Surveying and Establishment of a Comprehensive Database for the Marine Environment of Kuwait eMISK$_{Marine}$

The State Of the Marine Environment Report (SOMER) for Kuwait

Date: 07/03/2017

Centre for Environment Fisheries & Aquaculture Science

Cefas
www.cefas.co.uk

Cefas Document Control

Title: The State of the Marine Environment Report (SOMER) for Kuwait

Submitted to:	Hessa AL-Khaled
Date submitted:	2/12/2016
Project Manager:	Dr Will Le Quesne
Report compiled by:	Dr Michelle Devlin
Authorised by:	Sergio Vettese
Quality control by:	Dr Will Le Quesne
Version:	1.0

Version Control History

Author	Date	Comment	Version
M Devlin	30/09/2016	Initial draft concept	Draft
B Harley	29/11/2016	Review initial draft	Draft
M Devlin	02/12/2016	Submit initial draft	Draft
B Harley	11/12/2016	Reviewed as Final	Submitted draft
W Le Quesne	19/02/2017	Final review	Final
W Le Quesne	7/03/2017	Revision following external review.	Revised Final 1.0

Project Team

Project Executive

Dr Mohammed Dawood Al-Ahmad

Deputy Director General for Sector of Environmental Monitoring Affairs, Environment Public Authority, State of Kuwait

Project Managers

Hessa Al-Khaled, Environment Public Authority, State of Kuwait

Dr Will Le Quesne, Cefas, United Kingdom

Contributors

EPA

Eisa Abdul Kareem, Ghaida Hussain, Shaikha Al-Rubaiaan, Mohammed Al-Hamad, Mohammad Gholoom, Lujain Alsayegh, Fatma Al-mutawa, Fahad Alajmi, Abdullah Al-Zaidan, Francisco Perles.

Cefas

Dr Michelle Devlin, Amelia Araujo, Dr John Bacon, Nathan Edmonds, Luz Garcia, Brian Harley, David Haverson, Simon Kershaw, Dr Will Le Quesne, Dr Brett Lyons, Dr Thomas Maes, Dr Nathan Merchant, Manuel Nicolas, Dave Sheahan, Dr Paul Stebbing, Stefania Schinaia, Dr Bryony Townhill

We acknowledge Dieter Tracey for help in graphical outputs.

Executive Summary

Overview

This report summarises the available information on the state of the Kuwait marine environment to provide an overall assessment of the state of the marine environment for Kuwait.

This State Of the Marine Environment Report presents is organised according to 6 major themes.

- Biodiversity
- Food and Water Quality for Human Health
- Environmental Pollution
- Eutrophication and Water Quality
- Fisheries
- Coastal processes.

An assessment of the state of the marine environment is presented for each theme along with a summary of the evidence that was used to develop the assessment. Within each theme separate assessments are presented for different aspects of the environment.

A seventh theme – human pressures is presented alongside the assessments of environmental status to provide an overview of the main activities and pressures that are influencing the state of the environment. Specific human pressures are also addressed within each theme.

The purpose of this State Of the Marine Environment Report is to provide assessment of all aspects of the Kuwaiti marine environment in a coordinated and structured manner, and to identify priority areas of concern.

Assessment process

Assessments of the state of the marine environment can be undertaken in many ways. This can vary from quantitative assessment against a quantitative standard, where numerical data is directly compared to a numerical standard, thorough to qualitative narrative assessments, where the assessment takes the form of a discussion of trends in the data with no reference to specific numerical standards for the status of the environment.

However, numerical standards for environmental status have only been defined in Kuwait for a limited number of components of the marine environment, and similarly regular systematic monitoring is only conducted in Kuwait for a limited number of components of the marine environment.

Therefore, in this State Of the Marine Environment Report a variety of approaches are used to carry out the assessments. Numerical assessments in comparison with numerical standards are conducted for aspects of the environment where quantitative data is collected and can be compared with defined numerical standards. For other aspects of the marine environment where either no numerical standards have been defined, or where regular systematic monitoring data is not available, alternative approaches for conducting the assessments are utilised such as narrative assessments in relation to a narrative target for environmental status. However even in the absence of regular systematic monitoring data, narrative assessments based on all available evidence can identify priority areas of concern and establish a baseline for future assessments.

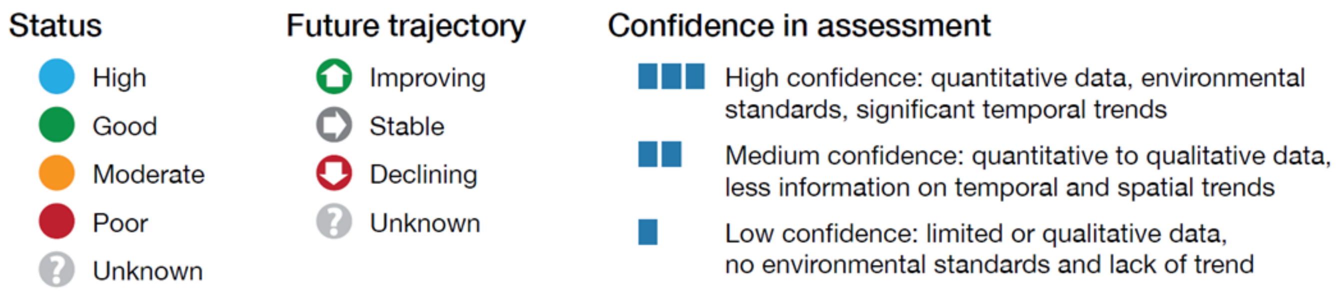
Using a mixture of qualitative and quantitative assessment methods allows all aspects of the marine environment to be assessed in a single structured process, although the level confidence in the accuracy of the assessment will vary depending on the amount and type of information available to carry out the assessment for each different ecosystem component.

The information used to conduct the State Of the Marine Environment Report includes data from Environment Public Authority monitoring programmes, and information from scientific papers, management reports, volunteer networks and appropriate regional and international studies.

Assessment outcomes

A summary of the assessment is presented below in a series of tables. For each component of the ecosystem the tables present an assessment of status and predicted future trajectory. The summary tables also identify the level of confidence associated with the assessment for each component of the environment.

The assessments are categorised using the categories and symbols illustrated below.



THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
						Biodiversity — Overall Assessment
SPECIES ABUNDANCE	Rare and vulnerable fish	Population abundance	●	⬇	■	**Status assessment is MODERATE**. The state is considered to be declining but with low confidence in the assessment due to sparse data available for rare and vulnerable fish species. The assessment also takes account of wider regional and international assessments of the decline state of many rare and vulnerable fish.
SPECIES ABUNDANCE	Cetaceans (Whales and Dolphins)	Population abundance	?	?	■	**Status assessment is UNKNOWN**. Several species of cetaceans, including resident populations of Indo- Pacific humpbacked dolphin and finless porpoise occur in Kuwait, however there is no systematic information on the abundance and distribution of cetaceans in Kuwaiti waters. Bycatch may occur and dead cetaceans, especially hump-back dolphins and finless porpoise are periodically washed up on Kuwait beaches. Due to the limited information on population status no assessment can be made at this stage. Focused monitoring efforts are required to enable assessment of the status of cetaceans in Kuwait, although the population dynamics of many of the cetacean species occurring in Kuwait will be driven by factors outside Kuwaiti waters.
SPECIES ABUNDANCE	Marine Turtles	Occurrence of nesting	●	⬇	■■	**Status assessment is POOR**. Both hawksbill and green turtles have been observed nesting in Kuwait. The decline in turtles is predominantly due to degradation of turtle nesting areas, and due to bycatch of turtles in fisheries. Recent surveys revealed a small number of nests within Kuwait. The extent of degradation of nesting beaches has significantly reduced the area suitable for nesting from original conditions. Immediate conservation action is required to protect remaining turtle nest sites from further degradation, and to reduce by-catch in fisheries. Without such efforts it is likely that breeding populations of turtles will be lost from Kuwaiti waters.
SPECIES ABUNDANCE	Seabirds	Population abundance	?	⬇	■	**Status assessment is UNKNOWN**. Sea bird populations in Kuwait consist of both resident and migratory species. There is limited systematic information on population abundance. However, the prediction of future "decline" is based on local and international pressures for migratory species and habitat degradation and loss. The migratory species require a variety of marine and terrestrial habitats during different seasons and life stages and can be affected by habitat loss and impacts across their migratory range. Seabirds can be long lived and even quite small increases in mortality can lead to significant population declines.
ALIEN SPECIES	Alien species	Frequency of occurrence	?	?	■	**Status assessment is UNKNOWN**. This is based on limited information and no long term monitoring data. Many of the alien species identified in the Gulf have been introduced as a result of commercial shipping activities, such as ballast water exchange or hull fouling, given the large volume of shipping in the Arabian Gulf. Some of the alien species have been associated with adverse impacts within invaded areas, although others have not been associated with adverse impacts. Further risk assessment of these species, would allow for prioritisation of the species in relation to potential impact and relative risk.
HABITATS	Coral Reefs	% cover	●	⬇	■■	**Status assessment is MODERATE**. This assessment is based on data available from a small number of studies focused on the monitoring of overall extent and % living coral cover on Kuwait coral reefs. Data available for Kuwait coral reefs is sporadic with limited long term monitoring information, however the information that has been reported for some of Kuwait coral reefs indicates that they were considered stable, with % coral cover varying between 15-48% up to 2005. More recently, the increased pressures facing Kuwait waters and the Arabian Gulf have thought to further impacted Kuwait coral reefs. Impacts are due to local pressures, such as anchor damage and overfishing regional and global pressures including decline in water quality, coastal development activity and climate change driven increase in water temperature. Due to the factors the predicted trajectory for the status of Kuwait coral reefs is for a future decline.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
HABITATS	Seagrass	Area and condition				Status assessment is UNKNOWN. Information on Kuwait seagrass beds is limited and difficult to extrapolate to a known status. A more comprehensive assessment of state and trajectory would require additional and targeted monitoring efforts. However there is concern that coastal development and other urban pressures are impacting on seagrass stability. In the Arabian Gulf, the extent of mangroves and seagrasses has been declining due to the impacts of unplanned coastal development and some of those same pressures would be expected to be impacting on Kuwait seagrass areas.
HABITATS	Coastal habitats	Area and condition				Status assessment in MODERATE. Coastal development has led to the reduction (and destruction) of coastal habitats with more than 40% of the coastline of the Arabian Gulf now developed. The Kuwait coastline is comprised of a mixture of salt marches, mudflats, sand plains, coarse habitats and exposed bedrock, all which support Kuwait's biodiversity. Protection of these habitats is necessary for the successful survival of a variety of dependant species, such as birds and turtles. The productivity of broader habitats such as mud flats and seagrasses is crucial to the viability of those dependant species. Industrialisation and modern development of Kuwait has intensified since 1986, with habitat condition and extent of all coastal types decreasing in response to increasing coastal development. Special consideration is given to the coastal habitats surrounding Kuwait's islands, especially those around Boubyan, which has internationally important bird species, seagrass and coral reefs, but has been identified for possible future developments.
Food and Water Quality for Human Health						
FOOD AND WQ FOR HUMAN HEALTH	Microbial Water Quality	Microbial counts				Status assessment is POOR, and the predicted trajectory continuing to decline. This is based on continual and persistent breaches of microbial guidelines. Microbial contamination is one of the most chronic issues facing Kuwait. Clear hotspots of contamination were detected during and after the Mishref sewage crisis, particularly around Al-Bedaa and Al-Messila and Doha Bay. Analysis of the data clearly demonstrates that failures in microbial water quality standards occur on a regular basis and are exceeding KEPA national thresholds and European Union Bathing Water Directives thresholds. The analysis of faecal sterols in sediments provides further proof that the environment is regularly impacted by sewage discharges with high levels of contamination found along the Gulf coast and inner Kuwait Bay.
FOOD AND WQ FOR HUMAN HEALTH	Food health	Seafood contamination				Status assessment is MODERATE. Some indication that contaminants in fish tissue may occasionally exceed EC maximum allowable concentrations. This assessment has low confidence given the lack of a dedicated monitoring making it difficult to draw firm conclusions. Despite this uncertainty, there is a high reliance of seafood in Kuwait where fish consumption forms an important component of diet. This reliance coupled with chronic issues associated with sewage discharge and evidence of contamination in fish tissue, there is significant potential for impacts on human health..

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
Environmental Pollution						
ENVIRONMENTAL POLLUTION	Water	Total Petroleum Hydrocarbons (TPH)	●	→	■■■	Status assessment is GOOD, as concentrations of TPH in water samples from the EPA monitoring stations are all below the national environmental standards. Confidence is high with data indicating improvements at some locations.
		Heavy metals < thresholds	●	→	■■■	Status assessment is GOOD, as concentrations of metals in water samples from the EPA monitoring stations are generally below the national environmental standards. Confidence is high with data indicating improvements at some locations.
	Ecotoxicology	Toxicity/endocrine disrupting chemicals	●	?	■	Status assessment is POOR due to toxic and endocrine disrupting chemicals having been detected in effluents discharged into Kuwait's marine environment. There is evidence that water collected from Kuwait Bay can pose a toxic threat to sensitive marine species. However, the dataset is very limited, so low confidence in the assessment.
	Sediment	PAH	●	?	■■	Status assessment is GOOD as, in general, the concentrations of PAHs in sediment samples collected from Kuwait's waters were below international sediment quality guidelines, and are not thought to pose a toxic risk to marine species. The only identified area considered to be contaminated was around the Shuaiba Industrial Area. Trajectory unknown and medium confidence.
		PCB	●	↑	■■	Status assessment is GOOD. The status is considered to be improving with medium confidence. There is a low level of PCB contamination in Kuwait's marine sediments and current levels are not thought to pose a toxicological risk. The only marine area considered to be contaminated is associated with the Shuaiba Industrial Area. Sediment cores analysed from sites in Kuwait Bay indicate that peak PCB contamination occurred in the early 1990's and levels have since fallen.
		Metals	●	→	■■	Status assessment is MODERATE. Current levels are above the background concentrations previously proposed for the region. However, assessment criteria developed in other regions (e.g. Europe and North America) are not suitable for use in the Arabian Gulf. Further work is required to develop regional specific sediment quality guidelines. Until then it will be difficult to assess the toxicological risk current levels contamination pose.
		PBDE	●	?	■	Status assessment is GOOD, but unknown trajectory for future state. In global terms the concentrations of PBDEs reported for Kuwait's marine environment are low, with values often an order of magnitude below those reported for other industrialised regions. The only hotspots identified were associated with sediments sampled close to the Shuaiba Industrial Area and a site located in western Kuwait Bay (Doha Bay). However, the dataset is limited, so confidence in the assessment is low.
		Faecal sterols	●	↓	■■■	Status assessment is POOR, and the predicted trajectory is that it will continue to decline. Assessment made with high confidence due to the data availability and focused studies. There is wide spread sewage contamination of Kuwait's coastal marine environment. Hotspots are located at multiple points around the coast with highly contaminated areas identified in Kuwait Bay (including Doha and Sulaibikhat Bay), and residential areas along the Gulf coast. Multiple studies conducted both by the EPA and KISR support this assessment.
	Biota	Chemical contamination	●	?	■	Status assessment is GOOD as, in general, concentrations of contaminants in fish and shellfish collected from Kuwaiti waters appear to be below concentartions thought to pose a toxicological threat to marine species. However the data limited to a small number of studies so trajectory unknown and confidence low.
		Fish health	●	?	■	Status assessment is GOOD. A survey of fish health indicates that fish residing in Kuwaiti waters contain a low prevalence of disease and pathologies associated with contaminant exposure. However, the dataset is limited to a small number of fish species, so low confidence in the assessment.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
						Commercial Fisheries
FISHERIES	Commercial fish stocks	Fishing activity	🟠	⬇	■	**Status assessment is MODERATE**. Catch estimates, show declines in all major species. Recreational fishing has a significant impact on fish resources in Kuwait with recent data suggesting that there are many more recreational fishing boats than commercial fishing boats. There has been a reduction in the total number of commercial fishing vessels. However there are no formal measures of the level of fishing activity so confidence in the assessment is low.
FISHERIES	Prawns	Annual catch estimates	🟠	?	■	**Status assessment is MODERATE**. Prawns are Kuwait's second most valuable export after oil. Catches are believed to have fallen in recent years. An additional issue for Kuwait is the amount of discarding, particularly in the shrimp fishery where up to 98% of the bycatch is discarded. Catches of prawns have significantly reduced throughout the region in recent years through overexploitation of the shrimp fisheries and the reduction in flow from the Shatt-Al-Arab river.
FISHERIES	Cephalopods	Annual catch estimates	?	?	■	**Status assessment is UNKNOWN**. Trajectory is also unknown due to limited data and no systematic monitoring data is collected. Cuttlefish, squid and octopus are opportunistically harvested within Kuwait waters. Cuttlefish are the primary commercial species however, insufficient information on taxonomy, abundance and distribution in Kuwait waters prohibits an accurate assessment. Cuttlefish populations are believed to be influenced by seasonal rises in sea temperature and the availability of muddy seafloor substrates.
						Water Quality (Eutrophication and Harmful Algal Blooms)
WATER QUALITY (EUTROPHICATION AND HABS)	Eutrophication	Dissolved Inorganic Nitrogen (DIN)	🔴	⬇	■■■	**Status assessment is POOR**. Predicted trajectory is a continued declining state. Dissolved inorganic Nitrogen has increased across Kuwait marine waters, especially around Kuwait city and developed areas. Nitrate has been increasing from the early 2000's associated with industrialisation and inputs from Shatt Al-Arab. However chronic sewage discharges since 2007 have caused an increase in ammonium. Levels of DIN are reducing over the last two years due to some reduction in sewage discharges, however concentrations are still high in contrast to EPA thresholds and baseline concentrations.
WATER QUALITY (EUTROPHICATION AND HABS)	Eutrophication	Dissolved Inorganic Phosphorus (DIP)	🔴	⬇	■■■	**Status assessment is POOR**. Predicted trajectory is a continued declining state. Dissolved inorganic Phosphorus has also increased rapidly since the late 1990's, associated with the increased urbanisation and coastal discharges. DIP is also linked to the river flow, and exhibits long term variability.
WATER QUALITY (EUTROPHICATION AND HABS)	Eutrophication	Phytoplankton—Chlorophyll-a	🟠	⬇	■■	**Status assessment is MODERATE**. The long-term chlorophyll-a data shows a reduction in the phytoplankton biomass associated with seasonal blooms particularly around the period of the extended contamination associated with sewage discharges from 2007. This may relate to a shift in the species composition of the phytoplankton community in response to the elevated ammonium concentrations. However confidence in this assessment is low due to limited understanding of the phytoplankton community.
WATER QUALITY (EUTROPHICATION AND HABS)	Eutrophication	Phytoplankton—Community composition	?	?	■	**Status assessment is unknown**. Phytoplankton data was not available for analysis in this assessment. Recommendation for further work as a key measurement in eutrophication assessment.
WATER QUALITY (EUTROPHICATION AND HABS)	Eutrophication	Dissolved oxygen	🟠	➡	■	**Status assessment is MODERATE**. Whilst the dissolved oxygen concentrations are generally stable, there have been low dissolved oxygen events occurring more frequently in areas around Kuwait City and Kuwait Bay. On occasions the oxygen concentrations drop below ecological thresholds. Historic fish kills were associated with DO sags, and thus issues with low DO may be a possibility in coastal waters. The newly established EPA buoy network will provide fuller data for future assessment.
WATER QUALITY (EUTROPHICATION AND HABS)	Eutrophication	Water quality index	🟠	⬇	■■	**Status assessment is MODERATE**. The water quality index combines the nutrient, phytoplankton and oxygen data to obtain an overall index of water quality in relation to eutrophication. The overall eutrophication assessment of MODERATE is based on evidence of increased nutrient concentrations and nutrient ratios, changes in the phytoplankton and reduced dissolved oxygen.
WATER QUALITY (EUTROPHICATION AND HABS)	HABs	Harmful Algal Blooms	🟠	?	■	**Status assessment is MODERATE**. There has been evidence of HABs outbreaks across the wider Arabian Gulf having had severe consequences. HABs identified associated with fish kills in 1999 and 2001. However, there have been no large systemic HABs outbreaks in Kuwait in recent years. However, the conditions thought to promote HABs are still occurring and could potentially lead to additional outbreaks.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
						Coastal Processes and Drivers
COASTAL PROCESSES AND DRIVERS	Coastline stability	Coastal change	Good	Stable	Low	Status assessment is GOOD. Despite coastal development, Kuwait's coastal stability has been markedly resilient, with only localised impacts of measured stress. However, some local hot spots next to major developments with sediment starvation as a result of impacts on sediment transport processes. Low confidence in the assessment and prediction of future status due to a lack of information on the impact of the upcoming developments.
		Changes in sedimentology	Moderate	Stable	Low	Status assessment is MODERATE. As with coastal change, there has been little documented evidence of any major movement of sediment, or increasing turbidity in the Arabian gulf. Some evidence of increasing turbidity in Kuwait Bay, potentially related to discharges into the Bay. Coastal sediments usually coarse, so only limited localised impact on turbidity.
	Coastal currents	River flow	Poor	Declining	Medium	Status assessment is POOR. Poor status due to a change in river flow impacting on sedimentology, and a major driver in changing turbidity. Further impacts on primary productivity, but wider impacts on Kuwait marine waters unknown.

Status

- High
- Good
- Moderate
- Poor
- Unknown

Future trajectory

- Improving
- Stable
- Declining
- Unknown

Confidence in assessment

- High confidence: quantitative data, environmental standards, significant temporal trends
- Medium confidence: quantitative to qualitative data, less information on temporal and spatial trends
- Low confidence: limited or qualitative data, no environmental standards and lack of trend

Biodiversity - Overall assessment - Moderate to Poor Status

The MODERATE status reflects the concern that has been identified in relation to turtles, rare and vulnerable fish, seabirds, coral reefs and coastal habitats. The status of turtles is a priority given global concern over the conservation status of turtle species occurring in Kuwaiti waters. Furthermore, there is significant uncertainty over the status of a number of other aspects of biodiversity in the marine environment of Kuwait.

The main impacts on biodiversity in Kuwait are coastal developments and coastal activity removing or damaging coastal and nearshore habitats, sewage inputs impacting water quality and fishing affecting vulnerable species and habitats.

Future trajectories of coral reefs, seagrass beds, coastal habitats, turtles and seabirds are likely to continue to decline in status based on current knowledge and future projections. Confidence in the assessment and prediction of trajectories for sharks, rays, whales, dolphins and impacts from alien species is low, reflecting a lack of knowledge on both the current state and the impacts of future pressures.

What this assessment does show is that Kuwait is home to many iconic species which are ecologically, commercially and socially important and require significant conservation measures.

- There are major concerns for turtles due to destruction of nesting beaches.
- The occurrence of alien species is increasing and many alien species, which have caused impacts in other areas, have been identified in Kuwait marine waters.
- Seabirds are facing local habitat destruction coupled with international pressures that are affecting the numbers of migratory birds.
- Coral reefs are facing regional and global crises that are severely impacting on their long-term viability.
- Seagrasses and all coastal habitats are under threat from continued coastal expansion
- There is an urgent need for improved monitoring programs to increase knowledge of the state and trajectory of biodiversity.

Development of management objectives with environmental standards is required to recognise the importance of biodiversity and provide guidance for management actions.

In conclusion, based on local information and extrapolation from additional studies conducted across the Arabian Gulf, there is considerable concern that the state of biodiversity will continue to decline. There are particular concerns for the current and future state of turtles, coral reefs and coastal habitats.

Commercial fishing - Overall assessment - Moderate Status

The assessment of status is MODERATE based on the declining catches reported in landings data. The status of commercial fish stocks are predicted to continue to decline in without additional management action. Recreational fishing has a significant impact on fish resources in Kuwait with recent data suggesting that there are 30 times more recreational fishing boats than commercial fishing boats.

- Landings data shows a significant decline over last 15 years.
- There has been a reduction in total fishing vessels, which may be related to the reduced national catch. In contrast, the imported fish numbers have increased over time.
- An additional issue for Kuwait is the amount of discarding, particularly in the shrimp fishery where up to 98% of the bycatch is discarded.
- Habitat loss and habitat modification, including coastal wetlands, sea grass beds and coral reefs, may cause a decline in the productivity of fisheries in addition to direct overexploitation.
- Catches of prawns have significantly reduced throughout the region in recent years through overexploitation of the shrimp fisheries and the reduction in flow from the Shatt-Al-Arab river.
- Cuttlefish, squid and octopus are targeted, and opportunistically harvested within Kuwait waters. Cuttlefish are the primary commercial species however, insufficient information on the taxonomy, abundance and distribution of cephalopods species prohibits an accurate assessment of the fishery.

Current data is not sufficient to predict future trajectories of stock sizes, with the exception of the shrimp fisheries. Improved data collection and reporting is required to enable robust assessment and management of fisheries.

In conclusion, from available catch information and extrapolation from additional studies conducted across the Arabian Gulf region, many commercial fish stocks have deteriorated or collapsed. Further decline of the status of Kuwait commercial fish stocks is expected.

Environmental Pollution - Overall assessment - Good Status

Assessment of the current status is given as GOOD, with the trajectory of change predicted to be stable with high confidence in these assessments of state and trajectory.

Assessment of water contamination data from the national EPA monitoring program across all Kuwaiti waters demonstrated no ecologically significant change in water contamination occurred during this period, indicating that for metals and petroleum hydrocarbon contamination there is no ongoing deterioration over time. In general, throughout the period monitored the concentration of metals and total petroleum hydrocarbons in water are below levels thought to pose a toxicological threat. However, there are isolated hotspots of contamination at levels that does cause toxicological impact around some of the outfalls along the coastline.

Similarly, assessment of current levels of sediment contamination by metals, PAHs and PCBs indicated little toxicological risk to marine biota inhabiting the areas sampled. The levels of contamination detected indicate that, in general, Kuwait's marine environment is relatively unpolluted when compared with other industrialised regions of the world. Where detected, hot spots of PAH and PCB contamination were restricted to locations associated with industry.

However, indicators of sewage contamination highlights that sewage contamination is widespread in coastal areas around Kuwait City. Sewage discharges are known to contain a complex mixture of chemical contaminants and these have been shown to be both directly toxic to marine species and contain endocrine disrupting properties.

In conclusion, the analysis of chemical contamination in biota along with the levels of contaminant associated disease in fish supports the conclusion of GOOD status with levels generally indicative of unpolluted environment. However, there are localized hotspots of industrial pollution, and pollution due to sewage discharges continues to be a serious and persistent threat to Kuwait's marine environment. These aspects require urgent investigation and could impact on the current good status.

Eutrophication and HABs - Overall assessment – Moderate to Poor status

Status assessment is MODERATE due to long term increases in all nutrients, changes in phytoplankton and reduced dissolved oxygen. One of the most serious concerns facing Kuwait's coastal and marine waters is the continued discharges of raw and untreated sewage, which is responsible for elevated nutrient loads into the coastal environment as well as other impacts considered under other themes.

A combination of chronic and diffuse nutrient loads has had a major impact on water quality, particularly the concentrations of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) which have increased significantly over the last 30 years. There was a rapid increase in ammonium concentrations between 2009 and 2012 linked to the malfunctioning of Mishref sewage pump station between 2009 and 2012. In addition, the long-term EPA monitoring data also shows the influence of the diffuse nutrient inputs, evident in increasing nitrate concentrations from the Shatt Al-Arab River from the early 1990's. However, in recent times, diffuse nutrient inputs into northern Kuwait waters has been reduced due to the reduction in freshwater flow from the Shatt Al-Arab due to upstream dam construction. These dams have virtually eliminated seasonal flood events, which were extremely important for nutrient input, lowering salinities, and triggering certain biological events such as migration or spawning.

The long-term chlorophyll-a data shows a significant reduction in the phytoplankton biomass associated with seasonal blooms particularly around the period of the extended contamination associated with sewage discharges after 2007. This may relate to a shift in the species composition of the phytoplankton community in response to the extremely elevated ammonium concentrations.

Low dissolved oxygen events occur frequently in areas around Kuwait City and Kuwait Bay; these low oxygen events will be driven by excess nutrients. On occasions the oxygen concentrations drop below ecological thresholds.

