified in the *Great Barrier Reef Outlook Report 2009*.[10]

* Coastal habitats (rivers, estuaries, seagrasses, mangroves and wetlands) are under increasing pressure from human activities. More than 85 per cent of Queensland's population live on the coastal fringe. Predicted strong population growth means the intensity of activity and development in coastal zones is likely to persist.[19]

The purpose of the vulnerability assessment process is to provide a mechanism to highlight key concerns and make assessments of the vulnerabilities that species, groups of species or habitats have to known sources of pressure within the Great Barrier Reef World Heritage Area (the World Heritage Area) using a standardised and transparent process. This was undertaken using a standard approach to assess exposure and sensitivity and adaptive capacity to potential impacts (Figure 1) based on the best-available information on that particular habitat, species or group of species.

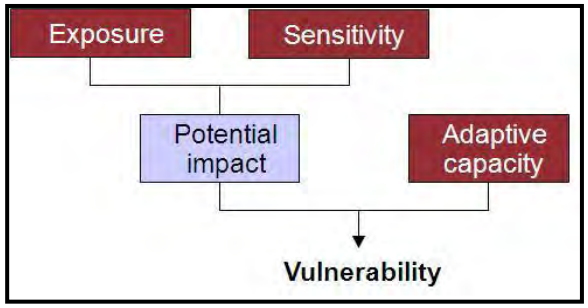

Figure 1. The key components of vulnerability assessments (Adapted from Wachenfeld *et al*., 2007)

To achieve this objective it has been necessary to apply a linear relationship to comparisons that are sometimes non-linear by nature. For example, when applying the potential impact matrix[d] to create a combined score for exposure and sensitivity, if a species, group of species or habitat has a very high level of exposure to a pressure but low sensitivity to it, it is scored as having a medium-high potential impact score. This medium-high score may be the same as determined for another assessment where there may be a low level of exposure but a very high level of sensitivity. This implies a linear relationship for the sensitivity a species or habitat has to a given level of exposure, which may not necessarily be the case. However, it does provide managers with the required level of resolution on these relationships for the purpose of the vulnerability assessments that inform the *Great Barrier Reef Biodiversity Conservation Strategy 2012*.

The methods used to determine the degree of exposure or sensitivity of sea snakes of the World Heritage Area against each source of pressure are described within the vulnerability assessments page of the GBRMPA website.

The natural capacity of sea snakes to adapt to pressures in the Great Barrier Reef, and the capacity of management to intervene (which in turn may assist sea snakes to adapt to these pressures), are considered as two dynamics that affect their residual vulnerability to any of the identified pressures. These two dynamics are then combined to produce an overall rating for adaptive capacity and then applied to the potential impact rating to provide a score for the residual vulnerability that sea snakes may be expected to experience for the given pressure. An explanation of the procedure by which this process has been applied and qualifying statements for the assessment of adaptive capacity (natural and management) scores are provided within the vulnerability assessments page of the GBRMPA website.

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[d] The potential impact matrix is described within the vulnerability assessments page of the GBRMPA website.