Harmful Algal Blooms (HABs) outbreaks have been recorded in recent times but at small scales. The conditions which were responsible for the previous recorded HAB outbreaks continue to occur and thus the estimates of future trajectory must consider that re-occurrence of HAB outbreaks is likely.

In conclusion, combining the different water quality indicators for a coordinated assessment indicates MODERATE status for eutrophication. Confidence attached to this assessment is moderate due to a lack of appropriate environmental standards for the water quality indicators. This is driven by nutrient inputs to Kuwait Bay and around Kuwait City. This may have knock-on effects for higher trophic levels. HABS have not occurred in high numbers in recent years, however conditions that are linked to HABS outbreaks are present.

Water Quality for Food and Human Health - Overall assessment – Poor status

The status of Food and Water Quality for Human Health is assessed as POOR status, and is recognised as one of the major issues facing Kuwait marine waters.

The assessment of POOR is due to chronic sewage pollution causing undesireable microbial and pollutant contamination along most of the coastline around Kuwait City and the south of Kuwait Bay. The malfunctioning of Mishref sewage pump station between 2009 and 2012 resulted in discharges of around 150,000 m3 per day of untreated sewage directly into the sea. Continued high levels of microbial contamination illustrates that raw and partially treated sewage discharges are an ongoing problem, particularly around Kuwait City. Additional hot spots were identified in Doha Bay and Sulaibikhat Bay.

Microbial water quality at locations monitored around Kuwait City regularly breaches regional and European recreational water quality guidelines indicating a heightened risk to human health from coming into conact with seawater thorugh swimming and other recreational water activites, as well as risk to people who come into contact with seawater at work.

The highlevels of sewage contamination of coastal waters is partly attributed to the failure of the sewage treatment network to keep pace with demands for capacity due to rapid population growth, and illegal and unregulated discharges of sewage directly into the sea and via the stormwater drainage network.

The assessment of the poor status of coastal waters from microbial contamination is made with high confidewnce due to the availability of long term monitoring data frm the EPA national monitoring programme as well as supporting information from research studies.

Limited data that indicates that poor water quality may cause adverse seafood contamination, with possible consequences for human health. There is no regular monitoring of seafood contamination due to environmental exposure to pollutants, however there is some evidence suggesting that fish tissues from fish caught in Kuwaiti waters may occasionally exceed EC maximum allowable concentrations. This assessment is made with low confidence given the lack of a dedicated monitoring, and only limited research data available.

In conclusion, sewage contamination of coastal water is severe and a threat to human health. The continued chronic sewage contamination is also a cause for concern related around seafood quality in seafood caught in Kuwaiti waters.

Coastal processes - Overall assessment – Good status

The current assessment of the status in relation to coastal stability and coastal erosion is GOOD. Kuwait coastal stability is still resilient, with only localised impacts of measured stress, despite rapid coastal development over the past 30 years.

This assessment is made with low confidence due to a lack of information on current development and concern regarding the impact of the upcoming developments, particularly in relation to vulnerable areas such as the coastal region of Boubiyan Island.

However, some local hot spots next to major developments have resulted in sediment starvation due to differential sediment transport processes.

The future coastal development trajectories are predicted to decline from current levels, given the continued modifications of the coastal zone. This is particularly exacerbated by the expansion of the northern residential area and the causeway. Coastal Processes

In conclusion, coastal development has changed the shape of the Kuwait coastline, however, coastal stability is still functioning well. There are concerns for many of the future coastal development plans which could significantly impact on coastal processes and sedimentology.

Emerging issues

As well as considering existing and impacts it is important to identify emerging issues which have the potential of becoming major threats to the Kuwait marine environment. Three specifi emerging issues of concern have been identified for the Kuwait marine environment. These are seawater temperature rise, underwater noise and marine litter.

Seawater temperature rise

Increaseing seawater temperatures can have adverse impacts on a range of species and habitats including coral reefs. Sea water temperature in the Kuwait Bay has been increasing at a rate three times higher than global estimates (0.6 ±0.3°C/decade). This is mainly driven by global climate change and El-Nino, but this is further increased by local human impact, and 17% of the warming has been attributed to human activities along the Kuwait coastline. Power and desalinisation plants generate thermal plumes in coastal zones that contribute 1.1°/decade to the temperature trends of the in the Northern Arabian Gulf. Urban storm drain runoff and treated sewage discharge which are untreated regarding temperature can also contributing to SST rises in areas of restricted circulation such as Kuwait Bay.

Climate modelling is becoming more advanced for the Arabian Gulf, and so the understanding of how changes will affect the marine environment in future decades is starting to become clearer. However, there is still a lack of information regarding how these changes will affect the ecosystems within the Arabian Gulf and around Kuwait, when compared to some other regions of the world. Research to date suggests that the northern Arabian Gulf may be less affected by climate change than the southern areas, and that the ecosystems and marine species may also be less impacted (particularly from findings of the UAE LNRCC project). However, the IPCC (2014) states that more investigation is required of the physical, chemical and biological responses to climate change in the region.

Underwater Noise

Underwater noise pollution from human activities is a growing environmental concern worldwide, as it can have a range of negative effects on marine life. Governments and international bodies are beginning to act to monitor and mitigate underwater noise, and to regulate activities which produce high noise levels. Exposure to underwater noise can cause behavioural reactions in marine animals, such as avoidance and changes in normal behaviour patterns. The presence of noise in the environment can also cover important sound cues through acoustic masking. For example, noise from a passing ship may ‘drown out’ communication signals or predator/prey sounds. Finally, exposure to noise can increase levels of physiological stress, which could have significant long-term health effects through repeated exposures. Whilst knowledge of these impacts is growing, very little is known about direct and indirect impacts in Kuwait marine waters. However, it is an issue which needs to be further studied, particularly for the vulnerable marine species that migrate through the Gulf.

Marine Litter

The term “Marine Litter” or “Marine Debris” has been introduced to describe discarded, disposed of, or abandoned man-made objects present in the marine and coastal environment. It consists of articles that have been made or used by people and, subsequently, deliberately discarded or accidentally lost. They originate from ocean-based or land-based sources and can be found in marine environments around the globe, posing environmental, economic, health and aesthetic problems. Most sources of marine pollution are land based. Marine litter, mainly plastic, poses a serious environmental threat to marine organisms, as well as a series of economic and social problems.

Disposal of plastic waste has emerged as an important environmental challenge in the Middle East where plastics make up as much as one-tenth of the solid waste stream. In affluent GCC nations, plastic waste composition in municipal solid waste is around 12 – 16 percent. Plastic waste in the region is continuously increasing due to increasing use of plastics in daily life. Rapid population growth and increasing GDP per capita result in higher consumer spending. Moreover, the latter translates to greater importance, given to ‘convenience and hygienic shopping’ resulting in higher demand for plastics in packaging and shopping.

The Middle East is responsible for about 8 percent of the global plastic production. The gross urban waste generation from all Middle East countries exceeds 150 million tons per annum, out of which 10-15 percent is contributed by plastic wastes. Plastic waste is a source of greenhouse gas emissions, economic and ecological damage. The majority of items found on beaches across the region contain plastic which pose a serious danger to marine life. Plastic waste disposal is a major challenge due to non-biodegradable nature of plastics and such wastes are visibly present in landfill sites for a long time.

The frequency of occurrence, composition, and distribution of litter accumulating in the marine environment of the Middle East is relatively unknown. Apart from infrastructural roadblocks, lack of awareness and low level of community participation are major factors behind increasing generation of plastic wastes. The staggering amount of plastic wastes generated in the Middle East demands a concerted effort from policy-makers and urban planners to devise an effective plastic waste collection and recycling strategy to tackle the menace of plastic wastes.

1 Introduction

1.1 Purpose of document

The purpose of this SOMER is to present a comprehensive and coordinated review and assessment of the state of Kuwait's marine environment based on current available information. The SOMER considers the whole of Kuwait's marine environment; where possible and appropriate the state of Kuwait Bay is considered as a separate assessment area. The SOMER is structured according to different themes, and summary assessments are provided for each theme to identify priority impacts and pressures on the environment that could be the focus of specific management action within the National Plan for Marine Environmental Management.

1.2 Kuwait National Plan

Article 65 of the Kuwait Environment Law requires the EPA to develop a National Plan for Marine Environmental Management (National Plan). A key component of the national plan will be coordinated and comprehensive assessment national assessment f the state of the marine environment to identify the progress and need for marine environmental management.

A wide variety of different human activities, ranging from fishing, industry, transport and tourism, utilise and depend upon the marine environment. Therefore, integrated ecosystem-based management of the marine environment requires coordinating and integrating management across multiple regulatory bodies and industrial sectors, and across legislation and regulation. To achieve this the National Plan does not only need to develop new activity, but also needs to provide a framework to clearly identify and coordinate existing legislation, regulation and management activity related to the marine environment. In recognition of this the proposed framework for development of the National Plan emphasises the importance of reviewing and identifying existing legislation and regulation, and defining responsibility for managing different areas of activity.

The framework for developing the National Plan specifically incorporates a process of periodic review, evaluation and update to the National Plan. The review process is important as it allows the effectiveness of the National Plan to be evaluated, and the National Plan updated to ensure that environmental objectives are met. Furthermore, the review process recognises that policy priorities, scientific understanding and human activities change over time. The review and update process enables the National Plan to be adapted to maintain relevance to the key priorities of the time.

1.3 Preparing a State of the Marine Environment Report

A state of the Marine Environment Report is recognised under The United Nations General Assembly (UNGA) decision to establish "a regular process under the United Nations for global reporting and assessment of the state of the marine environment to prepare proposals on modalities for a regular process for global reporting and assessment of the state of the marine environment, drawing, inter alia, upon the work of UNEP".

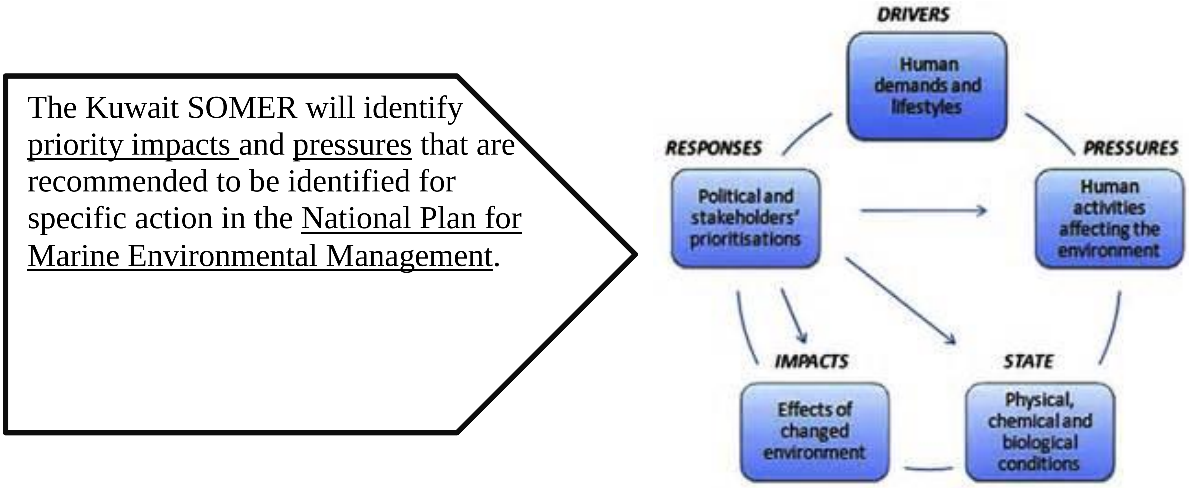
A State of the Marine Environment Report (SOMER) provides an up-to-date assessment of the state of the marine environment, and the pressures acting on it based on available data. This SOMER report includes a clear summary assessment of the state of the environment and an associated detailed technical document that provides the supporting evidence for the summary assessment.

Where possible the SOMER has been prepared to assess the state of the environment in relation to the specific management objectives identified for the Kuwait marine environment (see objectives and indicator report) in support of the National Plan (Figure 1-1). The Kuwait SOMER has identified priority impacts and pressures that are recommended to be identified for specific action in the National Plan for Marine Environmental Management.

The SOMER will

- Provides an assessment of the Kuwait marine environment
- Needs to build on our current understanding of the environment
- Different types of reporting based on the available data.
- Data can be quantitative or qualitative
- International examples can provide a good starting point.
- Modify to suit Kuwait unique ecosystems

Figure 1-1: Link between SOMER report, national plan and DPSIR approach.



2 SOMER overview for Kuwait

2.1 Introduction

This State of the Marine Environment Report (SOMER) provides an up-to-date assessment of the state of the Kuwait marine environment, and the pressures acting on it based on available data. The SOMER report includes a clear summary assessment of the state of the environment and an associated detailed technical document that provides the supporting evidence for the summary assessment.

Conclusions on the state of the Kuwait marine environment will depend on the extent and quality of available data. In some instances, where little information is available it will be necessary to use subjective expert judgement, or an assessment may not be possible. It is expected that the SOMER predominantly takes the form of a qualitative narrative assessment.

2.2 The importance of our marine systems

Monitoring the status and health of the marine ecosystem, and compliance with minimum standards, is a critical component of many international frameworks. This reflects the values that international communities set on their marine ecosystem services. Ecosystem services (ESS) have been defined as “the benefits people obtain from ecosystems” (Millennium Ecosystem Assessment, 2005), and divided them into four ecosystem service categories: supporting, provisioning, regulating and cultural services. Whist this report will not present an assessment of the scale or cost associated with the marine ecosystems service of Kuwait Marine waters, it will explore the wide range of benefits that may be offered by a functioning marine ecosystem.

2.3 Cost benefits associated with marine ecosystem services.

The economic value (i.e., contribution to human welfare) of an ESS is, as with any good or service, determined by its supply and demand. The supply side of an ESS is largely determined by ecological processes and characteristics (e.g., functioning, fragmentation, productivity, resilience or climate) that may be influenced by human activities, either deliberately or inadvertently. The under- standing and modelling of the supply of ESS has largely been taken up by natural scientists (e.g., ecologists, geographers, hydrologists). The demand side is largely determined by the characteristics of human beneficiaries of the ESS (population, preferences, distance to resource etc.). The understanding and modelling of the demand side has largely been taken up by economists.

Human activities in the marine environment are extensive and few areas are now untouched by them. Competition between these activities for space and resources is increasing, especially in coastal zones, leading to growing calls for more effective management of marine ecosystems. Since the 1990s, there has been a shift in marine management thinking from a single activity ('sectoral') approach toward management focused on ecosystems, acknowledging the interactions between components of ecosystems and the position of humans within these systems (Atkins et al., 2011). This ecosystem approach to management requires a deeper understanding of the linkages and dynamic relationships between ecological, social and economic systems (Borja et al., 2010).

2.4 Themes

Seven themes are presented in this SOMER, based on agreed themes developed under the eMisk project. These themes are linked to strategic reporting that is being developed under the objectives and indicators work (Table 3-1). The themes include:

- Human Activities.
- Biodiversity
- Food and Water Quality for Human Health
- Pollution
- Eutrophication and HABS
- Fisheries
- Coastal processes and Oceanography

Each theme, other than human activities, will be reported via the assessment of indicators that describe each theme. Each theme will be presented as an overview of current information and a short summary of the current status of that theme. The themes have several strategic goals within them and each of those goals will, where appropriate, be presented against an indicator that describe information against those goals (Table 2-1). Data and information for each indicator will be presented as quantitative and/or qualitative assessments.

Table 2-1: The strategic goals associated with each SOMER theme and described as the main overarching objectives.

Biodiversity
• B-SG1: to prevent extinction of threatened and vulnerable species, and where possible, maintain abundant populations of all species.

• B-SG2: to prevent introduction and establishment of invasive species.
• B-SG3: to maintain the condition and extent of threatened and vulnerable habitats, and critical habitats that support threatened or vulnerable species; and to maintain all habitats in a condition to support key ecosystem functions that are dependent on them.
• B-SG4: to maintain community structure and food webs to ensure long-term abundance of species and productivity at all levels.
Food and Water Quality for Human Health
• FW-SG1: to maintain the quality of seawater to protect human health.
• FW-SG2: to ensure contaminants in fish and other seafood for human consumption do not lead to unacceptable risk to human health.
Environmental Pollution
• P-SG1: to ensure that marine ecosystems are not adversely impacted by contaminants.
Fisheries
• F-SG1: to ensure all stocks of commercially exploited species are at levels that enable high long-term sustainable yield consistent with the concept of maximum sustainable yield.
Eutrophication and Harmful Algal Blooms (HABs)
• EH-SG1: to minimise human-induced eutrophication, and its adverse or undesirable effects.
• EH-SG2: to reduce the frequency of human-induced Harmful Algal Blooms, and, where possible, minimise the adverse consequences of HABs.
Coastal Processes and Oceanography

• CO-SG1: to minimise changes in sediment transport by coastal and offshore structures and developments that may lead to increased flood risk and undesirable erosion or changes in the shoreline.
• CO-SG2: alterations to the hydrodynamic conditions do not adversely affect coastal and marine ecosystems.

Assessment of the SOMER will be presented in six parts (Figure 2-1) with each assessment focused on the a multimetric approach to assessing each main theme. Whilst the themes will be presented as stand-alone assessments, it should be recognised that the themes are interlinked through a multiple cause and effect process. The cumulative impacts from multiple pressures is also important to consider (Table 2-2) and will become more important in consecutive SOMER reports.

Table 2-2: Interaction between themes and pressures in Kuwait marine waters

	Seabed habitats	Water column habitats	Marine inverts	Marine fish	Turtles	Seabirds and water birds	Marine mammals	Marine food webs
Biodiversity	x	x	x	x	x	x	x	x
Food and WQ			x	x			x	x
Environmental Pollution		x	x	x	x			x
Fisheries				x				x
Eutrophication and HABS	x	x						x
Coastal changes	x		x		x			
Human activities	x	x	x	x	x	x	x	x

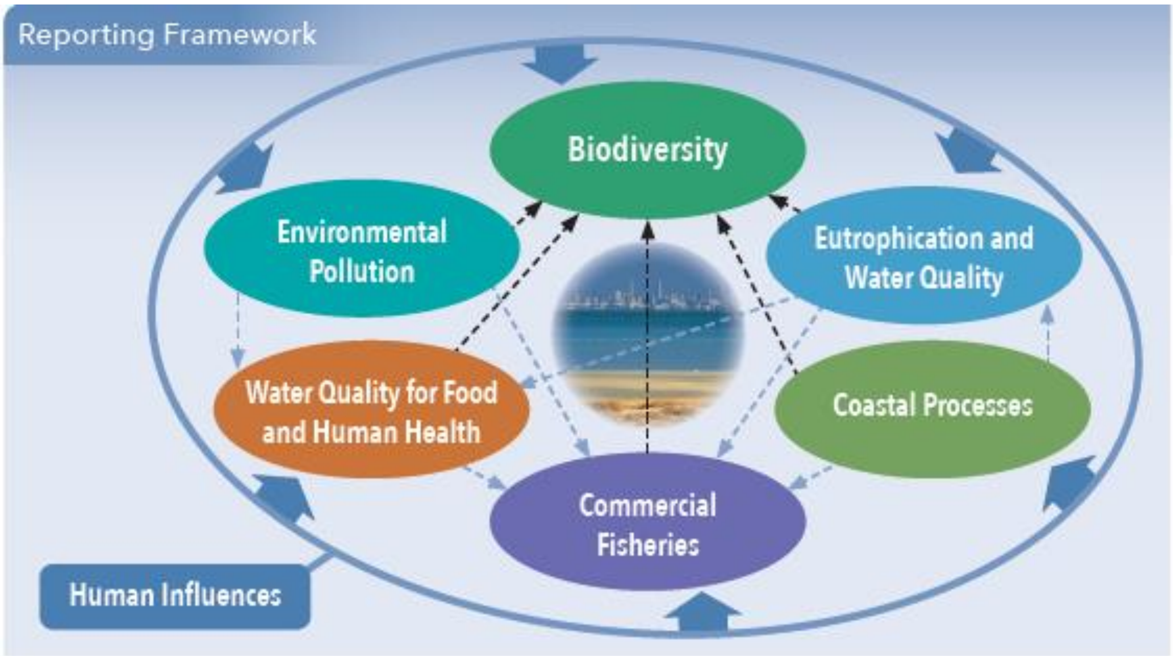


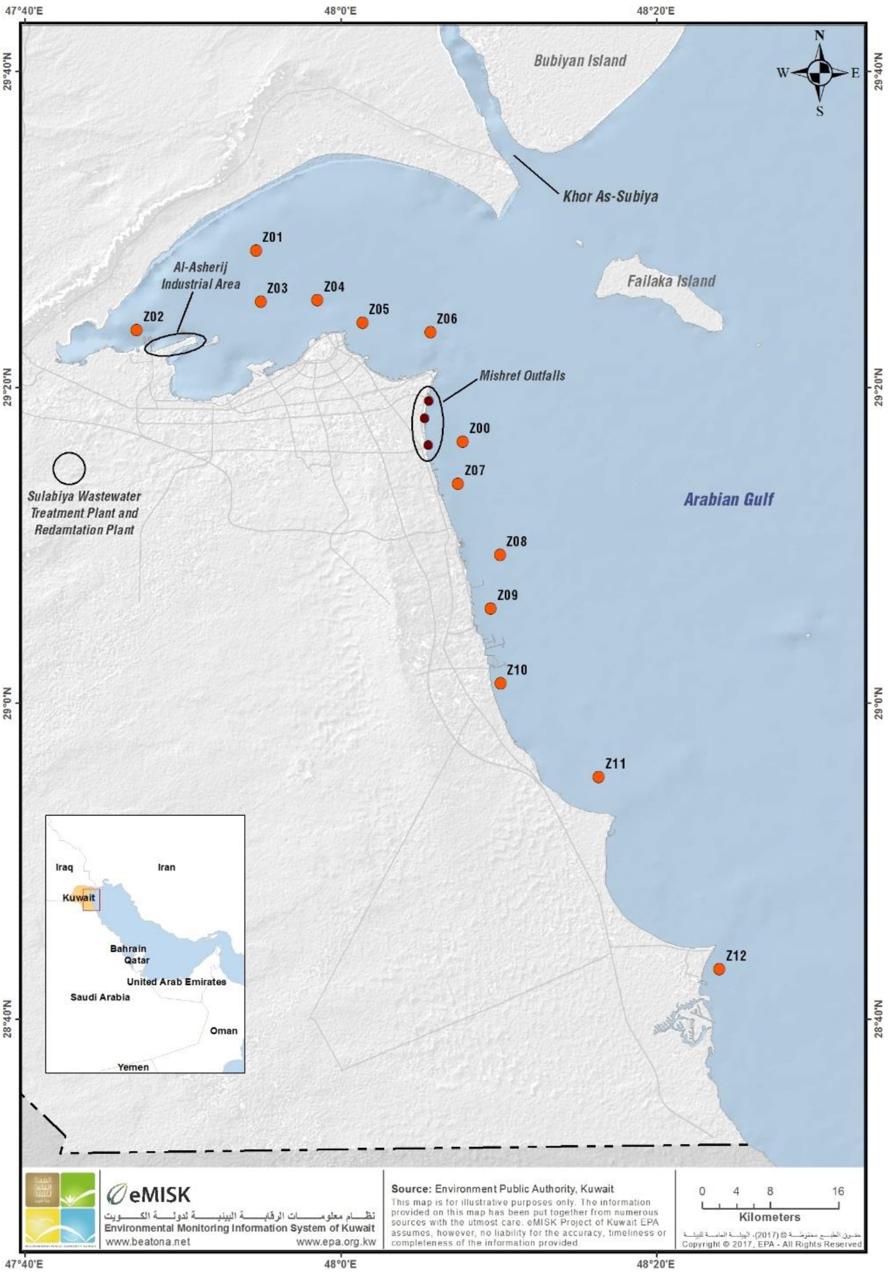
Figure 2-1: Summary of the six main themes to be presented in the SOMER report, and the main linkages between each theme. Human activities is presented around all themes, as the impacts of human activities will be the main driver of change within each theme.

2.5 Area of assessment

The SOMER presents assessment for the total marine area of Kuwait, which ranges from the coastline, intertidal area, Kuwait Bay, the Arabian coast, the coral reefs, seagrass beds, mangroves. It stretches from the coast, into the Bay and out along the Arabian Gulf and north up to the Shatt Al-Arab river, covering the full extent of Kuwait waters. There are four main areas – Kuwait Bay, Inner Arabian Gulf, Shallow Northern Gulf, offshore Gulf area (Figure 2-2). However, for this first SOMER report, given the limitation of data for many of the indicators, the area will be assessed over the total area of the marine waters, apart from the water quality and environmental pollution assessment, where more details are provided around sites and areas. The eutrophication assessment will be provided for Kuwait Bay and the inner Arabian Gulf area to reflect where much of the data has been collected and an assessment is possible. The environmental pollution and microbial data will be reported at a site level but aggregated into a full marine assessment. The water quality and environmental pollution data is mainly focused on data collected within Kuwait Bay and the inner Arabian Gulf, reflecting the influence of these contaminants on the near shore coastal environment. Coral reefs habitats are located in the shallow northern gulf and offshore gulf area. Many of the species listed under the biodiversity assessment are found across all four areas but with limited data so this initial assessment will be provided across the marine system. Further SOMER reporting cycles will provide a more detailed geographical assessment as the data collected can better represent the spatial variability across the marine system

In conclusion, due to the limitations of data for the first SOMER, this first assessment mainly focuses on reporting the indicators across the whole of the Kuwait marine area. However, the environmental pollution and water quality data will also be reported for Kuwait Bay and the inner Arabian gulf at a site level, reflecting the issues of coastal pollution into those impacted areas.

Figure 2-2: Map of the full marine areas with the long term EPA monitoring sitse (Z sites).



2.6 SOMER Assessment process

At present, there are spatial and temporal differences in existing monitoring programs for separate descriptors; they were designed as stand-alone indicators, rather than an integrated assessment. There is also considerable diversity in the way that data for different descriptors have and will be collected in Kuwait. It is therefore necessary to consider and understand how different sampling techniques and limited data can introduce different constraints in terms of assessment that relate largely to the spatial and temporal coverage. Reporting will be based on the quantity and quality of data around each theme and objective. There will be four broad scenarios for assessment as described in Table 2-3.

The different styles of assessment tend to reflect the type of data that is held for that objective and environmental standard. This can range from a situation in which we have long term, spatially rich data, and an environmental standard at which we can assess the quantitative data to provide a value or assessment of state. There are four different types of assessment processes applied across the four themes, with the type of assessment and the selection of an environmental standard (threshold) dependent on the type, quantity and quality of data collected against the indicator and/or theme.

We can have quantitative data, but without an accepted environmental standard or threshold the assessment of the data relies on assessment of change over time and space, but not against an agreed standard. It is also possible, particularly with Kuwait biodiversity data, to have little to no quantitative data and thus we need to rely on alternate research and government literature that may help guide a qualitative assessment, and provide a narrative around the state of the objective from that literature. Finally, we can also have a situation where there is little to no data, and little to no information on any environmental standard and our assessment is based on a very broad international understanding of the pressures and impacts, typically using international literature. The type of assessment available for each theme is summarised in Table 2-3. For each of the themes, data collected under EPA monitoring programs have been a key source of information, but particularly for environmental pollution, microbial and water quality data. Data for these three themes has been collected over 30 years, and have provided a key source of data in a, generally, quantitative assessment. For other themes, particularly biodiversity, there has been limited long term data collected under current EPA monitoring programs, apart from some data that has been collected for phytoplankton and zooplankton data. The assessment of biodiversity comes from scientific papers, particularly from KISR and Kuwait University, government reports and volunteer and NGO groups. For all themes, even those with long term data, there are no to very limited understanding of ecological thresholds and environmental standards, and caution has been applied when comparing to international thresholds. Again, there are exceptions, particularly for the microbial assessments, where international standards for human health have been applied.

There are also differences in how we develop environmental standards, and again, as with the assessment process, the type of standard reflects the type of data and the understanding of the connectivity between drivers and response. This report will broadly focus on two types of indicators:

I. Monitoring indicators (based on available data – making a judgment on the monitored change in the data. These types of indicators are represented in some of the water quality and environmental data where the indicator is developed through the assessment of long term data.
II. Management indicators – an indicator that requires an understanding of the system. Provides guidance to managers. This type of indicator is best represented by the microbial water quality assessment, where international guidelines on standards which can impact on human health are used to provide a very clear assessment using the long term microbial data.

Data that has been used in these assessments has been sourced from many areas, including historical and government reports and scientific literature based on work carried out in Kuwait, Arabian Gulf and comparable work at an international scale. However, where possible, the quantitative data used in the microbial, environmental pollution and water quality assessments has been sourced from the long running EPA monitoring programs (Table 2-4).

Table 2-3: Types of assessment applied in the SOMER process.

Assessment	Description	Examples – current objectives applied in SOMER
Type 1	Assessment with long term quantitative data, and an agreed and relevant ecological threshold at which we can assess the quantitative data	• Heavy metals, trace metals, PCBs – annual means against internationally accepted thresholds – Environmental pollutants • Microbial counts – Faecal coliforms (cells/L) – European Bathing Water Directive – Water Quality for human health

Type 2	Assessment with long term quantitative data, but without appropriate environmental standards so an assessment of the data is made over analysis of changes in time/space	• Nutrient concentration data – annual mean values compared against threshold – WQ/Eutrophication • Chlorophyll-a – occurrence of high biomass – 90th percentile value over seasonal period – WQ/Eutrophication • Changes in phytoplankton community–WQ/Eutrophication and Biodiversity • Changes in zooplankton community-–WQ/Eutrophication
Type 3	Assessment with no quantitative data, but alternate research information, grey literature, modelling on the Kuwait system that may help guide a qualitative assessment	• % annual coral cover • Changes in coastal dynamics – Coastal processes • Seagrass health • Seabirds
Type 4	Assessment which has very little to no data, and little to no information – and we make an assessment based on international understanding of the pressures and impacts.	• Number of alien species - Biodiversity • Number of migratory whales

Sampling scheme	Site locations	Biodiversity	Microbiology	Chemical contaminants	Water quality & eutrophication	Additional sampling	Comments
Offshore water Quality	Z-sites	Zooplankton and phytoplankton sampling from 9 selected sites ID, qualitative and quantitative (since 2007 for phytoplankton) and zooplankton.	Clostridium Perfringens; Faecal Coliform; Faecal streptococci; Salmonella SP; Total Coliform	Total Organic Carbon; Total Petroleum Hydrocarbons Compounds; Arsenic; Cadmium; Copper; Iron; Lead; Mercury; Nickel; Vanadium	Water Temperature; Salinity; Transparency; Ammonium Chlorophyll-a; Dissolved Oxygen; Hydrogen Ion Concentration; Nitrate; Nitrite; Phosphate; Silicate; TSS	Fish collection for Trace Metals primarily trawled and, from market. Usually 2-3 sp. of edible fish biannual freq	13 stations (Z00 to Z12) Frequency = monthly for microbiology, WQ & eutrophication / bi-monthly for chemical contaminants Trace metals analysed in triplicate (A,B,C) per location.
Offshore sediment survey	Z-sites	n/a	n/a	Total Petroleum Hydrocarbons Compounds; Arsenic; Cadmium; Copper; Iron; Lead; Mercury; Nickel; Vanadium, Zinc	n/a		13 stations (Z00 to Z12) Frequency = biannually for metals and TPH Just grab sampling (no more core sampling) Trace metals analysed in duplicate (A,B) per location
Coastal Water Quality	S-sites	Not Anymore	Clostridium Perfringens; Faecal Coliform; Faecal streptococci; Salmonella spp; Total Coliform; Escherichia Coliform	Not Anymore	Not Anymore		12 stations (S00 to S11) Frequency = weekly for microbiology
Algal Bloom Monitoring stations	KB-4, KB-6 (edge of Kuwait bay)	n/a	n/a	n/a	Nutrients (nitrate, nitrites, ammonia, phosphate, silicate), Chlorophyll-a		monthly sampling
Bivalve sampling program	Z2, Z6, Z0, Z9 sampled offshore,	n/a	n/a	Arsenic; Cadmium; Copper; Iron; Lead; Mercury; Nickel; Vanadium, Zinc	n/a		6 coastal stations, 4 offshore stations Frequency = biannually

Sampling scheme	Site locations	Biodiversity	Microbiology	Chemical contaminants	Water quality & eutrophication	Additional sampling	Comments
Beach Profile	Coastal zone monitoring sites	n/a	n/a	Total Petroleum Hydrocarbons Compounds; Arsenic; Cadmium; Copper; Iron; Lead; Mercury; Nickel; Vanadium, Zinc	n/a	Beach profile, PSA samples, litter, and obvious pollution	13 positions, 4 times a year Not being carried out now due to equipment failure
Bird survey	Jahra nature Reserve	Identification of birds to species level					Daily monitoring of bird and identification to species level at the Jahra Nature Reserve
Seaweed survey - Macroalgae	8 sites between Shuwaikh -north to Fahaheel south	Seaweed ID to species level, no quantitative analysis other than approximate coverage.	n/a	n/a	Water Temperature; Salinity; Dissolved Oxygen;pH		8 locations, monthly
Meiofauna survey	M sites	ID, not quantitative.	n/a	n/a	Chlorophyll in sediments, Total Organic Matter and particle size analysis, water temperature, salinity, pH, Dissolved Oxygen, Nutrients in water; wind speed and direction, air temperature and humidity		Sediment: 6 locations, 2 sampled 8 times a year, 4 sampled 4 times a year. Water: only 2 locations (KB-4 and KB-6) with samples theoretically collected every 2 weeks at 1m and 3m depths. Locations are possibly Algal Bloom Monitoring Locations

Table 2-4: Summary of the data collected by the EPA and used in the SOMER assessment.

3 Human activities

3.1 A historical perspective of change

The State of Kuwait is situated at the north-western corner of the Arabian Gulf and has a coastline of approximately 500 km. The waters surrounding Kuwait are characterised by mean winter temperatures of 14^0C, mean summer values of 30^0C and an average salinity of 41‰ (Al-Rifaie et al., 2007). One of the main features of its marine environment is Kuwait Bay itself (Figure 3-1). The bay is situated at the north-western tip of the Arabian Gulf. It is characterised by a semi-enclosed shallow body of water about 35 km wide with a mean depth of 5 m, an asymmetric slope pattern and a maximum depth of about 20 m, covering an area about 750 km^2 (Al-Sarawi et al., 1988; Al-Abdulghani et al., 2013). Due to the negligible residual current in Kuwait Bay, this area is generally a depositional environment. The net sediment transport is estimated to be modest, primarily re-circulating fine sediments within the bay, which are slowly deposited in low energy zones. However, local erosion is evident at specific sites along the southern shore where sand and sandy mud sediments are deposited in a moderate-to-high energy zone (Khalaf *et al*., 1984). The area provides vital habitats for the breeding and propagation of fish, shrimp and other marine organisms. It is also an area of industrial growth, major port activity, fishing and recreation. The southern coast of the bay has undergone a major development programme since the discovery of oil, including land reclamation, construction projects and dredging (Al-Abdulghani et al., 2013).

Given the environmental extremes of the region many of Kuwait's marine species are functioning close to their physiological limits. Therefore, it is clear to see why concern has been raised by a number studies as to the additional role anthropogenic activity may play in further stressing Kuwait's marine ecosystem (Al-Ghadban et al., 2002; Sheppard et al., 2010; Al-Abdulghani et al., 2013).

The marine environment around Kuwait represents a major source of seawater for the purposes of desalination to provide drinking water. It is also a highly productive ecosystem and is an important breeding ground for commercially important species of crustaceans and fish (Al-Rifaie et al., 2007). As such, six marine sites with a total area covering 625.4 km^2 (11.7% of Kuwait's territorial waters) have been designated as Marine Protected Areas (MPA) by Amiri Decree (Hanneke & Klaus, 2013). Established in 1988, the Doha Nature Reserve is located on the south side of Kuwait Bay. The first three nautical miles off the coast of Kuwait are protected from fishing. Currently a small MPA is being planned (1.4 km^2) in Sulaibikhat Bay (a sub-system in the south-western corner of Kuwait Bay) with the purpose of compensating loss of ecosystem services during the war with Iraq. Kuwait's MPAs fall under the jurisdiction of a number of public bodies including the EPA and the Public Authority for Agriculture and Fish Resources (PAAFR).

Kuwait has undergone major economic, social and industrial development following the discovery and exploitation of its vast oil reserves (Al-Abdulghani et al., 2013). The rapid expansion of Kuwait's industrial sector has mainly occurred around its coastal margins and has had significant impact. This has led to a variety of contaminants being discharged directly to the marine environment, including petroleum hydrocarbons, trace metals, nutrients (from domestic sewage), and contaminated brine from desalination plants (Readman et al., 1992; Al-Ghadban et al., 2002; Beg et al., 2003b; Al-Dousari, 2009; Al-Sarawi et al., 2015). The impact of these activities are exacerbated by natural sources of marine pollution that include atmospheric deposition of particulates from dust storms, natural oil seeps and particulate matter transported from the Shatt Al-Arab River that is formed by the confluence of the Euphrates and the Tigris in southern Iraq (Al-Ghadban et al., 2002; Al-Ghadban and El-Sammak, 2005).

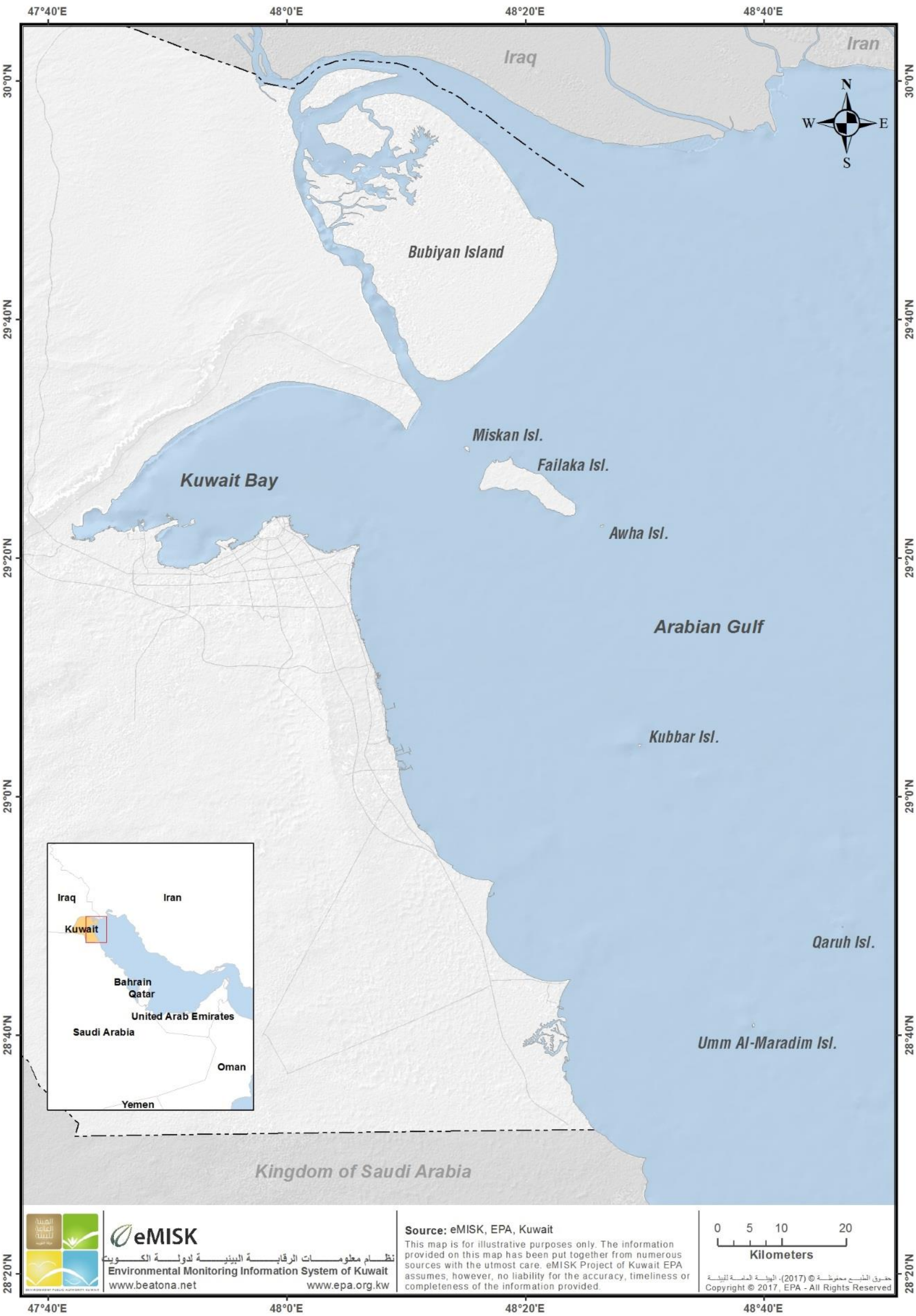


Figure 3-1: Kuwait coast line along Kuwait Bay and the Arabian Gulf within the larger Arabian Gulf area.

3.2 Human activities – Drivers of change in Kuwait

The Arabian Gulf is considered to contain the largest reserve of oil in the world (Literathy et al., 2002). Kuwait, along with other GCC states has expanded its industrial infrastructure to meet the demands of oil extraction, refining and transport. As would be anticipated, this has led to hot spots of marine degradation and contamination in areas associated with these industries (Wake, 2005; Sale et al., 2010). Historically events such as the 1991 Gulf War have exacerbated problems associated with rapid industrialization. During this period, it is thought that 9 to 10.8 million barrels of oil were deliberately released into the coastal waters of Kuwait from sabotaged tankers and pipelines at the Al-Ahmadi terminal (Al-Abdali et al., 1996; Reedman et al., 1996). During and after the 1991 Gulf War, the environment was exposed to an array of contaminants, which included pyrolytic petroleum hydrocarbons from burning oil wells, hazardous wastes from war damaged industries (such as polychlorinated biphenyls (PCBs) and heavy metals), along with spent or discarded munitions (Massoud et al., 1998; Al-Sarawi et al., 2001). In addition, areas of natural oil seepage have been identified and are thought to be important point sources of contamination at various locations around the coast (Zarba et al., 1985; Massoud et al., 1996; Massoud et al., 1998; Al-Ghadbun et al., 2001).

The arid climatic conditions of Kuwait, associated with limited sources of natural fresh water, means that the human population depends heavily on desalinating waters collected from the Gulf as its major source of potable water (Al-Dousari 2009). The combined seawater desalination capacity in the Gulf countries exceeds 11 million m^3 per day, which is 60% of the total world capacity (Purnama et al., 2005; Lattemann and Hopner, 2008). Most of the desalination plants are located along the shallow Arabian shoreline of the Gulf with each individual country having varying reliance on these systems. Kuwait has a capacity of 1.7 million m^3/d (Taqi et al., 2015). Desalination plants were identified as a main source of land-based marine pollution in the Gulf (UNEP, 1999; quoted in Taqi et al., 2015). Marine impacts of desalination plants are the intake of large quantities of seawater and the release of correspondent outfall brine wastewaters, with effects on the water and sediment quality in coastal areas. The very saline wastewater affects marine life and the functioning of the coastal ecosystem (Taqi et al., 2015). The intake of unprocessed water has significant consequences on various organisms entrained into the plant together with the seawater and this may also affect ecosystem dynamics and marine life (Khordagui, 2002, in Taqi et al., 2015). To counter biofouling of the complex desalination systems, chemicals are injected and water quality, in addition to salt content is impacted as a result. Several studies have shown that the chlorine concentration near the outlet of a desalination plant may is higher than ambient waters and threshold values of toxicity for many aquatic species are exceeded (Taqi et al., 2015).

In 2002 Kuwait's annual production of desalinated water had reached 455 million m^3, representing over 93% of all the fresh water used in the country (Darwisk and Al-Nejem, 2005). While essential to the growth and prosperity of the region the desalination industries have an associated environmental cost (Purnama et al., 2005; Al-Dousari, 2009). The regions desalination industries return over 7 km^3 per year of super saline water to the Gulf, which is commonly warmer than receiving waters and often containing pollutants such as biocides introduced to prevent biofouling (Hashim and Hajjaj, 2005; Sheppard et al., 2010). These can cause elevations of temperature (up to 5 ^{0}C) and salinity (up to 4‰) in the receiving waters, which are already warm and highly saline (Linden et al., 1988; Al-Dousari, 2009).

The Doha (Sulaibikhat Bay) and Subiyah desalination plants in Kuwait Bay play a key role in serving much of the population of the country with freshwater and power (Figure 3-2).The Doho plant has an estimated intake rate of 209 cumecs and is located outside the bay and an outflow rate of 197 cumecs at the west extreme of the Bay. Subiyah plant, located to the north-east of the Kuwait Bay, has almost half of Doha plant's capacity with approximately 85 cumecs for the intake and outflow respectively (Pokavanich and Alosairi, 2014; Taqi et al., 2015).

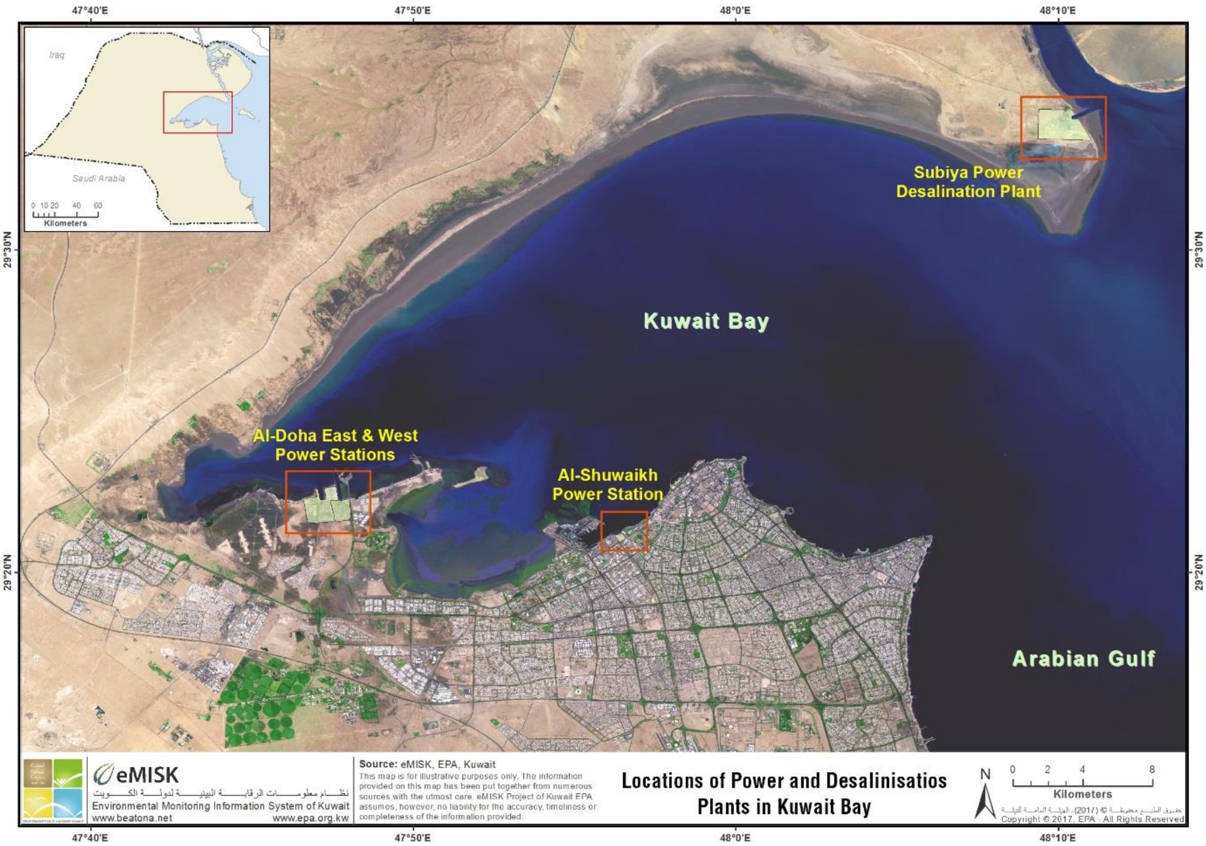


Figure 3-2: Locations of Power and Desalinisation plants in Kuwait Bay in relation to the City (From Taqi et al., 2015, and Al-Rashidi et al., 2009).

Modelling undertaken by Taqi et al. (2015), concluded that Kuwait Bay is very sensitive regarding the location of the desalination plants outfalls. Semi-enclosed embayments within Kuwait Bay were found significantly affected by the discharged plume due to the low energy hydrodynamics at the inner parts of the Kuwait Bay (Taqi et al., 2015). Modelling the injection of tracers, the study also found two main hydrodynamic behaviours within the bay. In the northern area, the effluent is mainly advected towards the mouth of the bay with minimal dilution by the residual currents; in the southern region, trapping within Sulaibikhat Bay plays a key role in building up the concentration of the tracer.

A large proportion of Kuwait's population is situated along its coastal margin leading to the accumulation of high levels of bacterial contamination (e.g. faecal coliforms and faecal streptococci) associated with domestic sewage discharge. It is known that the organic content of the sewage dumped into Kuwaiti waters is also relatively high and often septic due to low flows, long retention times, high ambient temperatures and concomitant anaerobicity (Al-Ghadban et al., 2001). Trace metals have been detected close to known discharges of domestic sewage and their accumulation has been attributed to the closed, shallow nature of the receiving beaches and the fact outlets often discharge within a few meters of the shoreline (Al-Obaid et al., 2001). In recent years, environmental disasters, such as the Mishref pumping station plant breakdown, have also contributed to the degradation of Kuwait's marine environment (Saeed et al., 2012, Lyons et al., 2015; Devlin et al., 2015). The Mishref pumping station malfunctioned in August 2009, resulting in the discharge of around 150,000 m^3 per day of untreated sewage directly into the sea over a 24-month period. The discharge occurred via three main outfalls at Al-Bidda, Al-Khitabi and Al-Messela, and impacted beaches in a number of areas important for tourism and residential housing. Monitoring undertaken by Kuwait Environment Public Authority (KEPA) during this period indicated that approximately 20 km of coastline was affected, with water quality (e.g., ammonia and phosphate) and bacterial indicators greater than permitted guidelines (Decree 210/2001; Lyons et al., 2015).

At present, many industrial outfalls, storm water culverts and earth channels are situated along the coastline of Kuwait and discharge directly into the sea. Many of the sewage and storm-water drains are located on the southern coast of Kuwait Bay (e.g. Al-Ghazali) and these are often misused and are known to emit non-consented discharges (Al-Abdulghani et al., 2013). Invariably this has led to Kuwait's marine environment becoming a sink for potentially hazardous chemical and sewage related contaminants, discharged from both industrial and domestic sources.

Surveys of sediment and biota (both fish and shellfish) have shown the marine environment around Kuwait to be contaminated with a range of aliphatic and polycyclic aromatic hydrocarbons (PAHs) as well as organochlorine contaminants (Beg *et al.,* 2009; de Mora *et al*., 2010). Trace metal concentrations in the surface sediments of

Sulaibikhat Bay, located in the south-western corner of Kuwait Bay, are known to be elevated above background levels (Alsemmari *et al*., 2010). Several sites near the Al-Ghazali outfall have been shown to be heavily contaminated with trace metals including arsenic, cobalt, copper and nickel. At selected sites, levels of these metals have exceeded international sediment quality guidelines (e.g. Canadian Environmental Quality Guidelines, ISQG; Alsemmari *et al*., 2010). Power generating industries and desalination plants are also known to be point sources of contamination and elevated levels of heavy metals have been observed in deposit feeding clams (*Amiantis umbonella*) collected from Kuwait Bay (Tarique *et al*., 2012). In selected samples at contaminated locations within Kuwait Bay, the levels of lead and cadmium in *A. Umbonella* exceeded safety limits for human consumption (Tarique *et al*., 2013).

4 Biodiversity

4.1 Introduction

Biodiversity encompasses many levels of organisation including genes, species, habitats, communities and ecosystems. Measures of diversity can demonstrate variation in the functional roles of species (rather than the number of species or gene types), within a community or ecosystem, which will describe the utility and value of the species or habitats.

Kuwait has a rich and valuable ecosystem, despite harsh environmental conditions (Devlin et al., 2015) and has many valuable biodiversity assets. Kuwait Bay and the Arabian Gulf supports a range of coastal and marine ecosystems such as seagrass beds, coral reefs, and mud and sand flats. These ecosystems contribute to the maintenance of genetic and biological diversity in the marine environment and provide valuable ecological and economic functions (Table 4-1). The drivers and pressures of human activities can impact on all aspects of biodiversity which can be presented through a DPSIR framework (Figure 4-1).

Table 4-1: The importance of biodiversity and demonstrated examples.

Biodiversity asset	Examples
Benefits to ecosystem and economic productivity	40% of the world's economy derived from biological resources. Productive and sustainable ecosystems support productive fisheries that provide food and employment. Health and diverse habitats provide feeding and nursery grounds for a variety of commercially important marine organisms (Naser, 2011a; Naser et al. 2011b). Tourism and recreation (scuba diving, birdwatching, turtle watches
Indicators of ecosystem and environmental health	Diversity and abundance of species, especially top predators (cetaceans, birds, turtles), indicative of environmental health Indicator species can provide early warnings of marine pollution, contamination or over exploitation.

Biodiversity asset	Examples
Responsibility to preserve biodiversity future generations.	Medical discoveries, economic development and adaptive responses to climate change

There is a perception that Kuwait is dominated by a flat and stony desert with no rivers or natural lakes, however, it has a varied and important diverse ecological system. Its location at the confluence of three distinct ecoregions –the Arabian Desert, the subtropical Gulf coast and the Mesopotamian Delta – means that on a local scale Kuwait has a variety of biodiversity-rich habitats. Its marine waters and tidal coastlines are some of the Gulf's most biologically productive, historically being fed by the nutrient-rich delta plume on the vast tidal estuary of the two great rivers, the Tigris and Euphrates. And unlike other Gulf States, Kuwait has a surprisingly seasonal climate with a distinct cool and often a relatively moist winter period.

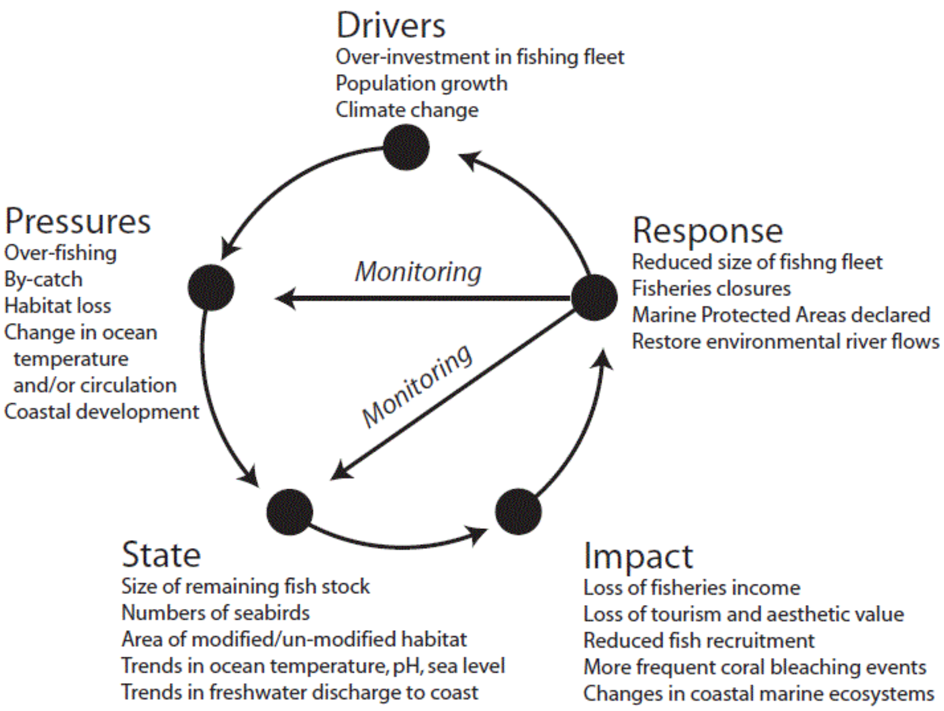


Figure 4-1: Interactions between human pressure and biodiversity impacts set across the DPSIR framework.

4.2 Drivers and pressures on biodiversity

Impacts on coral, sea grass and algal biota of the Bay and the wider Gulf, following the Gulf war in 1991, are a combination of the naturally stressful conditions (associated with temperature and salinity) and various anthropogenic inputs, including hydrocarbons, heavy metals and non-essential trace metals (Price, 1998; Price and Robinson, 1993). Such anthropogenic influences are thought to have been a key driver in numerous biological catastrophes in Kuwaiti waters, including well-documented fish kills during 1999 and 2001 (Glibert et al., 2002). Combined sources of marine pollution to the Bay include the aftermath of the Gulf war (Literathy, 1993; Massoud et al., 1998), atmospheric fallouts carried by North Western dust storms (Foda et al., 1985; Khalaf and Al-Ajmi, 1993) and particulate matter derived by river transport from Shatt Al-Arab (Abaychi et al., 1988; Al-Yamani, 2008). Contaminants discharged into this environment include petroleum hydrocarbons, nutrients from domestic sewage (nitrogen and phosphorus compounds), heavy and non-essential trace metals (from partly treated/raw sewage), cooling water from disused power plants, and various effluents from light industries ; Al-Sarawi, 2001; Banat et al., 1998; Massoud et al., 1996; Sen Gupta et al., 1993).

Kuwait has seen rapid expansion over the past 40 years with the last official census in 2005 reporting over 2.2 million people with a 17-fold increase from a population of 152,000 in 1950. In addition, nearly 98% of the population in Kuwait is urbanized, with approximately 83% of the total population resides in Kuwait City. This current situation, coupled with an urbanization rate of 2.1% per year, places pressure on managers to deal with the increasing point source discharges into the marine environment (Anon et al., 2012). Rapid urbanisation and industrialisation of Kuwait in the mid-1970s resulted in an insufficient capacity to treat wastewater until the commissioning of the Sulaibia wastewater plant in 2004 (Al-Ajmi et al., 1988; UNEP, 2001). Further, Kuwait Bay has been historically impacted by a deliberate release of oil and industrial contamination, as well as with ordnance and shipwrecks from the 1991 Gulf war. In addition, a serious malfunction at the Mishref pumping station in 2009 (commencing August, 2009), resulted in the discharge of approximately 70 million m^3 of raw sewage to the southern marine coastal areas, compromising an already anthropogenic stressed system (Saeed et al., 2012; Lyons et al., 2015: Devlin et al., 2015) (Table 4-2).

Table 4-2: Description of the main demographic changes in Kuwait over a period of 30 years (1983 – 2013).

Time period	Description of Kuwait population and main anthropogenic pressures (www.e.gov.kw)
1983 - 1988	Population increase from 152,000 in 1950 to 1.58 million in 1983. Increased urbanisation, but relatively low rates of development
1989 - 1999	Gulf War associated pressures including PAH and heavy metal contamination. Population increase to 2.06 million in 1990 but decreases over next 6 years to 1.59 million.
2000 - 2003	Population increase rapidly to 2.1 million in 2003. Nearly 98% of the population in Kuwait is urbanized, with approximately 83% of the total population resides in the area of Ku wait City.
2004-2007	The last official census (2005) reports over 2.3 million people with a 17-fold increase from a population in 1950. Continued urban and industrial (urban, oil, freshwater extraction) expansion and sewerage discharges. with an urbanization rate of 2.1% per year)
2008 - 2013	Population increases to 3.37 million in 2013. Mishref pumping station malfunctions in August 2009, discharging 150,000 m^3 day-1 of raw sewage sea over 24 months. The discharge occurred via three main outfalls at Al-Bidda, Al-Khitabi and Al-Messela. Increased industrial expansion highlighted by contamination in inner Kuwait Bay. **Climate change** – with increasing temperature of global (+1 -2degrees) and local (+1.5) degree warming

4.3 Data sources

There is currently only a limited monitoring program for many of the key aspects pf biodiversity, with for example only limited information on species abundance and diversity of cetaceans and turtles and only limited information on coral reefs and interntial marshes (Figure 4-2). There have been several science publications on marine mammals in the Arabian Gulf, and several of these have been extrapolated to Kuwait. The data collected and presented here are “type 4” assessments, where a qualitative narrative is presented on the state of the biodiversity measure based on available technical and scientific information due to the absence of quantitative data. There are no environmental standards presented for any of the biodiversity measures. However, the underlying assumption for environmental standards is that the vulnerable habitats and species are important and need to be protected from further deterioration and stable over time. Thus, the assessment is made against several of these measures with the provision that recognises the importance of these species, and that their population remains stable, i.e. is not decreasing, and that the habitats which are part of the biodiversity system, such as coral reefs, are also stable and not responding to anthropogenic pressures. The development of more quantitative standards at which to compare biodiversity measures against are being developed through the Objectives and Indicators process, and through the characterisations surveys to be run under eMisk program.

4.4 Assessment process for biodiversity

Biodiversity assessment is based on a qualitative process by which all available information is presented for each habitat and each set of species within the biodiversity group (Figure 4-3Figure 4-2). The information related to that biodiversity is taken from current literature and government reports and provides a snapshot of the status of biodiversity in Kuwait waters.

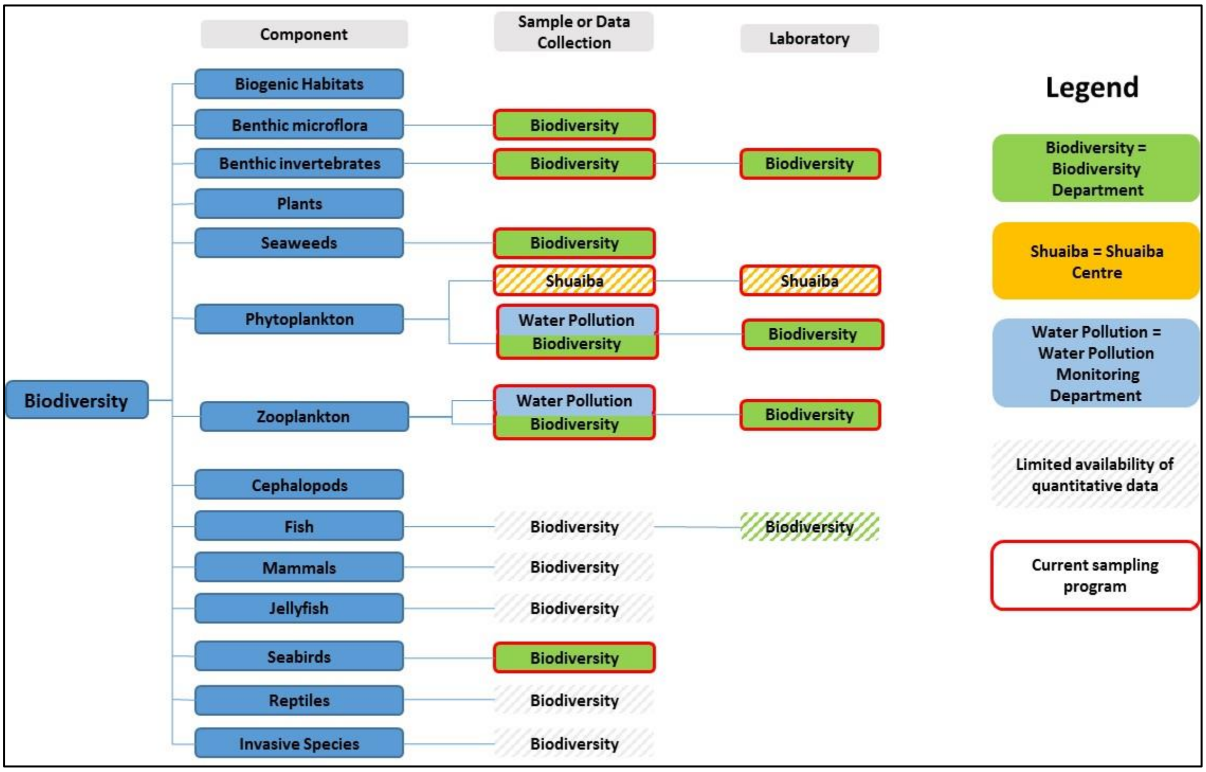
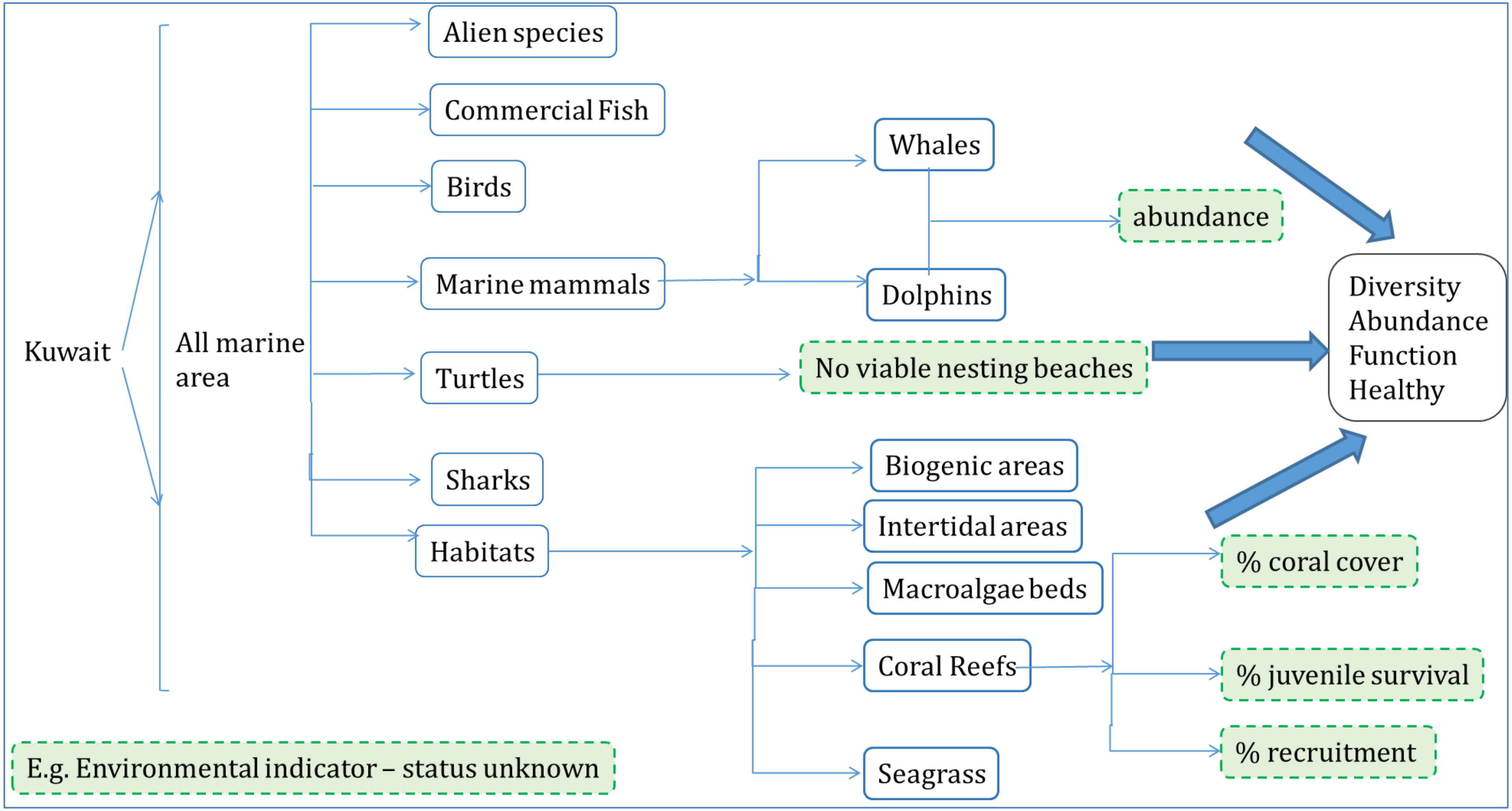


Figure 4-2: Summary of biodiversity data held in the current EPA monitoring programs

Figure 4-3: Assessment of biodiversity indicators. Green shaded boxes presented as example of environmental standards.



4.5 Summary of outcomes

The assessment of biodiversity has been based on a review and analysis of existing available data. Data on the distribution and biology of most of the species is limited, and this is reflected in the low confidence against each species. Habitats, such as coral reefs and seagrass beds are recognised as important, but are not able to be fully assess due to limitation of long term monitoring and data, and again there is only low confidence in the outcome of this assessment. As with the assessment of species, the assessment of habitats relies on the review of all past and current literature on the possible status.

The species examined under this report include:

- Rare and vulnerable fish (such as sharks, manta rays)
- Turtles
- Cetaceans
- Alien Species
- Seabirds

The habitats examined under this report include:

- Coral Reefs
- Seagrass beds
- Coastal habitats

Typically, most of the biodiversity assessments are based around a type 4 approach (Table 2-3) which focuses on qualitative information and provides a narrative around the understanding of the current state. There are no agreed environmental standards, and whilst objective and indicators are being developed (Le Quesne et al., 2016), they have not been fully agreed for implementation. The amount of data around the biodiversity assessment, whilst valuable, draws on wider studies with extrapolation out to the wider Arabian Gulf issues, and is not applicable for any type of quantitative assessment. The summary of the biodiversity assessment is detailed in Table 4-3. Most of the indicators (alien species, seagrass bed, coastal habitats, whales and vulnerable species) are difficult to fully assess due to lack of data and a lack of agreed objectives around the metric and the environmental standards. This is reflected in the status outcomes of “unknown” for each of these biodiversity measures. There are more details around coral reefs, marine turtles and seabirds which provides more certainty in identifying a future trajectory, reflected in the status outcomes of “moderate” to “poor”.

Table 4-3:Summary of biodiversity assessment for Kuwait Marine Areas.

Biodiversity — Overall Assessment

Status assessment is MODERATE. The moderate status is due to issues that have been identified with turtles, seabirds, coral reefs and coastal habitats and recognises that all of these components of biodiversity, even if current status is unknown, are considered important for the protection of Kuwait's unique biodiversity and are currently being impacted by coastal development, sewage inputs and other human activities. The status of coral reefs, seagrass beds, coastal habitats, turtles and seabirds are likely to continue to decline based on current knowledge and future projections. The biodiversity assessment has identified concerns regarding the sustainability of Kuwait's iconic species and habitats, however confidence in the assessment and prediction of trajectories for many aspects of Kuwait's marine biodiversity, including sharks, rays, whales, dolphins and alien species is low, reflecting a lack of knowledge on both the current state and the impacts of future pressures.

What this assessment does show is that Kuwait is home to many iconic species which are ecologically, commercially and socially important and require significant conservation measures. There are major concerns for turtles due to destruction of nesting beaches. The occurrence of alien species is increasing and many alien species, which have caused impacts in other areas, have been identified in Kuwait marine waters. Seabirds are facing local habitat destruction coupled with international pressures that are affecting the numbers of migratory birds. Coral reefs are facing regional and global crises that are severely impacting on their long term viability. Seagrasses and all coastal habitats are under threat from continued coastal expansion. There is an urgent need for improved monitoring programs to increase knowledge of the state and trajectory of biodiversity. Development of management objectives and associated environmental standards is required to recognise the importance of biodiversity and provide guidance for management actions. In conclusion, based on the current information and extrapolation out to many of the trends currently occurring in the Arabian Gulf, there is considerable concern that the state of many aspects of biodiversity will continue to decline. There are particular concerns for the state and trajectory for seabirds, turtles, coral reefs and coastal habitats given the importance of these components to biodiversity conservation and their vulnerability to coastal development.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
SPECIES ABUNDANCE	Rare and vulnerable fish	Population abundance	●	⇩	■	Status assessment is MODERATE. The state is considered to be declining but with low confidence in the assessment due to sparse data available for rare and vulnerable fish species. The assessment also takes account of wider regional and international assessments of the decline state of many rare and vulnerable fish.
SPECIES ABUNDANCE	Cetaceans (Whales and Dolphins)	Population abundance	?	?	■	Status assessment is UNKNOWN. Several species of cetaceans, including resident populations of Indo-Pacific humpbacked dolphin and finless porpoise occur in Kuwait, however there is no systematic information on the abundance and distribution of cetaceans in Kuwaiti waters. Bycatch may occur and dead cetaceans, especially hump-back dolphins and finless porpoise are periodically washed up on Kuwait beaches. Due to the limited information on population status no assessment can be made at this stage. Focused monitoring efforts are required to enable assessment of the status of cetaceans in Kuwait, although the population dynamics of many of the cetacean species occurring in Kuwait will be driven by factors outside Kuwaiti waters.
SPECIES ABUNDANCE	Marine Turtles	Occurrence of nesting	●	⇩	■■	Status assessment is POOR. Both hawksbill and green turtles have been observed nesting in Kuwait. The decline in turtles is predominantly due to degradation of turtle nesting areas, and due to bycatch of turtles in fisheries. Recent surveys revealed a small number of nests within Kuwait. The extent of degradation of nesting beaches has significantly reduced the area suitable for nesting from original conditions. Immediate conservation action is required to protect remaining turtle nest sites from further degradation, and to reduce by-catch in fisheries. Without such efforts it is likely that breeding populations of turtles will be lost from Kuwaiti waters.
SPECIES ABUNDANCE	Seabirds	Population abundance	?	⇩	■	Status assessment is UNKNOWN. Sea bird populations in Kuwait consist of both resident and migratory species. There is limited systematic information on population abundance. However, the prediction of future "decline" is based on local and international pressures for migratory species and habitat degradation and loss. The migratory species require a variety of marine and terrestrial habitats during different seasons and life stages and can be affected by habitat loss and impacts across their migratory range. Seabirds can be long lived and even quite small increases in mortality can lead to significant population declines.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
ALIEN SPECIES	Alien species	Frequency of occurrence	?	?		Status assessment is UNKNOWN. This is based on limited information and no long term monitoring data. Many of the alien species identified in the Gulf have been introduced as a result of commercial shipping activities, such as ballast water exchange or hull fouling, given the large volume of shipping in the Arabian Gulf. Some of the alien species have been associated with adverse impacts within invaded areas, although others have not been associated with adverse impacts. Further risk assessment of these species, would allow for prioritisation of the species in relation to potential impact and relative risk.
HABITATS	Coral Reefs	% cover				Status assessment is MODERATE. This assessment is based on data available from a small number of studies focused on the monitoring of overall extent and % living coral cover on Kuwait coral reefs. Data available for Kuwait coral reefs is sporadic with limited long term monitoring information, however the information that has been reported for some of Kuwait coral reefs indicates that they were considered stable, with % coral cover varying between 15-48% up to 2005. More recently, the increased pressures facing Kuwait waters and the Arabian Gulf have thought to further impacted Kuwait coral reefs. Impacts are due to local pressures, such as anchor damage and overfishing regional and global pressures including decline in water quality, coastal development activity and climate change driven increase in water temperature. Due to the factors the predicted trajectory for the status of Kuwait coral reefs is for a future decline.
	Seagrass	Area and condition	?			Status assessment is UNKNOWN. Information on Kuwait seagrass beds is limited and difficult to extrapolate to a known status. A more comprehensive assessment of state and trajectory would require additional and targeted monitoring efforts. However there is concern that coastal development and other urban pressures are impacting on seagrass stability. In the Arabian Gulf, the extent of mangroves and seagrasses has been declining due to the impacts of unplanned coastal development and some of those same pressures would be expected to be impacting on Kuwait seagrass areas.
	Coastal habitats	Area and condition				Status assessment in MODERATE. Coastal development has led to the reduction (and destruction) of coastal habitats with more than 40% of the coastline of the Arabian Gulf now developed. The Kuwait coastline is comprised of a mixture of salt marches, mudflats, sand plains, coarse habitats and exposed bedrock, all which support Kuwait's biodiversity. Protection of these habitats is necessary for the successful survival of a variety of dependant species, such as birds and turtles. The productivity of broader habitats such as mud flats and seagrasses is crucial to the viability of those dependant species. Industrialisation and modern development of Kuwait has intensified since 1986, with habitat condition and extent of all coastal types decreasing in response to increasing coastal development. Special consideration is given to the coastal habitats surrounding Kuwait's islands, especially those around Boubyan, which has internationally important bird species, seagrass and coral reefs, but has been identified for possible future developments.

4.6 Biodiversity Indicator assessments

4.6.1 Rare and threatened species

4.6.1.1 Background

Many fishery species in the Gulf have been heavily exploited, and fishing effort already exceeds optimum levels for most demersal species (Sale et al., 2011; Grandcourt et al. 2004, 2009). Throughout the Gulf, data on stock status are limited, and many catch data are recorded only to the family level, reducing the ability of managers to use statistical catch-at-age methods for conducting species level assessments (Grandcourt, 2012). In addition, fisheries regulations are weak, are not rigorously enforced, or are inconsistent among jurisdictions that share stocks (Grandcourt, 2012), all problems common to many developing regions.

4.6.1.2 Current state of knowledge: Kuwait

Reliable information on species biodiversity is generally historic. Data on key commercial species generally shows a decline in abundance for the majority of species (Amani and Al-Zaidan, 2013). Data on rare and vulnerable species is sparse, however there has been recent work on smoothtooth blacktip shark, *Carcharhinus leiodon (*Moore, 2011; Moore et al., 2015*)*. The recent work by Moore et al., 2015 with previous studies indicate that potentially hazardous levels of mercury and other contaminants may occur in sharks in this region, adding further stressors to these vulnerable populations. Sawfishes, *Pristidae* (Moore, 2014) and mudskippers (Bahija E. Al-Behbehani, 2010) that can be referenced, are also in decline. In all instances of information on rare and vulnerable species, a decline has been observed.

4.6.1.3 Assessment approach and findings

Generally, all published evidence shows a decline in all species abundance and distribution throughout the waters of Kuwait.

4.6.1.4 Conclusion

Biodiversity surveys under eMISK$_{\text{Marine}}$ will start to give time series data that can be used to support management decisions to mitigate impacts. Ultimately, rare and vulnerable species are under threat throughout the world so those in Kuwait waters are no less likely to be affect by the human pressures affecting many species around the globe.

4.6.2 Cetaceans

4.6.2.1 Background

The Indian Ocean bottlenose dolphin (*Tursiops aduncus*) is the most common cetacean in Kuwait (71% of groups and individuals), followed by the Indo-Pacific humpback dolphin (*Sousa chinensis*; 27%) and finless porpoise (*Neophocaena phocaenoides*; 2%). The estimates of cetacean abundance in the UAE differed significantly between 1986 and 1999 and indicate a population decline of 71%, however this has only been documented for UAE (see Preen 2004).

A range of additional large cetacean species have been infrequently reported dead and alive within Kuwait waters including: blue whale (*Balaenoptera musculus*), false killer whale (*Pseudorca crassidens*), Bryde's whale (*Balaenoptera brydei*) and Killer whale (*Orcinus orca*) (see Baldwin et al., unknown publication date; Bohardi, 2015; Burahmah, 2013). However, the relatively shallow seas of Kuwait make the habitat sub-optimal for many larger species and it is likely, though unproven, that most reports are of vagrants or individuals suffering illness.

4.6.2.2 Current State: Kuwait

The Indo-Pacific hump-backed dolphin (*Sousa chinensis*) is a commonly reported dolphin from the Arabian Gulf (Bishop and Alsaffar, 2008) and is regularly sighted within Kuwait waters. A resident population of hump-backed dolphin is widely believed to persist within Kuwait around Boubyan Island and is supported by data to this effect (see Nithyanandan, 2010). The most recent sighting records of *S. chinensis* arose from opportunistic surveys during the period 2006-2009 (Bishop and Alsaffar, 2008; Nithyanandan, 2010) between Al Khiran (28° 39' N lat., 48° 23' E long.) and Min Al Zour (28º 42' N lat., 48º 24'E long.) within Kuwaiti coastal waters.

The Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) are listed as occurring within Kuwait waters and are believed to be the most abundant delphinids in the Arabian Gulf. Preen (2004) reports population sizes of around 1200 for the region although it is unclear what percentage of these animals use, or are resident within Kuwait waters. *T. aduncus* are known to prefer areas with rocky and coral reefs, or sea grass. The marine habitat of Kuwait is conducive to their presence as they are most frequently observed in waters shallower than 100 m preferring water temperatures of 20-30°C (Wang and Yang, 2009).

Populations are believed to have declined by 71% between 1986-1999 (Preen, 2004) and while causes are unknown it is likely that factors such as competition for food, pollution and bycatch are implicated (as with *S. chinensis*). As the species shows strong residency and limited population sizes in many regions there are serious concerns about the depletion of local populations (Wang and Yang, 2009).

No conclusive assessment on whales can be made at this time due to a lack of data on the migratory cycle and the amount of time that whales are found in Kuwait marine waters.

4.6.2.3 Assessment approach and findings

The exact abundance, temporo-spatial distribution and reproductive status of the Indo-Pacific dolphin population is undetermined at present, as is their fluctuation from pristine conditions. Where observed in Kuwait, the mean group size of *S. chinensis* is 7 individuals (Jefferson and Karczmarski, 2001) although group size ranging from 30-100 individuals have been recorded elsewhere in the Arabian Gulf and Arabian Sea (Baldwin et al., 2004). This may be indicative of unquantified anthropogenic pressures eliciting adoption ofdiscrete behavioural characteristics among the Kuwait population or even the presence of an, as yet, unconfirmed sub-species within the region.

Behaviour commensurate with mating has been observed within Kuwait waters between April-May (Nithyanandan, 2010) at a time when the species is known to conduct this activity around South Africa. Hence it is likely that Kuwait waters serve as breeding habitat for the species to a greater or lesser extent. While calves have been repeatedly observed swimming alongside mothers in mid-summer (July/August) near Min Al Zour and Al Mufateh entrance it is not known whether *S. chinensis* calves within Kuwait waters or elsewhere (Baldwin et al., 2004).

The feeding habits and behaviour of *S. chinensis* is largely unknown from Kuwait waters although daytime feeding on shoals of Gulf Herring (*Herklotsichthys lossei*) has been reported near Al Khiran in the past (Nithyanandan, 2010).

The finless porpoise (*Neophocaena phocaenoides*) has been recorded as inhabiting shallow and offshore waters of Kuwait (Clayton, 1983; Collins, 2013). Recent sightings by Willson (unpublished data) may provide a minimum estimate of 12 individuals for Kuwait Bay in 2005. A crude measure of effort can be applied to these sightings; Willson (unpublished data) has completed five years (approximately 3 boat trips per week) of boat based work in Kuwait and yet recorded only ten sightings.

Populations of *N. phocaenoids* in the broader Arabian Gulf are small patchy and at risk of further depletion as they are susceptible to oil spills, pollution, coastal development, habitat loss and red-tides (Aspinall and Baldwin, 1999; Price 1993a). By-catches are also recorded and may contribute to the species' rarity (Aspinall and Baldwin, 1999).

The exact abundance, distribution, health and breeding status of all other whale species within Kuwait waters is unknown.

4.6.2.4 Conclusions

It is reported that there has been a considerable reduction in dolphin populations within the Arabian Gulf (Preen, 2004). It is unclear to what extent this has been effected by

Gulf War oil spills in 1991 and reductions in riverine input (Al-Yamani et al., 2007) from the Shatt Al-Arab river, though both may be implicated.

While likely that Kuwait populations of *S. chinensis* are in direct competition with commercial fishermen (gill netters) for fisheries resources at the present, it is unclear to what extent. Bycatch may occur and dead or stranded hump-back dolphins are periodically washed up on Kuwait beaches, some of which are entangled in fishing gear (see Bohadi, 2015). No data sets or post mortems have been conducted to categorically ascertain causes of death to date.

4.6.3 Marine turtles

4.6.3.1 Background

Five species of IUCN endangered marine turtles have previously been recorded within the Arabian Gulf. Species encountered include: green turtle (*Chelonia mydas*), loggerhead turtle (*Caretta caretta*), hawksbill turtle (*Eretmochylys imbricata*), olive ridley turtle (*Lepidochelys olivacea*) and occasionally leatherback turtle (*Dermochelys coriacea*). Among these only the green turtle and hawksbill turtle have previously been recorded nesting on Kuwaiti beaches (Rees et al., 2013; Meakins and Mohanna, 2004; Meakins and Mohanna 2000). Sightings of *L. olivacea* and *D. coriacea* are believed to be of vagrants to Kuwait waters.

Marine turtles were historically harvested directly for food within the Arabian Gulf while by-catch from gill nets and 'hadra' traps still represent a serious continuing threat for remaining populations. In-water distribution and abundance of each turtle species is unknown for Kuwait, as are levels of mortality arising from by-catch. Nest mortality arising from synanthropic predators presents a further threat to turtle recruitment and can be so strong as to cause an almost complete reproductive failure in a populations of *E. imbricata* in Arabian Gulf rookeries (Ficetola 2008).

C. mydas generally display small, defined home ranges, but their foraging ecology is dependent on the extent of suitable habitat within a region together with turtle size and water temperature (Seminoff et al. 2002). Home ranges of tracked green turtles in Kuwait overlap with shallow coastal conditions suitable for sea grass and algae growth, which comprise the main food source of adult green turtles (Bjorndal 1997). Mapping marine sea grass and algal pastures in the northern Gulf region would, therefore, help to identify the extent of potential green turtle foraging habitat and, if supplemented with further tracking or in-water research, would facilitate directed conservation measures (Rees et al., 2013). Small scale tracking studies by Rees et al (2013) have shown *C. mydas* to reside for extended periods (>200 days) along the north coast of Failaka Island with individuals from this locality found to undertake periodic migration to waters off Saudi Arabia. This may indicate interconnection with

Saudi Arabian populations where thousands of turtles nest each year on shallow sea islands (Pilcher 2000) though genetic links are unproven.

E. imbricata favour shallow coral reef habitat and mangrove estuaries where they forage upon marine invertebrates, especially sponges (Rincon-Diaz, 2011). Though Kuwait coral reef habitat is believed to have been both degraded and reduced in size by up to 90% (Unknown, 2010), areas persist around Umm Al-Maradim and Qaruh Island thus it is here that hawksbills turtles are anticipated to remain.

4.6.3.2 Current state of knowledge: Kuwait

Nesting beach habitat has been widely degraded across Kuwait due to beach compaction, unregulated development and artificial illumination. Indirect anthropogenic effects can also occur through the alteration of natural vegetation along the coastline which can increase the temperature of nests and thus bias the sex ratio of hatchlings (Kamel and Mrosovsky 2006). Consequently, the only recorded turtle rookeries are confined to offshore islands and inaccessible beaches around oil refinery sites on the southern mainland. The only known remaining rookeries sites (Rees et al., 2013, Papathanasopoulou, 2015b, Papathanasopoulou, 2015c) are identified as:

- Umm Al-Maradim Island
- Qaruh Island
- Beaches alongside the Chevron Oil Complex (Mina Alzour area- South Kuwait)

It is possible, though unconfirmed, that turtles continue to nest in other remote and undisturbed localities which share the characteristics of these remaining nest sites and possible other sites include: Miskan Island, Kubbar Island, Auhah Island and Failaka Island.

The most recent scientific surveys by Rees et al., (2013) found that C. *mydas* no longer nests on Umm Al-Maradim Island though individuals were still found to be nesting on Qaruh Island. The number of nesting *C. mydas* females is low (5 were observed in 2008, 1 in both 2009 and 2010, and 3 in 2011), and none of the turtles were observed nesting in more than 1 year. Twelve green turtle nests were recorded during the 2012 nesting season, likely equating to only ~3 breeding females. As such, the breeding population of green turtles nesting in Kuwait is critically low and Quarah Island represents nationally important breeding habitat for the species.

Along with Quarah Island, the Chevron Oil Complex (Mina Alzour area) is the only recorded active breeding site for *E. imbricata* and likewise is of national importance for their continued presence in Kuwait. It is likely that breeding persists at these sites owing to their remoteness from public disturbance and inaccessibility to depredating canids. The numbers of hawksbill turtles nesting in Kuwait are unknown but the recorded presence of only two nests in 2015 (see Papathanasopoulou, 2015b and Papathanasopoulou, 2015c) suggest numbers of reproductively active females are also critically low.

4.6.3.3 Assessment approach and findings

No long-term data sets detailing the distribution and extent of sea turtle rookeries in Kuwait exist. It is likely, though unproven, that degradation of nesting habitat (sand compaction, light pollution and other stressors), by-catch and nest depredation have drastically reduced the abundance of marine turtles in Kuwait. Combined monitoring detailing availability of foraging areas, suitable nesting habitat and nest success would provide a mechanism to identify and protect key sites and improve the suitability of others.

4.6.3.4 Conclusions

Immediate and concerted conservation efforts are required to protect remaining turtle nest sites from further degradation and adults of reproductive age from by-catch. Without such efforts, it is likely that marine turtles will shortly cease to exist as breeding species within Kuwait waters.

4.6.4 Seabirds

4.6.4.1 Background

Due to its unique location on the boundary of Afrotropic, Eastern Palearctic and Western Palearctic regions, Kuwait supports a disproportionately rich diversity of bird species. Many of these are migrants exploiting Kuwait's unique location on the 'eastern flyway'. The East Asia - Pacific Flyway spans east Asia, from eastern Siberia to southeast Asia and Australasia (Estimates of total waterfowl population using this flyway range from 14-17 million. This flyway contains about 50 globally threatened migratory waterbirds species, including populations that are endangered or suffering significant population declines. The most prominent feature of Kuwait's birdlife is migration. Several major bird migration routes connecting three continents intersect at the head of the Gulf. This involves movements by long-distance migrants and by regional migrants some of which spend the winter in Kuwait. For many long-distance migrants that breed in northern Eurasia and overwinter in the subtropics the journey is remarkably long and crosses geographical obstacles such as the high ranges of the Caucasus, the Elburz, the Zagros Mountains and the wide expanses of the Black Sea, the Caspian Sea and the Gulf. The Arabian Desert is still another barrier – a sea of sand and rock inhospitable to most migrating birds.

There are more than 100 waterfowls mostly migratory, which are monitored on the coastlines of the State of Kuwai. They are found on the islands of Warba and North Bubiyan Island, the north-west coast of Failaka Island, Doha Kazma, the coast of

Sabah Al-Ahmad Nature Reserve, Doha Reserve Coast, Jahra Reserve, Umm Al-Namel Island, Southern John Asalbekhat Coast which extends between the free zone – Shuwaikh Port, the Southern Islands " Kubbar", Umm Maradim Island and Qaruh Island.

Each bird species may have a different migration route and different movement behaviour, so generalizing about migration pathways is problematic. Pathways may also not be precise thoroughfares but rather broad fronts. Conventional knowledge from initial observations in Kuwait and the surrounding region show the following two important routes for long-distance migrants that undergo a mass migration to breed in the temperate Eurasia and return to winter in the tropics. First, the Eastern Flyway is an important Central Eurasian migration route that runs east of the Caspian Sea and Elburz Mountains then southwest through passes in the Zagros across Kuwait and the Arabian Peninsula into eastern and central Africa via the Bab Al-Mandab straits. Many raptors such as eagles, falcons, harriers, and buzzards take this route. Another important route passes through Kuwait, coming from Eastern Europe along the Tigris-Euphrates valleys of Turkey and Iraq, across the head of the Gulf eastward along the western edge of the Zagros Mountains to Pakistan and India. Some songbirds take this route. Many birds also come from the Eurasian arctic and tundra to over-winter in the Gulf or other parts of the Indian Ocean shores and pass through Kuwait as well. For many northern birds, the water bodies are not barriers but the Arabian Desert definitely is, so they keep to the coast. Some northern species, even hardy ones such as swans, geese and ducks, may be obliged to travel further south than usual in seasons of severe winter weather. For many of these northern waterfowl the Mesopotamian Delta (including Kuwait Bay) is the southernmost place they're prepared to go. This accounts for the sporadic, rare occurrences of so many colourful waterfowl in some winters. Kuwait is in fact one of the only Arabian countries that regularly gets to see northern birds such as these (http://kuwaitbirds.org/kuwait/migratory-birds).

Recent observations also show that an important number of birds do breed regularly in Kuwait – and many of them tend to breed early in the spring whilst some also nest during the scorching early summer. These habitats include the Mesopotamian Delta with low lying mud-built islands such as Warba, Boubyan and many small islets and sand banks in North-eastern Kuwait. In the past huge numbers of water birds have bred there. Although the large nesting colonies of pelicans and cormorants that once bred no longer exist, the numbers of shorebirds currently breeding are of international significance. This includes one of the world's highest concentrations of Crab-plovers. Other birds that breed in large numbers include herons, egrets, spoonbills, gulls, and terns. Boubyan still hosts large numbers of Great Cormorants that roost overnight in winter and even flamingo rookeries gather irregularly, but they no longer breed there. Other breeding areas include the offshore islet seabird colonies. Small islets such as Kubbar and Um Al-Maradim host some of the northern Gulf's largest seabird colonies, particularly of four breeding tern species. These are the most north-western coral cays in the Gulf and birds nesting here feed in the waters of the nearby Mesopotamian Delta plume. Artificial wetlands, including reed beds from water treatment plants, are now important sites where many birds that nest nowhere else in the Arabian Peninsula now breed, albeit in very small numbers. The total number of breeding birds in Kuwait's artificial wetlands includes 15 regularly occurring or recent breeders and at least 5 irregularly occurring or past breeders. Twenty-five or more bird species breed in gardens and agricultural habitats also. The vast Arabian desert reaches its northern edge in Kuwait. Birds endemic to this desert environment occur here but are usually widely dispersed. Their populations may also fluctuate remarkably depending on precipitation or other regional weather conditions. These desert habitat specialists are extremely interesting because some of them are very rare in the Western Palearctic realm. In total, approximately 20 species can be considered desert breeding specialists in Kuwait.

4.6.4.2 Current State

Kuwait's unique position between three major zoogeographic regions, the Western and Eastern Palearctic and the Afrotropic realms provides a vast region that hosts about 1100 species of birds – many of which are transients and vagrants, visiting from surrounding regions of Asia and Africa. Situated at the far eastern boundary of this region, Kuwait has the unusual privilege of seeing avian visitors from adjacent zoogeographic regions. Many species from the Indomalaya and Afrotropic realms also penetrate Kuwait's territory – many of which are seldom seen anywhere else in the Western Palearctic. Due to this large migratory system, there are no endemic bird species within Kuwait and none have gone extinct (BirdLife International, 2016 data). Ornithologists have long submitted lists of bird species observed within Kuwaiti to the Ornithological Society of the Middle East (OSME) and BirdLife International such that comprehensive understanding of bird diversity has long been established for the nation (see Table 4-4). To this end, 291 bird species have been recorded within Kuwait of which 42% (n= 124) are closely associated with aquatic habitats. No information exists in relation to current or historic abundance of discrete Kuwaiti seabirds making judgements about populations difficult. Nonetheless, given the mobile/migratory nature of most species it is likely that the status of species recorded has mirrored global trends of stark population declines.

Table 4-4: Kuwait water bird species and their conservation status

Common name	Latin name	Family	IUCN Category
Persian shearwater	*Puffinus persicus* (A)	Procellariidae	Least concern
Red-billed tropic bird	*Phaethon aethereus* (A)	Phaethontidae	Least concern

Common name	Latin name	Family	IUCN Category
Great cormorant	*Phalacrocorax carbo*	Phalacrocoracidae	Least concern
Socotra cormorant	*Phalacrocorax nigrogularis*	Phalacrocoracidae	Vulnerable
Pygmy cormorant	*Microcarbo pygmeus* (A)	Phalacrocoracidae	Least concern
Great white pelican	*Pelecanus onocrotalus*	Pelecanidae	Least concern
Dalmatian pelican	*Pelecanus crispus* (A)	Pelecanidae	Least concern
Crab-plover	*Dromas ardeola*	Dromadidae	Least concern
Eurasian oystercatcher	*Haematopus ostralegus*	Haematopodidae	Near threatened
Grey heron	*Ardea cinerea*	Ardeidae	Least concern
Purple heron	*Ardea purpurea*	Ardeidae	Least concern
Great egret	*Ardea alba*	Ardeidae	Least concern
Western reef egret	*Egretta gularis*	Ardeidae	Least concern
Little egret	*Egretta garzetta*	Ardeidae	Least concern
Squacco heron	*Ardeola ralloides*	Ardeidae	Least concern
Cattle egret	*Bubulcus ibis*	Ardeidae	Least concern
Black-crowned night heron	*Nycticorax nycticorax*	Ardeidae	Least concern
Great bittern	*Botaurus stellaris*	Ardeidae	Least concern
Sacred ibis	*Threskiornis aethiopicus* (A)	Threskiornithidae	Least concern
Glossy ibis	*Plegadis falcinellus*	Threskiornithidae	Least concern
Eurasian spoonbill	*Platalea leucorodia*	Threskiornithidae	Least concern
Black stork	*Ciconia nigra* (A)	Ciconiidae	Least concern
White stork	*Ciconia ciconia* (A)	Ciconiidae	Least concern
Greater flamingo	*Phoenicopterus roseus*	Phoenicopteridae	Least concern
Mute swan	*Cygnus olor* (A)	Anatidae	Least concern
Greater white-fronted goose	*Anser albifrons* (A)	Anatidae	Least concern

Common name	Latin name	Family	IUCN Category
Greylag goose	*Anser anser* (A)	Anatidae	Least concern
Ruddy shelduck	*Tadorna ferruginea* (A)	Anatidae	Least concern
Common shelduck	*Tadorna tadorna*	Anatidae	Least concern
Eurasian wigeon	*Anas penelope*	Anatidae	Least concern
Gadwall	*Anas strepera*	Anatidae	Least concern
Eurasian teal	*Anas crecca*	Anatidae	Least concern
Mallard	*Anas platyrhynchos*	Anatidae	Least concern
Northern pintail	*Anas acuta*	Anatidae	Least concern
Garganey	*Anas querquedula*	Anatidae	Least concern
Northern shoveler	*Anas clypeata*	Anatidae	Least concern
Marbled teal	*Marmaronetta angustirostris* (A)	Anatidae	Least concern
Common pochard	*Aythya ferina* (A)	Anatidae	Vulnerable
Ferruginous pochard	*Aythya nyroca* (A)	Anatidae	Near threatened
Tufted duck	*Aythya fuligula* (A)	Anatidae	Least concern
Red-breasted merganser	*Mergus serrator* (A)	Anatidae	Least concern
Water rail	*Rallus aquaticus*	Rallidae	Least concern
Corn crake	*Crex crex*	Rallidae	Least concern
Little crake	*Porzana parva*	Rallidae	Least concern
Baillon's crake	*Porzana pusilla*	Rallidae	Least concern
Spotted crake	*Porzana porzana*	Rallidae	Least concern
Grey-headed swamphen	*Porphyrio poliocephalus*	Rallidae	Least concern
Common moorhen	*Gallinula chloropus*	Rallidae	Least concern
Eurasian coot	*Fulica atra*	Rallidae	Least concern
Black-winged stilt	*Himantopus himantopus*	Recurvirostridae	Least concern
Pied avocet	*Recurvirostra avosetta*	Recurvirostridae	Least concern

Common name	Latin name	Family	IUCN Category
Eurasian thick-knee	*Burhinus oedicnemus*	Burhinidae	Least concern
Cream-coloured courser	*Cursorius cursor*	Glareolidae	Least concern
Collared pratincole	*Glareola pratincola*	Glareolidae	Least concern
Black-winged pratincole	*Glareola nordmanni*	Glareolidae	Near threatened
Northern lapwing	*Vanellus vanellus*	Charadriidae	Near threatened
Spur-winged plover	*Vanellus spinosus* (A)	Charadriidae	Least concern
Red-wattled lapwing	*Vanellus indicus*	Charadriidae	Least concern
Sociable lapwing	*Vanellus gregarius* (A)	Charadriidae	Least concern
White-tailed lapwing	*Vanellus leucurus*	Charadriidae	Least concern
Pacific golden plover	*Pluvialis fulva*	Charadriidae	Least concern
Black-bellied plover	*Pluvialis squatarola*	Charadriidae	Least concern
Common ringed plover	*Charadrius hiaticula*	Charadriidae	Least concern
Little ringed plover	*Charadrius dubius*	Charadriidae	Least concern
Kenish plover	*Charadrius alexandrines*	Charadriidae	Least concern
Lesser sandplover	*Charadrius mongolus*	Charadriidae	Least concern
Greater sandplover	*Charadrius leschenaultia*	Charadriidae	Least concern
Caspian plover	*Charadrius asiaticus*	Charadriidae	Least concern
Eurasian dotterel	*Charadrius morinellus* (A)	Charadriidae	Least concern
Eurasian woodcock	*Scolopax rusticola* (A)	Scolopacidae	Least concern
Jack snipe	*Lymnocryptes minimus*	Scolopacidae	Least concern
Great snipe	*Gallinago media* (A)	Scolopacidae	Near threatened
Common snipe	*Gallinago gallinago*	Scolopacidae	Least concern
Black-tailed godwit	*Limosa limosa*	Scolopacidae	Near threatened

Common name	Latin name	Family	IUCN Category
Bar-tailed godwit	*Limosa lapponica*	Scolopacidae	Near threatened
Whimbrel	*Numenius phaeopus*	Scolopacidae	Least concern
Slender-billed curlew	*Numenius tenuirostris* (A)	Scolopacidae	Least concern
Eurasian curlew	*Numenius arquata*	Scolopacidae	Near threatened
Spotted redshank	*Tringa erythropus*	Scolopacidae	Least concern
Common redshank	*Tringa tetanus*	Scolopacidae	Least concern
Marsh sandpiper	*Tringa stagnatilis*	Scolopacidae	Least concern
Common greenshank	*Tringa nebularia*	Scolopacidae	Least concern
Green sandpiper	*Tringa ochropus*	Scolopacidae	Least concern
Wood sandpiper	*Tringa glareola*	Scolopacidae	Least concern
Terek sandpiper	*Xenus cinereus*	Scolopacidae	Least concern
Common sandpiper	*Actitis hypoleucus*	Scolopacidae	Least concern
Ruddy turnstone	*Arenaria interpres*	Scolopacidae	Least concern
Great knot	*Calidris tenuirostris*	Scolopacidae	Endangered
Red knot	*Calidris canutus* (A)	Scolopacidae	Least concern
Sanderling	*Calidris alba*	Scolopacidae	Least concern
Little stint	*Calidris minuta*	Scolopacidae	Least concern
Temminck's stint	*Calidris temminckii*	Scolopacidae	Least concern
Curlew sandpiper	*Calidris ferruginea*	Scolopacidae	Near threatened
Dunlin	*Calidris alpine*	Scolopacidae	Least concern
Broad-billed sandpiper	*Limicola falcinellus*	Scolopacidae	Least concern
Ruff	*Philomachus pugnax*	Scolopacidae	Least concern
Red-necked phalarope	*Phalaropus lobatus*	Scolopacidae	Least concern

Common name	Latin name	Family	IUCN Category
Red phalarope	*Phalaropus fulicarius* (A)	Scolopacidae	Least concern
Common gull	*Larus canus*	Laridae	Least concern
Lesser black-backed gull	*Larus fuscus*	Laridae	Least concern
Heuglin's gull	*Larus heuglini*	Laridae	Least concern
Caspian gull	*Larus cachinnans*	Laridae	Least concern
Pallas's gull	*Ichthyaetus ichthyaetus*	Laridae	Least concern
Black-headed gull	*Chroicocephalus ridibundus*	Laridae	Least concern
Slender-billed gull	*Chroicocephalus genei*	Laridae	Least concern
Mediterranean gull	*Ichthyaetus melanocephalus* (A)	Laridae	Least concern
Little gull	*Hydrocoloeus minutus* (A)	Laridae	Least concern
Gull-billed tern	*Gelochelidon nilotica*	Sternidae	Least concern
Caspian tern	*Hydroprogne caspia*	Sternidae	Least concern
Lesser crested tern	*Thalasseus bengalensis*	Sternidae	Least concern
Sandwich tern	*Thalasseus sandvicensis*	Sternidae	Least concern
Great crested tern	*Thalasseus bergii*	Sternidae	Least concern
Common tern	*Sterna hirundo*	Sternidae	Least concern
Arctic tern	*Sterna paradisaea* (A)	Sternidae	Least concern
White-cheeked tern	*Sterna repressa*	Sternidae	Least concern
Little tern	*Sternula albifrons*	Sternidae	Least concern
Saunders's tern	*Sternula saundersi*	Sternidae	Least concern
Bridled tern	*Onychoprion anaethetus*	Sternidae	Least concern
Whiskered tern	*Chlidonias hybrida*	Sternidae	Least concern
White-winged tern	*Chlidonias leucopterus*	Sternidae	Least concern
Black tern	*Chlidonias niger* (A)	Sternidae	Least concern
White-tailed Eagle	*Haliaeetus albicilla*	Accipitridae	Least concern
Western osprey	*Pandion haliaetus*	Pandionidae	Least concern

Common name	Latin name	Family	IUCN Category
White-breasted Kingfisher	*Halcyon smyrnensis*	Alcedinidae	Least concern

4.6.4.3 Assessment approach and findings

Seabirds are the most threatened bird group and their decline has accelerated over recent decades. Globally 28% are threatened (5% are in the highest category of Critically Endangered) and a further 10 per cent are Near Threatened. Species whose small range or population is combined with decline (64 species) are of particular concern. Pelagic species are disproportionately represented in comparison with coastal species and those listed under the Agreement on the Conservation of Albatross and Petrels have fared worst of all (Ajawin et al., 2016). Kuwait currently has 1 water bird species identified as 'endangered', 2 listed as 'vulnerable', 8 listed as 'near threatened'. Priority species in this regard are listed as Great knot *Calidris tenuirostris* (endangered); Socotra cormorant *Phalacrocorax nigrogularis*, common potchard *Aythya ferina* (vulnerable); Eurasian oyster catcher *Haematopus ostralegus*, Ferruginous potchard *Aythya nyroca*, black-winged pratincole *Glareola nordmanni*, northern lapwing *Vanellus vanellus*, great snipe *Gallinago media*, black-tailed godwit *Limosa limosa*, bar-tailed godwit *Limosa lapponica*, curlew sandpiper *Calidris ferruginea* (near threatened).

General declines have been caused by ten primary pressures: At sea these include: incidental bycatch (in longline, gillnet and trawl fisheries); pollution (oil spills, marine debris)); overfishing; energy production and mining. On land, invasive alien species, problematic native species (e.g. those that have become super-abundant), human disturbance, infrastructural, commercial and residential development, hunting and trapping have driven declines. Climate change and severe weather affect seabirds on land and at sea (Ajawin et al., 2016).

Apart from 'problematic native species' all of these pressures are currently experienced by Kuwait seabirds. From a national perspective, pollution (oil spills), overfishing (average landings of finfish dropped 33% between 1995-2002), human disturbance (tourists around Umm Al-Maradim), uncontrolled coastal development and *especially* hunting represent the overriding threats to populations (Glibert et al., 2001; Al-Husaini et al., 2015; Baby, 2011; Kuwaitbirds.org, 2016).

4.6.4.4 Conclusions

Most seabirds are highly migratory species that require a variety of marine and terrestrial habitats during different seasons and life stages (Lascelles et al, 2014).

Many seabirds are long-lived and slow reproducing. These characteristics make them particularly vulnerable to a wide range of pressures, where even quite small increases in mortality can lead to significant population declines. In addition, many seabirds have highly specialised diets, being reliant on just a few prey species, the abundance and distribution of which can alter dramatically in response to abrupt environmental changes (Ajawin et al., 2016).

4.6.5 Alien Species

4.6.5.1 Background

Alien species, also known as non-native or non-indigenous species, are organisms that have been moved outside of their natural range as a result of human activities (either deliberately or accidentally) into novel geographical areas which the species would not normally reach through natural processes. Once introduced, alien species may become established and spread, either by further human activities or natural means. Introduced alien species can have significant impact, posing a great threat to the integrity of natural communities, resulting in the loss of biodiversity, in addition to having social and economic impact through the disruption of ecosystem services. In cases where the introduced alien species has an impact they are referred to as invasive alien species (IAS). In most cases the proportion of introduced alien species that become invasive is relatively low, but in heavily degraded areas IAS can dominate the ecosystem. With globalisation, the transfer and introduction of alien species has increased, resulting in a rise in the number of IAS being reported. There is an increasing need to manage alien species to prevent or reduce the environmental, social and economic impact these species are causing.

The Convention on Biological Diversity (CBD) lays out a 3-tiered approach the invasive alien species (IAS) management, prioritising: i) prevention of new species from being introduced; ii) early detection of new arrivals and rapid response to eradicate them as soon as they are detected and before they can spread, followed by iii) containment and long term control measures to be implemented to prevent the spread of established species, where eradication is not possible. For IAS, preventing further introductions from occurring is the most cost-effective and environmentally desirable approach than post-introduction measures, such as eradication or long-term containment. In the marine environment, prevention seems to be the only feasible alternative, as eradication is difficult to achieve in almost all cases except in the very early stages of introduction. In addition to reducing the risk of potentially further introductions from occurring, limiting or controlling the further spread of those IAS already established is also critical in reducing their impact.

Understanding which alien species are currently present in Kuwait marine waters and the pathways and vectors that may have led to their introduction is the initial step in developing and establishing a management programme, and determining how effective the programme is. This initial assessment presents information on those alien species currently found within Kuwait marine waters. The limitations of the assessment are discussed with further recommendations for further developments to address the issue of marine IAS in Kuwait marine waters.

4.6.5.2 Current state of Knowledge Kuwait

Information currently available in relation to alien species present within Kuwait marine waters is limited. With no consistent historical monitoring for alien species information sources tend to be from ad hoc findings reported in published scientific studies. While these studies do provide an indication of which alien species are currently present, without a comprehensive monitoring programme it is impossible to determine if this is a comprehensive list. It is most likely there are other alien species that have not been reported as such, or have not been identified as alien, present in Kuwait marine waters, which are therefore not present in the information presented here. The information presented is only in relation to the presence of the species in Kuwait marine waters, no reference is provided to their relative abundance, as without a consistent monitoring programme, relative abundance cannot be determined. The Regional Organisation for the Protection of the Marine Environment (ROPME) have made progress in raising awareness of alien species and in the development of regional plans for their management (Bailey and Munawar, 2015). Most notably, this has included the introduction of mandatory ballast water management regulations in 2009 consistent with provisions under the IMO Ballast Water Convention. There is however, clearly much more required work, which is discussed further in the conclusions section of this assessment.

4.6.5.3 Assessment approach and findings

Information for this assessment was gathered from both primary scientific literature, published grey literature and accessible data bases. From this search a total of 29 species were found that fell into the category of either alien or cryptogenic (e.g. uncertain origin) that had been reported as present in Kuwait marine waters. Given the current lack of available information in relation the distribution and abundance of the listed species, the species are listed in relation to their recorded presence within Kuwait marine waters. The taxonomic type, habitat the species normally occupies, suspected pathway of introduction and year of first record in addition to the original source of the information has been recorded (see table 1). Without the presence of a consistent monitoring programme it is impossible to determine the point of introduction (both geographically and temporally), therefore the year that the species was first recorded, rather than introduced, is provided. Additional information is also provided in relation to the impact that the species has had in other locations that it has invaded, providing an indication of the species invasiveness (text below). Information in relation to impact specific to Kuwait to currently difficult to obtain or absent.

The following is additional information on each of the 29 species listed (in order of date of reported) as presented in Table 4-5, in some cases, information on the species is limited.

Rhopalophthalmus tattersallae is a mysid only previously recorded from Kerala State, India (Grabe, 1989). The species inhabits neritic or estuarine waters. Due to its habitat preference and limited recordings, it is believed that this species was introduced rather than being a result of natural range expansion (Carlton and Geller 1993). It is hypothesised that the species may have been introduced by ballast water, although this is unclear. Impact the species may cause is unknown. Specimens recovered from Kuwait Bay were parasitized with an unidentified isopod, which may spread to native species.

Exopalaemon styliferus, the Roshna Prawn, was first recorded in Kuwait in 1983 (Salman and Bishop, 1990). The route of introduction and the impact this species may cause are unknown, although Carlton and Geller (1993) suggested it may have been via ballast water.

Cordylophora caspia a colonial hydroid, it preys on larval insects, possibly resulting in a reduction in food availability for fish species (Smith et. al. 2002). It may contribute to the restructuring of benthic and pelagic communities (Folino 2000). The route of introduction is unknown, but may be through bio-fouling or ballast water.

Palaemon elegans, the rock shrimp, euryhaline species, native to the Atlantic and Mediterranean. Has been shown to replace native shrimp in other invasion cases. The route of introduction for this species is unknown.

Rhinogobius brunneus, Amur Goby, the potential impact that this species may cause is unknown. Route of introduction is most likely via ballast, but potential through the aquarium trade.

Oreochromis aureus, the blue tilapia, competes with native fish for food and spawning areas, while exhibiting aggressive behaviour (McDonald, 1987). Blue tilapia can restructure whole communities as a result of their feeding preference for specific alage (McDonald, 1987). The most common route of introduction is for aquaculture purposes (Canonico *et al*. 2005).

Sparus aurata, gilthead bream, is a Mediterranean fish, common in aquaculture, this being the most likely route of introduction. Gilthead bream are voracious predators and it introduction may cause reductions in native fish stocks (Balart *et al*., 2009).

Polysiphonia brodiei, is a filamentous red alga, native to Europe, it has been introduced to a number of locations globally via ship movements (Adams, 1983). Main impacts include smothering, and shading of native species, possibly resulting in modifications to natural benthic communities.

Oreochromis mossambicus, the Mozambique tilapia, native to the southern and south eastern portions of the African continent. Introductions have often been associated with severe environmental change (Pullin et al. 1997). Most likely to have been introduced as a result of aquaculture activities.

Oreochromis niloticus, the Nile tilapia, native to the Nile River basin; the south-western Middle East; the Niger, Benue, Volta and Senegal rivers, and the lakes Chad, Tanganyika, Albert, Edward, and Kivu. The Nile tilapia is often described as 'pioneer' species, meaning it thrives in disturbed habitats, opportunistically migrating and reproducing. These traits mean that Nile tilapia often outcompetes native species in areas where it has been introduced. The most likely route of introduction is as a result of aquaculture activities (Pullin et al. 1997).

Tubastraea coccinea, the orange cup coral, native to the Indo-Pacific, it often competes with benthic invertebrates for space and compromises communities. Thought to have been introduced via ballast water (Al-Yamani et al. 2015).

Hypnea musciformis, is a macroalgae, which can smother native species, often dominating benthic algal growth. It is native to the Atlantic, with its presence as an alien species in Kuwait being identified by Al-Yamani et al. (2015). It is likely that this species was introduced for aquaculture purposes, or ballast water movements.

Schizoporella cf. errata, is a heavily calcified, encrusting cheilostome bryozoan. It colonises most freely available substratum, including artificial underwater structures and vessel hulls. It is native to the Mediterranean, although this is unclear. It is a common fouling species, which is found worldwide (Bishop Museum 2002). Although the species has been associated with aquaculture movements, the most likely route of introduction is via ship fouling.

Alexandrium minutum, is a photosynthetic dinoflagellate that, like many species in its genus, is responsible for outbreaks of Paralytic Shellfish Poisoning (PSP). This phytoplankton species can also form extremely dense blooms that have the capacity to kill finfish, in addition to their PSP toxin production. As this species forms a tough resting cyst, it is easily transport by ballast water and in translocated shellfish, and it has been reported from most continents and every ocean. The species was first recorded in Kuwait in 2001 and has been associated with fish kills (Glibert et al. 2002). Because of the species near ubiquitous distribution, it is considered here as cryptogenic to Kuwait.

Gymnodinium catenatum is a photosynthetic dinoflagellate, known to be responsible for paralytic shellfish poisoning (PSP). Populations form dense and extensive blooms confined largely to estuarine and coastal waters typically in calm conditions and stratified water columns after heavy rainfall (Hallegraeff et al., 1995). The most notable vector is ballast water (Hallegraeff and Bolch, 1992); other vectors include equipment contaminated with marine water or sediment (e.g. dredges and fishing gear), movements of commercial shellfish or other marine animals, attachment to flotsam/jetsam and seaweed. While a number of populations around the globe are suspected of being introduced, strong supporting evidence only exists for the introduction of Australasian *G. catenatum* from southern Japan. Because of the species near ubiquitous distribution, it is considered here as cryptogenic to Kuwait.

Karenia selliformis is a dinoflagellates. It was first discovered in New Zealand (Haywood et al. 2004). Karenia selliformis produces the highly toxic gymnodimine, and as such is a potentially harmful ocean dwellers. Gymnodimine is a nicotinic acetylcholine receptor-blocking phycotoxin, a source of shellfish poisoning. The main pathway of introduction of this species is thought to be ballast water. Because of the species near ubiquitous distribution, it is considered here as cryptogenic to Kuwait.

Eriocheir spp. are a clade of crab that have become invasive in numerous locations globally. Two in particular, Chinese Mitten crab, *Eriocheir sinensis,* and the Hepu crab, *Eriocheir hepuensis*, are of note to the Arabian Gulf, having been reported in the area (Naderloo, 2014; Naser et al. 2012; Hashim, 2010; Clark et al. 2006). While only the Hepu crab has been reported specifically from Kuwait waters (Naser et al. 2012), it is likely that both species are present. *E. sinensis* is considered highly invasive, burrowing causing the destabilisation of estuarine banks, the species can reach high densities (and therefore biomass), out competing native species for resource. The most likely route of introduction into Kuwait is via ballast water.

Cochlodinium polykrikoides is a dinoflagellate, first recorded in Puerto Rico in 1961. The geographic distribution of the species is now widespread. Notable for causing mas mortalities in wild and farmed fish, with harmful blooms persisting for up to 8 weeks (Richlen et al. 2010). The outbreak of the species in the Arabian Gulf, 2008, was responsible for killing thousands of tons of fish and limiting traditional fishery operations, damaging coral reefs, impacting coastal tourism, and forcing the closure of desalination plants, was so large that the species is likely to be present. The main pathway of introduction of this species is thought to be ballast water. Because of the species near ubiquitous distribution, it is considered here as cryptogenic to Kuwait.

Heterosigma akashiwo is a microscopic algae that episodically forms toxic surface aggregations or harmful algal bloom. The geographical distribution of the species is widespread. The species is associated with fish kills, but can also effect planktonic communities. The main pathway of introduction of this species is thought to be ballast water. Because of the species near ubiquitous distribution, it is considered here as cryptogenic to Kuwait.

Doto kya is a nudibranch sea slug, it was first reported in California and has been reported from the Pacific coast of Mexico, the United States and Canada. Reported as a suspected alien species in Kuwait (Al-Yamani et al. 2015), there is no information in relation to the date the species was first recorded. The species is not recognised as being invasive elsewhere, so there is no information in relation to the impact the species may have, if any. It is thought the most likely route of introduction is ballast water.

Eubranchus misakiensis, a nudibranch, native to Japan and introduced to California where it is established in San Francisco Bay. No ecological or economic impacts have been reported from native or introduced locations. Reported as a suspected alien species in Kuwait (Al-Yamani et al. 2015), there is no information in relation to the date the species was first recorded. It is thought the most likely route of introduction is ballast water.

Flabellina amabilis, a nudibranch, native to Japan. No ecological or economic impacts have been reported from native or introduced locations. Reported as a suspected alien species in Kuwait (Al-Yamani et al. 2015), there is no information in relation to the date the species was first recorded. It is thought the most likely route of introduction is ballast water.

Cuthona albocrusta, a nudibranch, native to California, it has been recorded along the eastern Pacific coastline. No ecological or economic impacts have been reported from native or introduced locations. Reported as a suspected alien species in Kuwait (Al-Yamani et al. 2015), there is no information in relation to the date the species was first recorded. It is thought the most likely route of introduction is ballast water.

Amphibalanus improvisus, a species of barnacle, most likely to have originated from the Atlantic coast of America, it is now found in many European countries for over 200 years. Introduction route is most likely via hull fouling or ballast water. The species forms dense layers, competing with native species for space. The species has been found on the carapace of a single Hepu crab (*Eriochier hepuensis*) found in the Arabian Gulf (Naser et al. 2015).

Tintinnopsis ampla*,* a ciliate, native to Japan. It has been reported as abundant in ballast water samples taken from ships from Japan destined to North America (Pierce et al. 1997), demonstrating the most likely form of introduction. No ecological or economic impacts have been reported from it native or introduced locations. The species was suggested as introduced into Kuwait by Al-Yamani et al. (2015).

Kryptoperidinium foliaceum, dinoflagellate, reported for the first time in Kuwait by Saburova et al. (2012). Although it is a bloom forming species, which may result in deoxygenation of the water, no ecological or economic impacts have been reported from it native or introduced locations. The species has an extensive global distribution, and as such is recorded as cryptogenic here.

Sargassum fluitans, is a marcoalage, native to the Sargasso Sea, the species have been introduced to much of the eastern Atlantic seaboard. The species is not known to have an impact, however, other *Sargassum* species can outcompete native species, and interfere with aquaculture. The species is likely to have been introduced as a result of ballast water movements.

Grateloupia filicina, is a marcoalgae, native to Japan, which may interfere with native species, but there are no known environmental or economic impacts recorded from the species native or introduced range. Routes of introduction into other invaded areas, such as the UK, have been through aquaculture movements, although introduction into Kuwait marine waters, may have been through ballast water (Al-Yamani et al. 2015).

Myrionema orbiculare, is a macroalgae, native to Europe, but also found in the Atlantic Islands, Africa, south-west Asia, and Japan. There is no clear evidence of this species causing an impact in either its native or introduced range. Possible route of introduction is via ballast water (Al-Yamani et al. 2015) or aquaculture movements.

Figure 4-4 shows the total number of new alien species reported per year. While this shows that there are frequent recordings of alien species not previously reported, in some years, numbers recorded are particularly high, namely 2001 and 2009, while in other years, for example, 1982 and 2007, so new species were recorded. This is likely to be a result of variation in monitoring effort over time, rather than a result of an actual indication of the number of species introduced in these years. Without consistent monitoring for marine alien species in Kuwait marine waters it is impossible to determine how the rate of introduction of alien species is changing over time. The line plotted on Figure 4-4 is of the cumulative number of alien species recorded over time. This line shows a relatively consistent increase of reported species over time, it also clearly illustrates these marked increases in reported species observed in 2001 and 2009. Although impossible to determine if all species recorded have subsequently become established, the plotted line also provides an indication of the total number of alien species present in Kuwait marine waters.

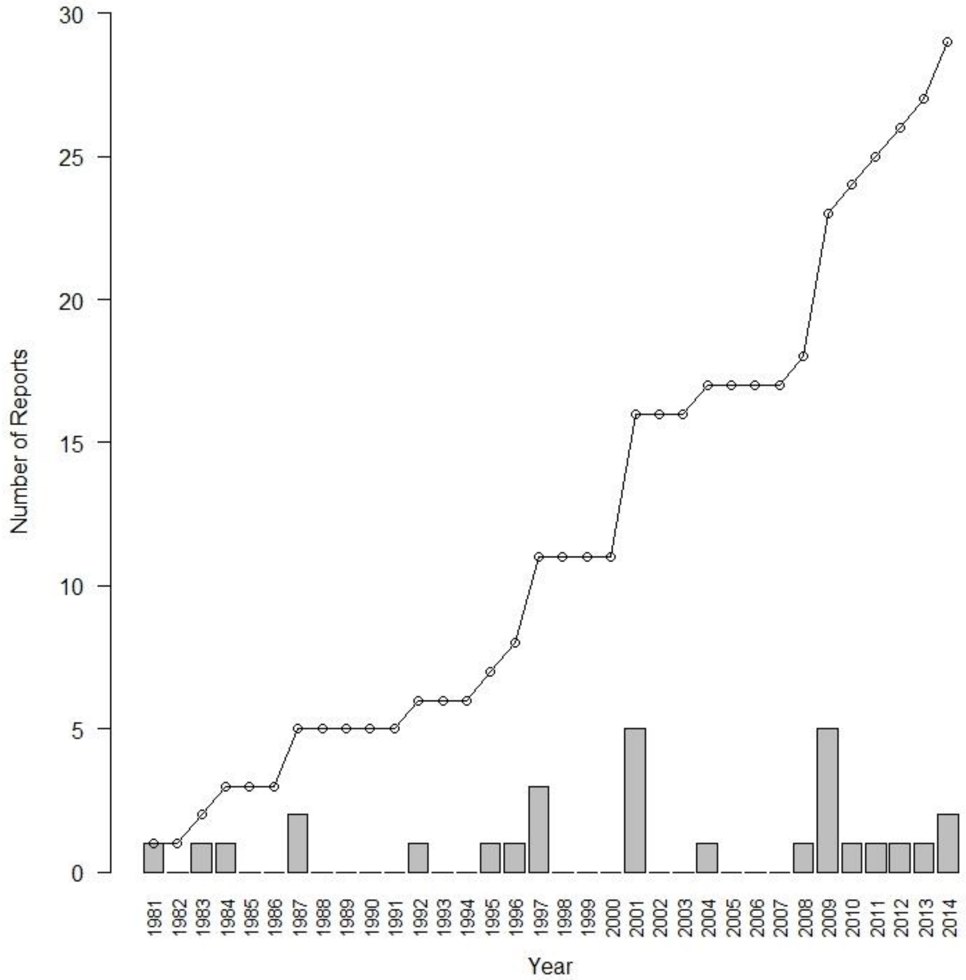


Figure 4-4:Graph showing the number of first recording of marine alien species made for Kuwait marine waters by year. The line shows the cumulative number of alien species over time, providing an indication of total alien species present.

4.6.5.4 Conclusion

The information presented here provides some indication of the total number of alien species currently recognised as present within Kuwait marine waters. This is not considered to be a comprehensive list of species as there is likely to be additional alien species present which have not been detected yet.

The 29 species that have been reported present a board range of taxa including fish, coral, crustacea, nudibranch, macroalgae and dinoflagellates. While some of these species have had clearly identified impact within invaded areas, others have not shown any clear impact. Further risk assessment of these species, would allow for prioritisation of the species in relation to the impact, and the relative risk, they may pose.

It is unsurprising that many of the species listed here are suspected to have been introduced because of commercial shipping activities, such as ballast water exchange or hull fouling, given the large volume of shipping in the Arabian Gulf. Although other likely pathways of introduction have also been identified, such as aquaculture. Determining if a species has been introduced or is a native species not previously recognised as such can be difficult. Several species within this study have been identified as cryptogenic, especially those with a wide global range.

Despite the introduction of ballast water control measures in 2009, new species have been recorded subsequently that are likely to have been introduced by this pathway. This is by no means an indication that these measures have been unsuccessful in controlling the introduction of alien species via ballast water, as it is likely that these species could have been introduced prior to the measures being implemented, but were not identified. This illustrates the need to have consistent monitoring programme for alien species. A monitoring programme would provide valuable data to more accurately determine changes in the rate of introduction of alien species in response to control measures, in addition to facilitating rapid response to new incursions.

Table 4-5: Summary of the 23 alien species that have been identified in Kuwait Marine waters with habitat description, record of initial report and information source.

Species name	Type	Habitat	Introduction pathway/vector	Year of first record	Information source
Rhopalophthalmus tattersallae	Mysid	Marine/brackish	Ballast water	1981	http://www.marinespecies.org/aphia.php?p=taxdetails&id=161452
Exopalaemon styliferus	Shrimp	Marine/brackish	Ballast water	1983	http://www.trjfas.org/uploads/pdf_419.pdf
Cordylophora caspia	Hydroid	Brackish	Unknown	1984	http://www.marinespecies.org/introduced/aphia.php?p=taxdetails&id=117428
Palaemon elegans	Shrimp	Marine	Unknown	1987	Fofonoff, P.W.; Ruiz, G.M.; Steves, B.; Carlton, J.T. (2014). National Exotic Marine and Estuarine Species Information System (NEMESIS) *available online at* http://invasions.si.edu/nemesis
Rhinogobius brunneus	Fish	Marine	Shipping/ballast	1987	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20

Species name	Type	Habitat	Introduction pathway/vector	Year of first record	Information source
Oreochromis aureus	Fish	Brackish	Aquaculture	1992	http://issg.org/database/species/ecology.asp?si=1323&fr=1&sts=&lang=EN
Sparus aurata	Fish	Marine/brackish	Aquaculture	1995	http://issg.org/database/species/ecology.asp?si=1703&fr=1&sts=&lang=EN
Polysiphonia brodiei	Macroalgae	Marine	Shipping/hull fouling	1996	http://www.cabi.org/isc/datasheet/107751#20067202895
Oreochromis mossambicus	Fish	Brackish	Aquacultur	1997	http://www.cabi.org/isc/datasheet/72085
Oreochromis niloticus	Fish	Brackish	Aquaculture	1997	http://www.cabi.org/isc/datasheet/72086
Tubastraea coccinea	Coral	Marine	Shipping/ballast	1997	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20
Hypnea musciformis	Macroalgae	Marine	Aquaculture/shipping/ ballast	2001	http://www.marinespecies.org/introduced/aphia.php?p=taxdetails&id=145634

Species name	Type	Habitat	Introduction pathway/vector	Year of first record	Information source
Schizoporella cf. errata	Bryozoan	Marine	Hull fouling	2001	http://www.cabi.org/isc/datasheet/109921
Alexandrium minutum	Dinoflagellate	Marine	Cryptogenic/Shipping/ ballast	2001	http://www.cabi.org/isc/datasheet/107755
Gymnodinium catenatum	Dinoflagellate	Marine	Cryptogenic/Shipping/ ballast	2001	http://www.cabi.org/isc/datasheet/107772
Karenia selliformis	Dinoflagellate	Marine	Shipping/ballast	2001	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20
Eriocheir spp.	Crab	Marine/brackish	Shipping/ballast	2004	https://www.researchgate.net/publication/224006803_Invasive_records_of_Eriocheir_hepuensis_Dai_1991_Crustacea_Brachyura_Grapsoidea_Varunidae_Implications_and_taxonomic_considerations
Cochlodinium polykrikoides	Dinoflagellate	Marine	Cryptogenic/Shipping/ ballast	2008	http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwiY2YqM9MXPAhWmJMAKHb11BhEQFggcMAA&url=http%3A%2F%2Fwww.moew.gov.ae%2Fassets%2Fdownload%2Fe83f5caa%2Frichlen_et_al_cochlodinium_in_the_arabian_gulf_091.aspx&usg=AFQjCNFtkv3KNA-Jdm4OURa OJfDJg9sPA&sig2=k_UsM8vXhrQpWuZv7nkO4Q&bvm=bv.134495766,d.d24

Species name	Type	Habitat	Introduction pathway/vector	Year of first record	Information source
Heterosigma akashiwo	algae	Marine/brackish	Cryptogenic/Shipping/ ballast	2009	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20
Doto kya	Nudibranch	Marine	Shipping/ballast	2009	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20
Eubranchus misakiensis	Nudibranch	Marine	Shipping/ballast	2009	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20
Flabellina amabilis	Nudibranch	Marine	Shipping/ballast	2009	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20
Cuthona albocrusta	Nudibranch	Marine	Shipping/ballast	2009	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20
Amphibalanus improvisus	Barnacle	Brackish/marine	Shipping/ballast/hull fouling	2010	http://www.reabic.net/journals/bir/2015/3/BIR_2015_Naser_etal.pdf
Tintinnopsis ampla	Ciliate	Marine	Shipping/ballast	2011	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20
Kryptoperidinium foliaceum	Dinoflagellate	Marine	Cryptogenic/shipping/ ballast	2012	https://www.researchgate.net/publication/259426099_First_record_of_Kryptoperidinium_foliaceum_Dinophyceae_Peridin

Species name	Type	Habitat	Introduction pathway/vector	Year of first record	Information source
					iales_from_a_hypersaline_environment_in_Kuwait_north-western_Arabian_Gulf
Sargassum fluitans	Macroalgae	Marine	Shipping/ballast/ Aquaculture	2013	http://issg.org/database/species/ecology.asp?si=1837&fr=1&sts=&lang=EN
Grateloupia filicina	Macroalgae	Marine	shipping/ballast/ aquaculture	2014	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20
Myrionema orbiculare	Macroalgae	Marine	Shipping/ballast/ Aquaculture	2014	http://www.tandfonline.com/doi/abs/10.1080/14634988.2015.1027135?journalCode=uaem20

4.6.6 Coral Reefs

4.6.6.1 Background

The condition and extent of habitats is maintained to ensure the persistence of threatened and vulnerable habitats, to protect critical habitats required to support threatened or vulnerable species, and to enable all habitats to support ecosystem functions that are dependent on them.

Whilst our knowledge of Kuwait coral reefs is limited due to a lack of long term monitoring programs (notwithstanding the volunteer work of the Kuwait Dive club), it is known that the coral reefs of Arabia are in significant decline, with Sheppard (2015) suggesting that a massive decline is occurring in the Gulf of all of its major marine systems including coral reefs, mangroves, seagrass beds and fish stocks, to the extent that it has been called a 'young sea, in decline' (Sheppard et al., 2010). Shepard et al; 2015 identifies several key reviews (Sheppard et al. 2010, 2012); with many detailed studies highlighting the ongoing, substantial degradation of coral reefs in the Arabian Gulf and the many causes that are driving this decline. Bento et al., 2016 reported on the extreme conditions that face Arabian reefs, however, despite these extreme conditions, they have, until recent times, been a unique and functioning habitat that supports many species of corals fish, and invertebrates. These coral reefs are amongst the most biologically diverse marine ecosystems in the world. These coral reefs and their associated mangrove and sea grass habitats play important ecological, economic, recreational and cultural roles. These habitats provide food and shelter for numerous fish and marine species, protect coastal areas from storm surge, prevent coastal erosion and support commercial fishing and an array of recreational activities. The health of coral reefs has continued to decline throughout the tropical and subtropical world where these habitats occur. According to Wilkinson (2000), 27% of the world's coral reefs are already degraded and probably lost. Unfortunately, the Arabian Gulf appears to be one of the areas which is most severely affected with Wilkinson (2000) estimating up to 35% of coral reefs may be already lost in the Arabian Gulf. More recent reviews by Sheppard (2015) and Burt et al., (2015) put this figure up to as high as 70% loss. Extreme temperatures are believed to be the single most important cause of coral reef decline and loss in the region, despite the immunity to higher temperatures that can exist in coral reefs systems in the Gulf. Other threats to coral reefs in the area include attacks by the crown-of-thorns starfish *Acanthaster planci*, and anthropogenic stresses including oil pollution, poor land use practices, urban runoff and impacts from commercial and recreational fishing and diving. Human stresses to corals in the region are mostly caused by industrial activity, dredging and land reclamation. Cooling water discharges from desalination and power plants add to the thermal load of a naturally stressed environment. Fishing activity, particularly industrial trawling and the use of artisanal gillnets is causing low level damage to corals throughout the region. However, many of the other stresses that damage coral reefs around the world such as pollution in fresh water runoff, destructive fishing, and over-exploitation are largely absent.

Impacts on fish, coral and sea grass of the Bay and the wider Gulf, particularly following the Gulf war in 1991 (Banat et al., 1998), are a combination of the naturally stressful conditions associated with temperature, salinity and other anthropogenic inputs, including hydrocarbons, heavy metals and non-essential trace metals (Al-Mussalam et al., 1999; Al-Sarawi et al., 2015; Al-Zaidan et al., 2015; Price, 1998; Price and Robinson, 1993). Such anthropogenic influences are thought to have been a key driver in numerous biological catastrophes in Kuwaiti waters, including well-documented fish kills during 1999 and 2001 (Glibert et al., 2002; Heil et al., 2001; Stentiford et al., 2014).

4.6.6.2 Current State of knowledge:Kuwait

Approximately 60 species of scleractinian coral have been described for the Arabian Gulf, representing approximately one tenth of corals known for the Indo-Pacific and 15% of those in the Indian Ocean (Burt et al. Coles 2003; Sheppard et al., 2016) The environmental extremes (Coles 2003) experienced in the Gulf, including Kuwait marine waters are responsible for depaurperate coral communities which are quite distinct from those in the major biogeographic regions surrounding the Arabian Peninsula (Sheppard 1987; Sheppard and Sheppard 1991).

We know that there is a very marked west to east gradient of effects both within the Gulf and within different areas within the Gulf (Burt et al., 2011) so exceptions do exist to any generalised reporting framework. Corals growing in most of this region are subjected to extreme environmental conditions, such as wide fluctuations of temperature and salinity. Mass coral bleaching and mortality in 1996 and 1998 reduced live coral cover significantly in many areas, particularly the Acropora species. However, the effects of the 1998 bleaching event in the Arabian Sea was minimised by the onset of the summer upwelling, which moderated the extreme temperatures in Southern Arabia. There are signs that recovery has commenced after 1998, however recent observations identified continued bleaching episodes that are impacting on coral health. Historical accounts of coral communities within the Arabian Gulf describe these reefs as being dominated by *Acropora sp*.,such as the tabular *Acropora clathrata* and *Acropora downingi*, up until the mid-1990s (George and John, 1999; Shinn, 1976). However, recurring bleaching events and coral mortality in 1996, 1998, 2002, 2010, and 2011 (Burt et al., 2008; George and John, 1999; Riegl, 1999, 2003;Sheppard and Loughland, 2002; Riegl and Purkis, 2012a), coral disease (Riegl et al., 2012c), and extensive coastal development and modification (Burt, 2014; Sale et al., 2011), over the past two decades have shifted these reefs from an Acropora-dominated configuration to a poritid- and faviid-dominated community (Bauman et al., 2013; Burt et al., 2011a; Riegl and Purkis, 2012b; Sheppard et al., 2012).

The coral reefs of Kuwait are marginal for reef development, being in high latitudes at 28° North 48° East and occur in a naturally environmentally stressed ecosystem, where the seawater temperatures are cool (16ºC) during the winter and very hot (35ºC) in summer

(Harrison et al., 1997). Coral growth in the north of the Gulf is limited to southern Kuwait with small patch and fringing reefs inshore, some offshore platform reefs and coral cays, but all growing in relatively shallow water. The natural forces which affect the reefs in Kuwait are not well understood (Downing, 1985), and coral assemblages vary markedly, even between reefs in neighbouring sites. Coral reefs in the Arabian Gulf have been subject to major pressures in recent years (Sheppard et al., 2010) including rapid development of coastal areas, climate change and increased tourist activity of diving and boating. Many coral reef ecological studies have been conducted in the Arabian Gulf (Benzoni et al., 2004; Coles, 1988; Coles, 1997; Coles and Fadlallah, 1991; Downing and Roberts, 1993; Fadlallah et al., 1995; Gerges, 1993; McCain et al., 1984; Price, 1998; Price et al., 1993; Sheppard et al., 1992; Sheppard and Wells, 1988; Sheppard, 1988; Sheppard and Sheppard, 1991). Previous surveys of the coral cover diversity in Kuwait has reported low coral diversity with 24 Scleractinian species in 17 genera (Downing, 1985). Early surveys of Kuwait's reefs indicated that significant periods of stress, bleaching and coral mortality occurred in 1982-83 (Downing, 1985), and 1984-85 (Downing, 1989), and in the winter of 1991-92 (Downing, 1992; Downing and Roberts, 1993). Gishler, *et al*. (2005) extracted *Porites lutea* cores on off Qaru reef and reported that these reefs had gone through several significant temperature stress periods and reconstructed seawater temperature ranging between 16 & 34˚C (Gischler et al., 2005).

A Kuwait focused study (Shaker, 2005) reported on the extreme environmental conditions and numerous acute and chronic stressors (e.g., coral bleaching, HABS, intensive coastal development) impacting reefs around the north-eastern Arabian Peninsula. However, the same study reported that there were no significant declines in total % coral cover over the 3-year period (2003–2005). There were consistent differences in the composition of the overall benthic communities and scleractinian coral communities between the three locations and temporal changes in the composition of coral communities. This spatial variation likely reflects the local environmental conditions experienced at Kuwait coral reefs (Bauman et al., 2013; Fishelson, 1973; Maina et al., 2011) and the disturbance history of each location (e.g., Berumen and Pratchett, 2006; Hughes, 1989).

4.6.6.3 Assessment approach and findings

Coral reefs in the Arabian Gulf have been severely affected by recent bleaching events as well as human impacts such as sediment runoff from dredging and reclamation activities and pollution from different land-based sources. Large-scale decline in coral reef has been observed. It is estimated that almost 70% of original reef cover in the Arabian Gulf may be considered lost and a further 27% threatened or at critical stages of degradation (Wilkinson, 2008).

The lack of a monitoring program and annual reporting has made it difficult to make a quantitative assessment of the Kuwait coral reefs. There is no doubt that the reefs of Kuwait have experience multiple anthropogenic impacts particularly at Umm AlMaradim and other areas of high boating traffic. However, from what is known, the state of Kuwait's coral reef level can be considered as being stable, with the living coral percentage cover recorded varying between 28 & 44.5% in 1989 (Downing, 1989) and 15-48% recorded in 2003, with no significant difference between 1989 and 2005. Note the high degree of variation in the living coral percentage cover, representing localised impacts at each of the coral sites. The reefs support and continue to support recreational activities, and still are providing for recreational diving, fishing and valuable habitat. However, since 2005, there have been ongoing pressures in Kuwait as has been reported for the Arabian Gulf, and would be expected to have an detrimental impact on the coral cover for the Kuwait coral reefs. However, future projections, as with all Arabian Gulf coral reefs is not good, both for local and global pressures, and, where possible, these drivers need to be addressed urgently.

If we take a broader view of the reefs across the Arabian Gulf, the community structure tends to be associated with considerable spatial heterogeneity in oceanic conditions, and strong directional environmental gradients (Bauman et al., 2013). Despite clear community differences, the most evident change across most reefs has been dramatic changes from *Acropora* dominated to poritid and faviid dominated communities. Although temperature and salinity have previously been cited as the major environmental factors structuring coral communities around the region, additional environmental parameters, including water quality, surface currents and winds are now shown to be important in structuring and changing reef communities throughout the north-eastern Arabian Peninsula.

4.6.6.4 Conclusions

Coral reefs in Kuwait occur mainly as numerous patch reefs. However, fringing reefs are also found around offshore islands. Coral diversity is low compared to the Red Sea (55-60 species vs. nearly 200 in the Red Sea). However, the coral reefs of Kuwait live in unique conditions. High and low water temperature and high salinities affect coral species diversity and many species live near their maximum tolerances. Immediate impacts from oil spills during the Gulf War were less than generally expected, indicating a high resilience to this type of pollution among reef communities in this area. Major ecological problems have now arisen from loss/degradation of productive coastal habitats, caused by anchoring, dredging, and sedimentation. Anchor damage to coral reefs is a major problem on Jurayd Island and is an issue for all the Kuwait coral reefs. Fishing pressure is also intensive in some areas, which affects biodiversity in places which are experiencing anchor damage (Price, 1993).

Although there has been a marked shift in coral assemblages in the Arabian Gulf over the past two decades, the current poritid and faviid dominated assemblages appears to be still intact despite multiple pressures.

Predictions for Arabian Gulf reefs using field-based fecundity estimates and demographic modelling show that Acroporids will remain functionally extinct in the southern Gulf under the current disturbance regime (Riegl and Purkis, 2009; Howells et al., 2016). The current poritid and faviid dominated assemblages, although less diverse and structurally complex than the previous Acropora-dominated assemblages (Burt et al., 2011a; Burt et al., 2008), appear to be resilient to the extreme environmental conditions and frequent disturbances of this region and this seems to be true for Kuwait coral reefs given the work by Shakaar et al., 2015. Multiple disturbances within the Arabian Gulf during 2008–2011 had minimal impacts on coral assemblages at study sites in Kuwait southern coral reefs, with the cover of Poritid and Faviid corals being maintained. The apparent resilience of these assemblages is remarkable given the 2010 thermal anomaly was the highest on record for the region (>35 °C for 3 weeks (Riegl et al., 2011) Recent observations using artificial substrata (i.e., settlement tiles) demonstrated that newly-settled corals in the Arabian Gulf were dominated by poritids and 'other' corals, with few Acropora and no Pocillopora recorded (Bauman et al., 2014). This is in marked contrast to similar studies elsewhere in which Acropora dominate assemblages of coral recruits (e.g. Hughes et al., 1999; Penin et al., 2010; Gilmour et al., 2013).

However, a region-wide harmful algal bloom (HAB) that initiated in the Gulf of Oman and extended into the Gulf in 2008–9, had its most severe impacts on reefs in the northern Gulf of Oman (Richlen et al., 2010; Riegl et al., 2012c). The HAB caused up to 80% mortality of corals (including Acroporids, Pocilloprids, Faviids, and Poritids) on reefs in the northern Gulf of Oman (Bauman et al., 2010; Foster et al., 2011, 2012). This HABS related mortality was not as severe in the Kuwait coral reefs which may be too far north from the initial outbreak. It does point to the fragility of the stability of faviid and poritid dominated reefs in the Arabian Gulf and despite some resistance to climate change pressures, there are still many anthropogenic drivers which many negatively impact on Kuwait coral reefs. Although the resistance to heating stress may protect the biodiversity, these other pressures, including structure damage from anchoring sites, overfishing, increased turbidity and water quality will invariably lead to reductions in the diversity and abundance of coral reefs and associated ecosystems and the goods and services they provide.

4.6.7 Seagrass beds

4.6.7.1 Background

Seagrass habitats in the Arabian Gulf constitute a critical marine resource in the region, sustaining a high primary production, harboring a high biodiversity of associated plant and animal species, and serving as important nursery grounds for penaeid shrimps, pearl oysters and various other marine organisms. Approximately 7,000 km^2 of seagrass habitat has been mapped in the Arabian Gulf to date, with particularly extensive meadows in the coastal waters of the United Arab Emirates, Bahrain and Qatar (Erftemeijer and Shuail 2012). This area also sustains the world's second largest population of approximately 5800 dugongs, which feed almost exclusively on seagrasses. Three species of seagrass occur in the Arabian Gulf; namely, Halodule uninervis, Halophila stipulacea and Halophila ovalis (Phillips, 2003) due to the environmental conditions in the Arabian Gulf, with major seasonal variations in water temperature and salinity being tolerated by those three opportunistic seagrass species (*Halodule uninervis, Halophila stipulacea* and *H. ovalis*). These species are generally tolerant to salinity and temperature extremes of the Arabian Gulf.

4.6.7.2 Current state of knowledge: Kuwait

Seagrass beds are distributed along most of the shores of the Arabian Gulf. Sale et al.,2011 reports they are particularly prevalent along southern and western shores (Price and Coles 1992; Sheppard et al. 1992), and are important habitats for many fishery species, including fishes which use them as a nursery habitat, and the commercially important shrimp, Penaeus semisulcatus, and the Pearl oyster, Pinctada radiata (Carpenter et al. 1997). These beds sustain the green turtle, Chelonia mydas, and the world's second largest population of the endangered dugong, Dugong dugong (Marsh et al. 2002; Preen 2004). Extensive growth of seagrass is typically associated with sandy and muddy substrates in nearshores and shallow waters (less than 10 m). The largest areas of seagrass beds occur off the coasts of United Arab Emirates and between Bahrain and Qatar with estimated areas of 5500 and 1000 km_2, respectively (Erftemeijer and Shuail, 2012).

4.6.7.3 Assessment approach and findings

Seagrasses occur principally in shallow (< 10 m) coastal areas of Kuwait and form the basis for many food chains. More than 530 species of plants and animals were recorded among seagrasses across the Gulf. Approximate figures from Tarut Bay (410 km^2) suggest these seagrass beds support production of 2 million kg of fish annually at a 1987 value of US $10 million, or the same quantity of shrimp worth US $12 million (Price, et al., 1993).

4.6.7.4 Conclusions

There has been little targeted monitoring and mapping of the seagrass areas in Kuwait, and makes it difficult to draw any major conclusions on seagrass beds in Kuwait coastal areas. Massive land-reclamation projects and rapid industrial developments (including power- and desalination plants) pose a major threat to seagrass habitats in this region and monitoring of these vulnerable and valuable habitats is a key requirement of any future SOMER assessment.

4.6.8 Coastal habitats

4.6.8.1 Background

Coastal and marine environments in the Arabian Gulf are where most of the major housing, recreational, and economic developments have occurred in recent decades (Naser et al., 2008). Coastal development has led to the reduction (and destruction) of coastal habitats through dredging and land reclamation. It is estimated that more than 40% of the coastline of the Arabian Gulf have been developed (Hamza and Munawar, 2009; quoted by Naser, 2014) and it is estimated that land reclamation will accelerate in the future to secure new land as the population continues to grow (Naser, 2014).

Kuwait has roughly 500 km of coastline, including the nine islands, (Failaka, Bubiyan, Miskan, Warba, Auha, Umm Al-Maradim, Umm Al-Namil, Kubbar,and Qaruh) comprising a range of coastal habitats. Many of these habitats are critical to the survival of a wide variety of biodiversity but are under threat from anthropogenic activities in the coastal area. Infaunal species, vegetation and hard substrate provide food and refuge for the wider ecosystem and as such deserve consideration as part of the wider Kuwaiti environmental assessment.

The Kuwait coastline is comprised of a mixture of salt marches, mudflats, sand plains, coarse habitats and exposed bedrock. These physical habitats are implicitly important for providing the environmental conditions that support Kuwaits biodiversity. Saltmarshes, for example, with their associated nabkas are dominated by salt tolerant halophytes. The nabkas importance is attributed to the presence of shallow ground water lenses that can float on saline water bodies. These are kept in existence by rainwater and surface drainage paths (Al-Dousari et al., 2008) that can replenish the nabkas habitat and thus support the saltmarshes vegetation. Sandy beaches provide important habitat for turtle nesting, whilst rocky regions provide holdfasts and refuge for algae and crustaceans alike.

The coastal area of Kuwait is dominated by sparse and salt tolerant shrubs and perennial herbs. The diversity and distribution is dictated by the volume and frequency of precipitation as well as the soils characteristics. Halwagy and Halwagy, (1977) report the distinct zonation of saltmarshes where more generally *H. strobilaceum* dominates on the supratidal zone and *N. retusa* dominates the middle marsh beyond the reach of highest tides. T*. aucheriana, Zygophyllum atarense, Suaeda aegyptiaca* and *Salsola imbricata* form further zones on the elevated landward edges of the marsh. The coastal sand dunes and sand plains are found to be dominated by H*. salicornicum* and *Cyperus conglomeratus (*Abd El-Wahab et al., 2016*)*. In winters and springs, other opportunistic species such as *Schismus barbatus*, *Plantago boissieri*, *Ifloga spicata*, *Stipa capensis*, *Filago pyramidata*, *Erodium laciniatum* and *Lotus halophilus* join the more established Haloxylon community (Abd El-Wahab et al., 2015).

The islands of Kuwait are known to provide refuge for some of the country's diversity and are important for coral reefs within the subtidal waters. Furthermore, the island of Boubyan is presented as a nationally significant region for bird species and supports its own salt marshes along its coastal region. These coastal beaches are reported to sustain the majority of the island's diversity, with 80% of the island itself being bare of vegetation (Omar and Roy, 2013).

In the Arabian Gulf, the extent of mangroves has been declining due to the impacts of unplanned coastal development, with only about 125-130 km^2 remaining (90 km^2 off Iran, 10 km^2 off Gulf coast of Saudi Arabia and Bahrain, remainder along the UAE coast). In Saudi Arabia, more than 40 percent of the Arabian Gulf coastline has been infilled and 50 percent of the mangroves lost.

4.6.8.2 Current state of knowledge: Kuwait

Mohammad Al-Sawari et al. (1985) explored the shoreline types and resources of the Kuwait coastline and classify the morphological features in to nine categories;

- Headlands (eg Ras Al-Ardh)
- Cliffs, sucha s the limestone cliffs found to the south of Kuwait
- Embayments
- Rocky outcrops
- Sabkhas
- Tidal creeks
- Islands
- Coastal dunes
- Tidal flats

They made shoreline observations at 25 sites to better understand the geological and biological characteristics of the nine shoreline types. Sediment samples were taken to allow for sediment and community analysis with the goal of exploring the shorelines potential sensitivity to spilled oil. From these assessments, the nine shoreline types were further categorised into ten shoreline types. These were ranked, in order of increasing sensitivity to oil spills, based on empirical observations and expert judgement on habitat sensitivity to this particular pressure;

1. Concrete seawalls and harbour structures
2. Beach rock outcrops
3. Fine-sand beaches
4. Medium to coarse sand beaches
5. Hard sand or mud tidal flats with low productivity
6. Boulder structures
7. Cobble/ boulder beaches
8. Exposed bedrock platforms
9. Hard sand or mud tidal flats with high productivity
10. Soft mud tidal flats with high productivity.

Though these observations are useful to contextualise the wider habitats of Kuwait, and their distribution, it does not assess present condition or the pressures that have been exerted across the coastal zone since these surveys were undertaken. Industrialisation and modern development of Kuwait has certainly intensified since 1986, and habitat condition and extent is likely to have decreased in response to this growing anthropogenic activity (Loughland et al., 2012; Baby et al., 2014).

Recent studies have looked at salt marshes and the potential impacts of anthropogenic activities on natural vegetation and plant diversity. Abd El -Wahab (2015) explored the species richness, structure and conservation of *Nitraria retusa* communities, a key feature of salt marshes in coastal Kuwait. He reports the decrease in *N. retusa* in Northern Kuwait from around 33% coverage in the 1970's, to 23% in the 2000's. The present study assesses present coverage, in the study area, as 12% and demonstrates a 50% decrease in community coverage over the past decade. This study presents the risks associated with coastal fragmentation caused by urban and industrialisation where removal of trees and shrubs from arid ecosystems decreases the chances of habitat recovery. Further to this, in the wider Gulf region Loughland et al. (2012) reports a loss of 90% of the saltmarshes due to urban development.

In addition to this study Abd El-Wahab (2016) has continued to explore the plant assemblage and diversity variability with anthropogenic activities, with a focus on the southern Kuwaiti coast. This area is dominated by limestone ridges, coastal dunes, sand plains and tidal lagoons. Furthermore, the coastal flats are bordered by saltmarshes. This study demonstrated a further decrease (up to 40%) in the annual species that are often seasonally present within the saltmarshes, beyond the annual dominant zonation. It is thought that this decrease is linked with the increased arid conditions associated with removal of trees and shrubs from urban developments. Abd El-Wahab (2016) reports a total loss of faunal coverage as 80% from human activities since the 1970's.

An intensive study of Boubyan island, at the northern reaches of Kuwait, explored some of the associated environment and ecology (Omar and Roy, 2013). This was undertaken in response to the political importance of the island as well as its unique biodiversity. Due to the island's strategic importance and its location at the northwest extreme of the Gulf, it provides habitat targeted for future developments, but must also be considered for its habitat importance and support of breeding/ feeding birds. Late to early March is recorded as the predominant nesting season with sabkha areas to the south and the intertidal regions to the north being the preferred habitats. The northern intertidal areas of Boubyan and Warbah islands are known to support over 30 species of waterfowl and are important both at a national and international level. Omar and Ray (2013) identified the northern areas as the most important area on the island, but noting that the coastal habitats to the east and southwest also support a diverse waterfowl and raptor community. Anthropogenic activities in the area risk impacting on these key habitats for breeding and foraging and should be carefully considered as a key habitat in any future Kuwait national planning in the marine and coastal area.

Mangroves are known to be a prominent, salt tolerant, forest tree that can survive intertidal regions characterised by hot climates and high irradiance. These coastal forests provide refuge, nurseries and foraging for a variety of species whilst also providing a natural coastal defence and trapping sediment and nutrients locally. Kuwait has historically supported mangroves but has no naturally surviving forests (Almulla et al., 2013). Plantations have been established along the Kuwaiti coast but these are not performing well. Almulla et al. (2013) consider this to be due to poor management and a lack of favourable conditions for the growth of pneumatophores. Poor urban planning and developments continue to negatively affect the coastal environment and disturb the natural anoxic layer, salinity and textural composition which would allow mangroves to better thrive in the Kuwaiti coastal area.

4.6.8.3 Assessment approach and findings

Information for this assessment was gathered from both primary scientific literature, published grey literature and accessible data bases. There have been few broad studies of the extent, distribution and composition of the Kuwaiti coastal habitats. These studies have demonstrated some of the established links between habitat condition and the wider condition of biodiversity across Kuwait. However, there is currently a lack of wide baseline information to assess the current condition of all of Kuwait's coastal habitats. The absence of this data leaves poor confidence in assessing their viability for supporting other species such as turtles, birds and seagrass. Habitats of importance to Kuwait are those that provide functional habitats (eg nursery areas, foraging, nesting etc.) supporting wider biodiversity. Further evidence from a dedicated monitoring programme, directed towards the condition of Kuwaiti coastal habitats is required to better assess these features. Such a condition assessment would form the basis for successful spatial management of the coastal area and better provide evidence based decision making on matters of conservational importance.

4.6.8.4 Conclusions

Though there have been several studies looking at the coastal habitats of Kuwait, there is little widespread evidence on the condition of these. What is clear is the importance of these habitats to the successful survival of a variety of dependant species, such as birds and turtles. The productivity of broader habitats such as mud flats and seagrasses is crucial to the viability of those dependant species. A dedicated baselining exercise is required to assess the current condition of coastal habitats and should be used as the beginnings of a long-term monitoring strategy that assess changes in condition over time so that management action can be taken where required.

This lack of data across all coastal habitats makes a quantitative assessment of Kuwait's coastal habitats difficult to make, however it is possible to infer the condition of habitats from the changes in anthropogenic coastal use over the last few decades. With the increasing urban and industrialisation of the coastal zone (Loughland et al., 2012, section 9.1), it is clear that coastal habitats are and will continue to be under threat in Kuwait. Recent work on the salt marsh habitats of Kuwait demonstrates the direct effects on vegetation of this developing region (Abd El-Wahab, 2014; 2016). Similarly, Almulla et al. (2013) discuss the possibilities of successfully re-introducing mangrove habitats to the Kuwaiti coastline, and the potential benefits of such an endeavour, but only where coastal management is appropriately monitored and observed.

Special consideration is given to the coastal habitats surrounding Kuwait's islands, especially those around Boubyan. This is for the diversity of bird species identified there, and for the national and international importance of some of those species. Similarly, with the porosity of suitable turtle nesting habitat and the ever-decreasing availability of this habitat it is important to better explore the causal links between such key species and the habitats/ ecosystems they are dependent on.

5 Food and Water Quality for human health

5.1 Introduction

Maintaining the health of coastal waters as functional and healthy ecosystems is essential for our future well-being. These coastal areas are impacted through pollution inputs due to changes in land use and hydrology, with vast amounts of our wastes entering daily. Ocean and estuarine ecosystems can therefore impact the extent to which humans are exposed to microbial pathogens, which include both marine-indigenous pathogens and externally introduced microbial contaminants. These pathogens can be found in association with marine animals, phytoplankton, zooplankton, sediments and detritus. Environmental factors, including salinity, temperature, nutrients and light, influence the survival and sometimes the proliferation of pathogens.

The condition or quality of coastal waters is very important for health and safety reasons and also for visual impact. Disease-carrying bacteria and viruses (or pathogens) associated with human and animal wastes pose threats to humans by contaminating seafood, drinking water and swimming areas. Eating seafood and even swimming can result in hepatitis, gastrointestinal disorders, and infections. There are several sources of bacterial contamination in coastal waters, e.g. leaking septic tanks, poorly maintained sewage treatment plants, discharges from boats, and runoff from the land during heavy rains and storms.

Water quality also depends on the level of nutrients. Excessive quantities of nutrients discharged into the coastal environment these can cause the rapid growth of marine plants, and result in algal blooms. Sewage discharges, and household and commercial waste that is carried to the sea by storm runoff, add excess nutrients to coastal waters. Detergents and fertilizers supply high quantities of nutrients to streams and rivers and ultimately the marine environment.

5.2 Drivers and pressures

Sewage and industrial contamination are key issues in the management of water quality in Kuwait’s marine waters (Al-Ghadban et al., 2002; Al-Abdulghani et al., 2013). It is known that the organic content of sewage discharged into Kuwait’s coastal waters is high and regularly septic due to long retention times, elevated ambient temperatures and concomitant anaerobicity (Ghannoum et al., 1991; El-Desouki and Abdulraheem, 1998; Al-Ghadban et al., 2002). Other pollutants, including trace metals and oil related chemicals have been detected close to known point sources of sewage effluent, which often are discharged within a few meters of the shoreline (Al-Ghadban et al., 2002). Microbial water quality surveillance monitoring for the assessment of beach quality is conducted by KEPA, who undertake sampling at 12 coastal sites located in the vicinity of emergency sewage outfalls and recreational beaches (Al-Ghadban et al., 2002).

It is estimated that 98% of Kuwait's 3.6 million inhabitants live within the 810 km^2 that covers the Kuwait Metropolitan Area. This major population centre is currently served by 5 main Sewage Treatment Plants (STP), along with additional smaller facilities at Failaka Island, Al-Khiran and Al Wafra. As recently as 2011 it was estimated the treatment network was receiving up to 100,000 m^3 day^{-1} of sewage above its design capacity, leading to frequent discharges of raw or partially treated effluent into the marine environment. In recent years environmental disasters, such as the Mishref pumping station breakdown, have also contributed to the degradation of Kuwait's marine environment (Saeed et al., 2012). The Mishref pumping station malfunctioned in August 2009, resulting in the discharge of around 150,000 m^3 day^{-1} of raw sewage directly into the sea over a 36 month period. The discharge occurred via three main outfalls at Al-Bidda, Al-Khitabi and Al-Messela, impacting beaches in a number of areas important for tourism and residential housing. Monitoring undertaken by Kuwait Environment Public Authority (KEPA) during this period indicated that approximately 20 km of coastline was affected, with water quality and bacterial indicators greater than permitted guidelines (EPA 2001).

5.3 Data sources

Historic datasets detailing total and faecal coliforms, faecal streptococci and *Escherichia coli* (*E.coli*) concentrations at S-site location around Kuwait were made available by KEPA. All analysis was undertaken according to membrane filtration methods as outlined in Standard Methods for the Examination of Water & Wastewater (2005). Briefly, replicate water samples (4-6 per site) were taken from each S-site (Figure 1) and stored on ice for no longer than 6 hours, before being returned to the laboratory for analysis. Samples (volume governed by degree of contamination) were filtered, from the highest dilution in order to avoid contamination, through sterile membranes (0.45micron pore size) using aseptic techniques. The membrane filter was removed with flamed sterilized forceps and placed in Petri dishes containing agar and appropriate media. Petri dishes containing the membrane filters were sealed and incubated immediately for 24 hours at 36˚C (total coliform media), 48 hours at 36˚C (faecal streptococci) or 24 hours at 44.5˚C for (faecal coliform). Blank and positive control samples were analysed in parallel with those collected from the field. Counts were adjusted to the number of colonies per 100/ml of sample filtered and presented as minimum, mean and maximum number of colonies per set of replicates (triplicate).

Data is available across the EPA monitoring network and the data utilised in this assessment is identified in Figure 5-1.

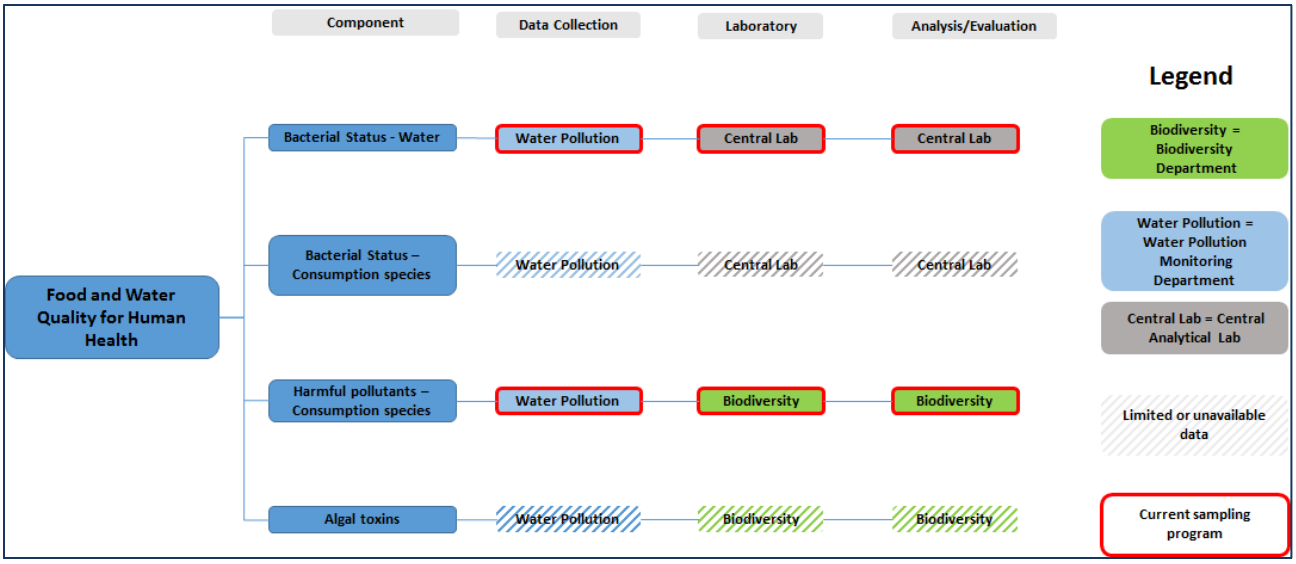


Figure 5-1: Sources of data for assessment collected by current EPA monitoring programs

5.4 Assessment process for food and human health

5.4.1 Microbial assessment

The assessment of microbial contamination is presented for both currently accepted KEPA guidelines and, as appropriate, assessed against European Union Bathing Water Directive that sets out clear guidelines on environmental standards around Faecal coliforms, *E.coli* and Faecal Streptococci.

No standard for *E. coli* in seawater is currently identified under Kuwaiti regulatory policy/byelaws. Under Kuwaiti EPA Decree No. 210/2001[1], the maximum limits of Pollutants in industrial water waste permissible to be discharged into the sea is 1,000 MP/N/100 ml. (counts as total coliforms). We applied standards for faecal coliforms in seawater as are currently identified under Kuwaiti regulatory policy/byelaws as 200CFU/100ml and 200 CFU/100ml for Faecal Streptococci (Table 5-1) which align with the European Bathing Water Directive 76/160/EEC, (now superseded). Finally, we applied the revised European Bathing Water Directive (2006/7/EC). The revised Directive introduces tougher standards, but based on only two parameters - intestinal enterococci (Faecal Streptocci) and Escherichia coli. The rBWD imperative guideline standards of 95-percentile compliance with 2,000 and compliance guidelines with 80-percentile compliance against a threshold of 100 faecal coliforms /100 ml were applied on the basis of 4 year rolling mean assessments.

Table 5-1: Kuwati and European Union standards set for microbial parameters set as counts per 100ml.

---

[1] Environment Public Authority Decision No. 210/2001 Pertaining to the Executive By-Law of the Law of Environment Public Authority Appendix No. (13).

Parameter	Unit	Maximum limit-EPA	EC(76/160/EEC)	
			Good quality (mandatory)	Excellent quality (guide)
Total Coliform	CFU/100ml	1000	-	-
Faecal Coliform	CFU/100ml	200	-	-
Escherichia coli	CFU/100ml		500	250
Faecal Streptococci	CFU/100ml	200	200	100

5.4.2 Food health

Chemical contamination of seafood most commonly occurs because of contamination of the marine environment either more locally due to spills or discharges and/or on a wider scale because of more diffuse atmospheric or riverine inputs derived from industrial and agricultural practices and through urbanisation. Dependent upon the source of chemical contamination of the marine environment and of chemical properties the subsequent contamination of seafood may result from the dominant presence of a single chemical or several chemicals. Where chemicals present in fish include lead, cadmium, mercury, dioxins or relevant dioxin-like chemicals and polycyclic aromatic hydrocarbons (PAHs) these can be evaluated against maximum acceptable concentrations set by international regulations. For other chemicals there are tolerable intake limits set on a daily, weekly, or monthly basis. As well as assessing whether a maximum value or time based intake threshold is likely to be exceeded for a seafood sample, it is important that any trends in contamination are also considered. A trend analysis that indicates a decline in seafood contamination is a primary indicator by which to judge the success of any management action taken to reduce chemical inputs to the marine environment.

5.5 Summary of outcomes

5.5.1 Microbial contamination

Microbial contamination is one of the most chronic issues facing Kuwait. This SOMER assessment focused on the reporting of the long-term (up to 30 years) microbial water quality data collected as part of the EPA's national monitoring programme (coastal S-site stations). Clear hotspots of contamination were detected during and after the Mishref sewage crisis, particularly around sites S00 (Al-Bedaa) and S07 (Al-Messila) and continue to be detected around S00 and Doha Bay (Kuwait Bay) for the 5 years following the Mishref crisis Analysis of the data clearly demonstrates that failures in microbial water quality standards (faecal coliform, faecal streptococci and *E.coli*) occur on a regular basis across all locations monitored, and that the actual frequency of S-sites failing both EPA and international microbial water quality standards at certain sites has not dramatically changed in recent years. This is attributed to the failure of the sewage treatment network to keep pace with demands for capacity driven by rapid population growth, which has almost trebled over the last 30 years. Importantly, it also demonstrates that while Mishref was an obvious and noticeable pollution incident, the coastline of Kuwait has, and still is, exposed to sewage contamination on a frequent basis as a result of the treatment networks failure to deal with the volume of waste being produced (Table 5-2).

5.5.2 Food health

Of the chemicals that have been analysed in seafood, total mercury and methyl mercury have been detected above acceptable maximum concentrations for several studies. In one study focussing on contamination in Kuwait Bay resulting from known discharges tissue samples of the non-commercial bivalve *Aminantis umbonella* had total mercury concentrations that were over ten times higher than EC standard levels (Tarique et al., 2013). In other studies, samples of fish tissue collected between 1996 and 1998 (Majed and Preston, 2000) and in some more recent data samples of shark collected in 2011 total mercury concentrations in tissue samples exceeded EC maximum limits. For lead fish tissue samples show a more variable picture with some fish species sampled from the marine environment in 1995 exceeding EC maximum levels but other market collected samples showing low concentrations of lead. The few data available for cadmium indicate that some non-commercial shellfish samples collected between 1999 and 2000 exceeded the EC maximum.

In more recent studies tissue samples from the Giant catfish (Arius thalassinus) from locations within and external to Kuwait Bay had generally low concentrations of all metals measured and total mercury, lead and cadmium concentrations that were all well below the EC maximum. Similarly, tissues of Rock oyster and Venus clam collected in 2013-2014 at coastal sites around Kuwait also have very low total mercury, lead and cadmium concentrations in their tissue, again well below the EC maximum (KEPA, Mishref data). Data for copper and zinc in shellfish by comparison to data for the North Sea and Mediterranean are in the same order of magnitude but have a higher range and for fish show concentrations of copper an order of magnitude higher and for zinc in a similar but higher range. For other contaminants, notably PAHs there is some evidence from Kuwait market collected samples in 2005 to suggest that fish tissue may just exceed EC maximum concentrations. Data for fish and shellfish collected in 2005 from the coast of Kuwait, did not show any concentrations that exceeded the maximum limit of 75 ng g-1 wet weight for ICES-6 PCBs (Table 5-2).

Table 5-2: Summary of outcomes for water quality for food and human health.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
Food and Water Quality for Human Health						
Status assessment is POOR. Food and Water Quality for Human Health is at POOR status, and is recognised as one of the major issues facing Kuwait marine waters. The assessment reflects the chronic sewage pollution causing microbial and pollutant contamination of many of the coastal sites. Continued failures of microbial water quality show that raw and partially treated sewage discharges continue to be a problem, particularly in certain hot spots around Kuwait city. Hot spots were further identified based on faecal sterol sediment contamination in Doha Bay and Sulaibikhat Bay. Microbial water quality regularly breaches regional and international water quality guidelines, this poses health risks for people coming in contact with contaminated water. There is some limited data that indicates that poor water quality may cause adverse seafood contamination, with possible consequences for human health. There is some evidence suggesting that fish tissue may occasionally exceed EC maximum allowable concentrations. In conclusion, microbial water quality issues are severe and a threat to human health and biodiversity. Given the continued chronic issues associated with sewage discharges, high recreational use of coastal areas around Kuwait City and the potential impact on seafood quality in a country where fish consumption forms an important component of diet this issue is a priory for management.						
FOOD AND WATER QUALITY FOR HUMAN HEALTH	Microbial Water Quality	Microbial counts	● (red)	⬇ (red)	■■■	Status assessment is POOR, and the predicted trajectory continuing to decline. This is based on continual and persistent breaches of microbial water quality standards and guidelines. Microbial contamination is one of the highest priority issues facing Kuwait. Clear hotspots of contamination were detected during and after the Mishref sewage crisis, particularly around Al-Bedaa and Al-Messila and Doha Bay. Monitoring data clearly demonstrates breaches of microbial water quality standards occur on a regular basis and ongoing basis, exceeding EPA national thresholds and international bathing waster standards. The analysis of faecal sterols in sediments provides further proof that the environment is regularly impacted by sewage discharges with high levels of contamination found along the Gulf coast and inner Kuwait Bay.
	Food health	Seafood contamination	● (orange)	?	■	Status assessment is MODERATE. Some indication that contaminants in fish tissue may occasionally exceed EC maximum allowable concentrations. This assessment has low confidence given the lack of a dedicated monitoring making it difficult to draw firm conclusions. Despite this uncertainty, there is a high reliance of seafood in Kuwait where fish consumption forms an important component of diet. This reliance coupled with chronic issues associated with sewage discharge and evidence of contamination in fish tissue, there is significant potential for impacts on human health.

5.6 Food and Water Quality for human health indicator assessments

5.6.1 Microbial contamination

5.6.1.1 Background

Sewage and industrial contamination are key issues in the management of water quality in Kuwait's marine waters (Al-Ghadban et al., 2002; Al-Abdulghani et al., 2013). It is known that the organic content of sewage discharged into Kuwait's coastal waters is high and regularly septic due to long retention times, elevated ambient temperatures and concomitant anaerobicity (Ghannoum et al., 1991; El-Desouki and Abdulraheem, 1998; Al-Ghadban et al., 2002). Other pollutants, including trace metals and oil related chemicals have been detected close to known point sources of sewage effluent, which often are discharged within a few meters of the shoreline (Al-Ghadban et al., 2002). Microbial water quality surveillance monitoring for the assessment of beach quality is conducted by KEPA, who undertake sampling at 12 coastal sites located in the vicinity of emergency sewage outfalls and recreational beaches (Al-Ghadban et al., 2002).

5.6.1.2 Current State of knowledge: Kuwait

Monitoring of inshore seawater sites for faecal indicator organisms (FIO) has taken place since 1986 at 12 sites spread between Doha Bay on the south side of Kuwait Bay and towards the south along the Arabian Gulf coast. Currently only summarised (monthly minimum, arithmetic mean and maximum) FIO data is available for assessment, this necessary limits the assessment and prevents certain detailed statistical analyses and evaluation commensurate with microbiological standards applied to coastal water quality by other national administrations. However, the long term data still provides a compelling assessment of the microbial water quality, identifying that continued high counts of the microbial community demonstrate persistent sewage contamination into the nearshore coastal areas along the Kuwait coastline.

Various international microbial water quality standards are available and those such as the coastal Bathing Water Directive (cBWD) adopted in the European Union (original Directive 76/160/EEC) sets out a number of microbiological and physio-chemical standards that bathing waters must either comply with ("mandatory" standards) or endeavour to meet ("guideline" standards). The two main standards used to assess the quality of bathing water are *E.coli* and Faecal streptococci as they are the main bacteria commonly found in the guts of humans and other warm-blooded animals, and as such, are good indicators of sewage related pollution. KEPA have established thresholds for faecal streptococci and *E.coli* which are compliant with the current European Bathing Water Directive (cBWD, Anon, 2006) and have been developed to protect bathing water sites by setting thresholds for the main microbiological organisms to avoid impact on human health. KEPA, in addition have maximum limits set against the number of total and faecal coliforms (Table 5-1) (EPA, 2001).

No standard for *E. coli* in seawater is currently identified under Kuwaiti regulatory policy/byelaws. Under Kuwaiti EPA Decree No. 210/2001[2] the maximum limits of pollutants in industrial water waste permissible to be discharged into the sea is 1,000 MP/N/100 ml. The maximum limits for faecal coliforms discharged to the seas is 200 cfu/100ml.

In respect to the standards set for total coliforms, data has been collected since 1986. All inshore total coliform results for the 12 inshore seawater monitoring stations (S00-S11) is presented for monthly maximum total coliform results (

Table 5-3) and for monthly average total coliform results (Table 5-4). All monthly values for both maximum and mean values exceed 1,000 cfu/100 ml and thus failing the EPA standards set for total coliforms.

[2] Environment Public Authority Decision No. 210/2001 Pertaining to the Executive By-Law of the Law of Environment Public Authority Appendix No. (13).

Table 5-3:Annual average of total coliform monthly maximum values

Year	S00	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11
1986	1645.5	23786.7	15371.7	4555.8	4927.9	3041.8	14680.5	2395.5	4479.1	11677.1	11588.2	10073.6
1987	1084.8	3060.4	5348.8	2177.6	2462.3	2516.1	2052.8	1521.2	2748.9	2244.4	3052.8	2931.3
1988	517.2	3749.5	5903.2	2643.9	2704.2	2176.3	297.9	796.0	1166.9	1035.2	2021.7	2152.9
1989	5533.3	18555.3	683500.0	5262.3	11044.3	13072.0	2864.0	889.0	6250.0	2700.0	4017.7	1309.0
1990	3095.7	58671.4	835000.0	9545.7	7269.3	15914.6	18605.3	2713.0	3112.6	4722.7	9994.3	4434.9
1991	1500.0	14014.1	22971.4	3701.4	6463.5	6106.6		5498.6	9817.4	9514.5		
1992		9797.3	10333.3	2376.3	2551.7	2092.5		2114.3	3541.5	3472.6		
1993	3394.0	20146.7	25900.0	14041.0	6113.6	3384.3	122748.1	3437.7	3725.5	7285.3	5916.4	5869.7
1994	2605.9	12695.8	8045.8	3276.4	9837.8	2371.8	3204.3	1181.8	2813.7	6078.8	1895.0	80690.8
1995	13653.9	357809.4	8450.0	920.1	148908.3	1347.1	1713.3	622.4	2190.6	3506.9	26233.8	27797.2
1996	4477.3	6993.6	10700.0	1254.8	2967.2	2798.9	2999.1	1453.8	1558.8	3170.6	2664.7	1449.8
1997	9100.7	6801.7		3190.3	5110.3	2909.3	2137.3	6587.7	5142.3	2797.1	5517.9	7508.3
1998	9956.7	4051.1		1884.1	10894.7	2662.4	4039.5	6893.5	12054.1	6612.8	8524.4	7371.2
1999	3024.4	2439.2	5171.3	2053.3	2163.3	1973.1	1706.7	1838.3	2292.3	1813.6	4526.1	2846.2
2000	2366.1	1390.4	1729.4	1210.0	2908.3	1154.6	1529.6	2901.3	1808.9	2982.3	1661.1	2157.3
2001	4343.2	6075.8	7192.8	1706.7	4291.7	1376.7	2811.7	6212.0	6663.1	6122.4	2850.2	6824.4
2002	3095.8	2901.7	2162.5	1772.3	2816.7	1713.3	2070.0	3805.4	3160.0	3042.3	3685.8	7655.0
2003	2592.0	3649.3	2241.4	1763.8	2706.7	2439.2	3267.8	3602.3	3303.8	2377.8	3007.8	1934.4
2004	4664.5	8120.6	4835.3	1434969	34821.7	7946.6	14851.1	39935.6	15721.7	14662.8	26808.3	16578.8
2005	5413.9	5220.3	4346.2	5856.1	5642.8	3954.8	3375.5	4868.3	3026.7	4832.3	5171.7	5143.9
2007	8778.9	1421.9	1375.3	6977.3	1566.8	1415.5	1400.3	292458.3	16640.0	9128.3	9562.8	8538.8
2008	2682.3	7900.0	5873.9	6436.7	7624.4	6356.7	4612.8	2085100	335020.0	2932.3	2092361	1001695
2009	1449.9	1618.0	1593.7	951.3	1494.8	1125.5	1500.8	12099.6	1617.0	1585.8	1779.4	1580.1
2010	55427.3	1307.3	1704.3	1520.0	1530.3	1480.0	1498.2	4321064	2346.6	2012.7	1646.7	1688.5
2011	25183750	18116.1	9085.6	2089.4	779544.4	2833.8	5792.5	838399417	2798.9	240092820	6875.0	1728.8

Year	S00	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11
2012	2137419.4	12205.0	26862.3	10538.9	13382.8	6835.0	6695.1	1710867	6500.0	4413.1	16405.5	13431.8
2013	3391.4	30471.1	4278.9	2805.0	1512.9	1575.6	2135.0	4137.8	1995.6	1894.3	5565.3	3921.6
2014	8557.1	15304.9	12935.3	2298.1	2991.4	2120.9	9608.7	7133.4	2121.0	1285.7	1798.1	1932.4
2015	13436.1	2680592	14804.5	1932.2	7393.1	1249.3	3033.3	15055.8	4030.4	4808.3	11314.4	5859.3
2016	4275.0	16700.0	16366.8	9915.0	9508.3	3008.3	5741.8	3816.8	2100.0	2568.3	3158.5	2426.5

Table 5-4:Annual average of total coliform monthly mean values

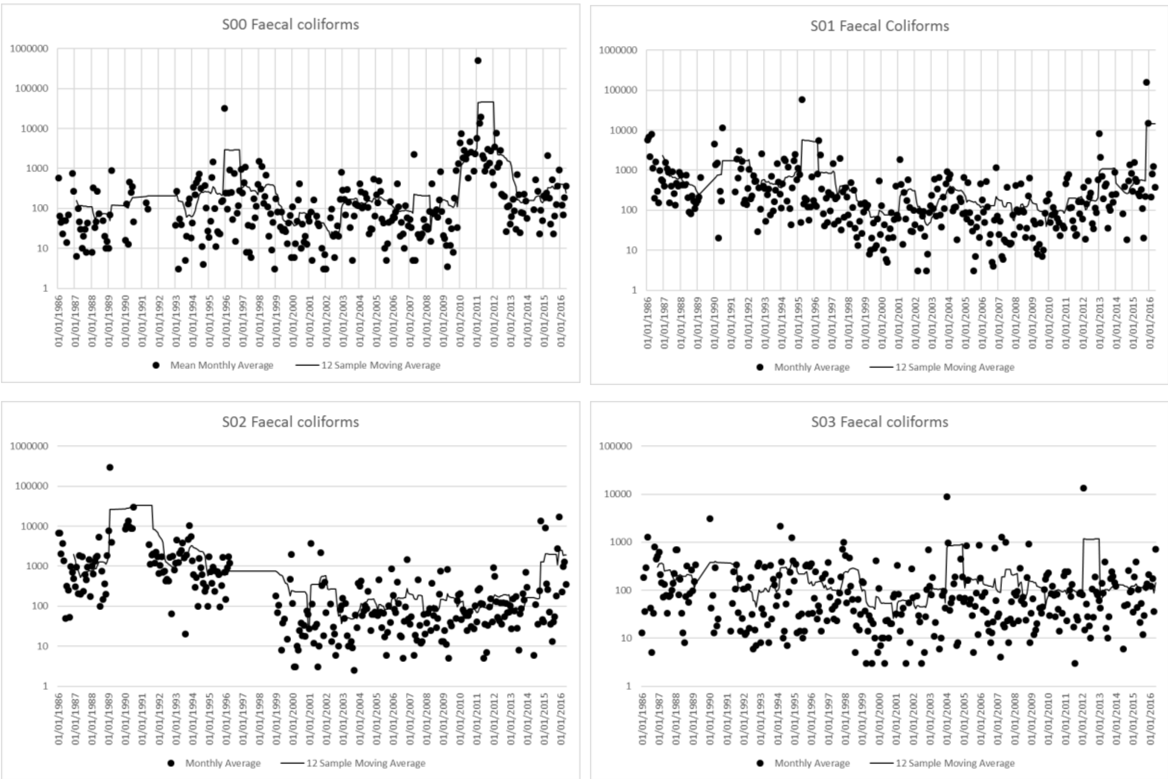
Year	S00	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11
1986	791.8	9024.3	5570.6	1891.9	1750.4	1227.5	3783.1	1048.6	1393.3	3212.3	3302.1	3030.5
1987	373.6	1392.4	2028.9	851.4	1121.0	1212.0	804.5	581.0	983.9	935.6	1160.6	1229.0
1988	279.5	1721.0	3070.7	1568.0	1410.3	1523.4	165.4	339.1	569.0	541.4	1247.2	1017.5
1989	1531.0	6895.0	233202.3	2909.7	5060.3	5696.7	1310.7	505.0	2246.0	1221.0	1203.0	659.7
1990	1496.1	18770.9	192719.7	3805.5	3530.9	5124.0	5017.5	1336.8	1518.3	1962.6	3661.1	1826.1
1991	1218.0	9712.2	14378.9	2538.9	3669.6	3509.4		3511.8	5236.2	8100.0		
1992		4765.4	5275.0	1276.2	1282.9	1006.8		984.4	1488.3	1726.7		
1993	1603.2	7111.6	11318.8	4007.0	2460.3	1461.0	31551.9	1149.8	1565.2	3323.8	2238.4	2790.8
1994	1084.8	5185.4	3371.5	1306.4	3150.0	1026.9	1339.9	526.3	982.4	2197.1	881.3	32141.4
1995	6858.7	80593.2	3085.7	423.3	33394.7	626.9	835.6	284.9	781.8	1306.3	12913.8	13757.5
1996	1546.2	4010.3	4547.5	447.3	1416.9	1118.9	1202.7	512.8	565.8	1302.8	1040.1	732.3
1997	2397.3	3018.3		1303.1	2139.5	928.3	860.9	1847.8	1491.3	914.7	1371.8	1948.4
1998	3767.5	1526.2		701.8	3390.9	881.9	1321.6	2433.1	3520.8	2023.6	2487.7	2185.6
1999	1099.8	856.2	1529.0	720.3	762.6	687.3	627.2	745.8	839.4	718.3	1543.1	1037.0
2000	877.8	745.4	829.6	616.2	1047.9	576.4	828.1	1035.7	792.8	1001.7	698.8	846.0
2001	1675.6	2710.1	2343.4	872.9	1585.9	652.1	1199.7	2981.5	3213.6	2208.4	1322.3	2458.4
2002	1366.8	1182.4	809.1	855.4	1029.8	667.0	834.3	1712.1	1480.0	1505.8	1718.9	2589.7

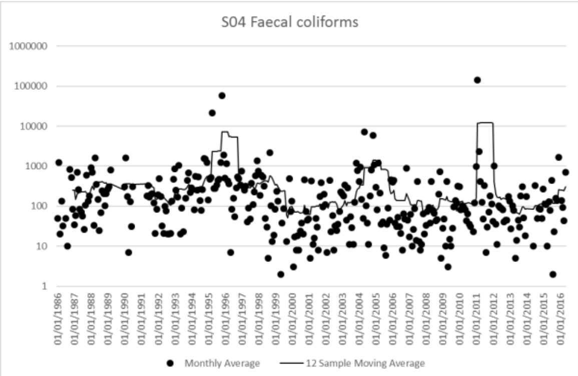
Year	S00	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11
2003	1200.1	1844.1	1002.6	948.8	1449.8	981.9	1505.1	1525.2	1293.1	1079.3	1221.0	853.4
2004	2009.1	3196.0	1701.6	361243.3	11024.7	2597.3	5504.7	14150.7	5288.9	4933.9	9031.5	5617.3
2005	2172.0	1907.3	1448.7	1890.3	2328.5	1421.1	1272.6	2168.8	1361.7	1913.7	2064.4	2192.0
2006	963.4	2153.7	1648.3	1233.3	1560.1	1737.7	2010.6	1664.6	1934.6	1180.1	659966.1	1852.7
2007	2057.8	656.9	674.8	1782.8	635.7	594.8	621.5	58763.1	3641.3	2138.3	2192.8	2075.1
2008	1177.2	2653.7	1890.4	2115.0	2281.6	2109.4	1673.9	525813.5	84140.6	1223.5	527972.7	255315.7
2009	728.1	591.6	597.0	495.2	623.6	460.0	681.0	6013.4	730.9	724.1	695.1	689.6
2010	18612.5	641.7	784.4	735.7	662.4	704.2	667.1	871590.2	873.1	844.5	725.5	718.8
2011	12554233	5067.4	3053.9	916.4	258281.1	1119.2	1529.6	418693860	1178.1	66872260	819.9	878.3
2012	547779.1	4544.5	7241.3	2811.6	3521.5	2163.5	2039.2	440448.7	2224.4	1543.8	4752.2	3809.8
2013	1461.7	9456.6	1308.6	1083.3	832.3	703.9	1034.3	1714.8	929.4	757.8	1797.9	1317.6
2014	3200.0	5185.3	3414.7	1082.1	1177.1	913.3	3065.6	2741.9	1036.4	909.6	989.3	1157.3
2015	3877.6	506655.2	7164.1	909.5	2514.5	655.8	1252.9	4349.9	1486.4	1416.0	3422.6	1999.4
2016	2117.3	4858.5	4840.0	2992.5	2797.5	1158.5	2184.5	1805.3	1124.5	1071.3	1555.3	1036.8

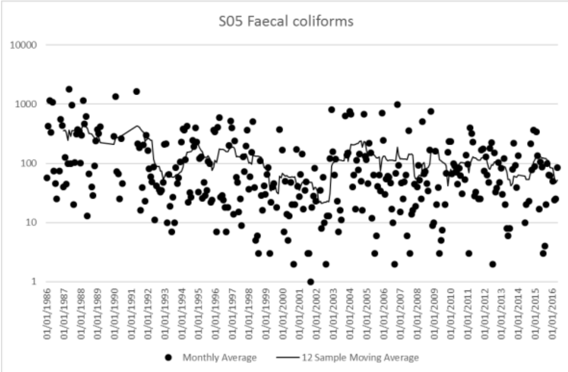
However, under the European Bathing Water Directive 76/160/EEC, (now superseded), imperative and guideline standards of 95-percentile compliance with 2,000 and 80-percentile compliance with 100 faecal coliforms /100 ml were and applied on the basis of annual assessments.

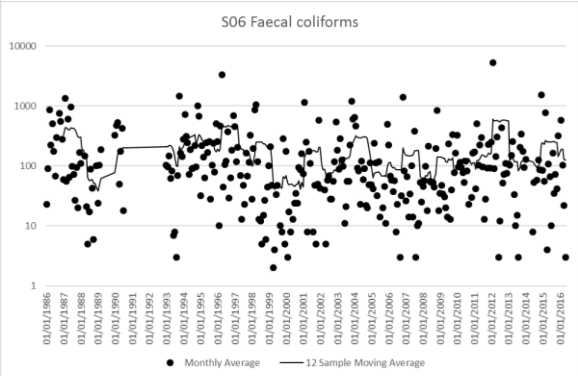
A 30-year data set (1986-2015) of monthly minimum, arithmetic mean (average) and maximum *E. coli* values is available for each of the 12 inshore seawater sites. An indication of the variability and possible trend in inshore water quality at each site is provided by plotting monthly average faecal coliform data overlain with a rolling 12-sample moving average trend line (Figure 5-2). A wide spread in monthly averages, of two to three orders of magnitude, is evident for most sites. In general, it is difficult to discern trends in this summarised data given the wide monthly variability over the whole time series.

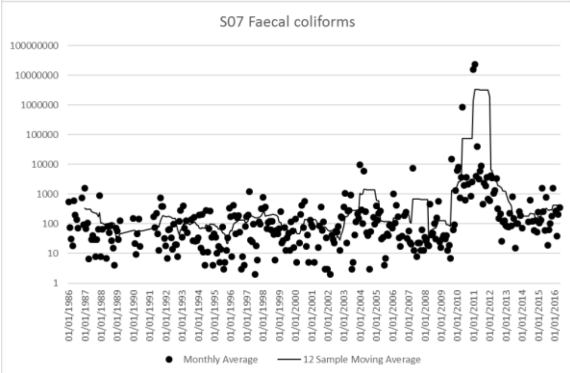
Figure 5-2: Monthly average faecal coliform data overlain with a rolling 12-sample moving average trend line

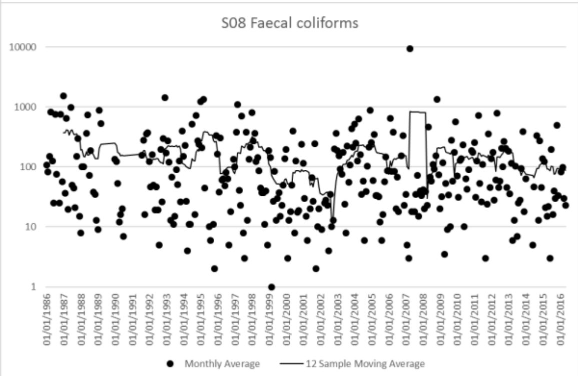


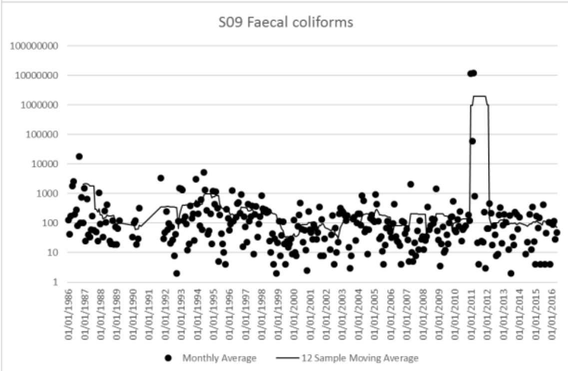


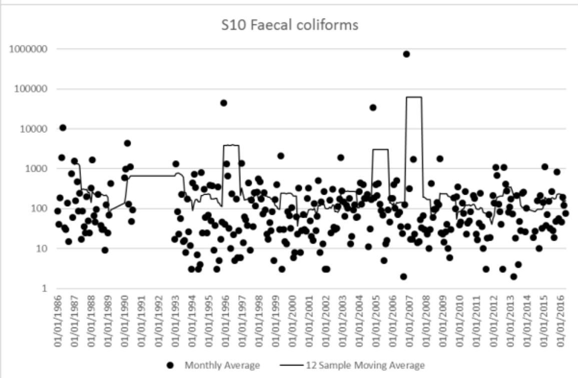


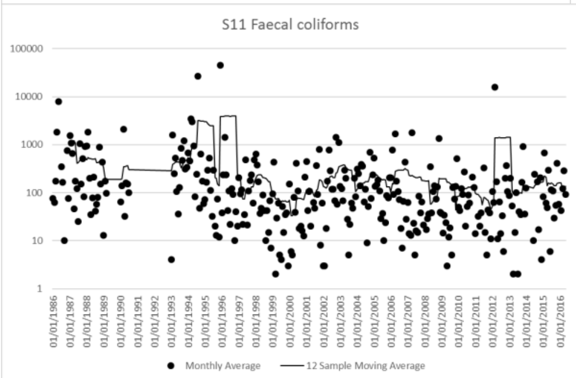












No standard for *E. coli* in seawater is currently identified under Kuwaiti regulatory policy/byelaws. Under the European Union revised bathing water directive (Directive 2006/7/EC) *E. coli* results from coastal recreational coastal bathing water monitoring results are evaluated annually on the basis of a rolling four-year data set (where available) to provide classifications (excellent, good, sufficient or poor, based on percentile compliance with threshold values (excellent 95-percentile compliance with 250 cfu/100 ml; good 95-percentile compliance with 500 cfu/100 ml, sufficient 90-percentile compliance with 500 cfu/100 ml, poor <90-percentile compliance with 500 cfu/100 ml).

A six-year data set (2010-2015 inclusive) of monthly minimum, arithmetic mean and maximum *E. coli* values is available for each of the 12 inshore seawater sites. An indication of the recent status of inshore water quality at each site is provided by plotting rolling 48-month (equivalent to four years' data) 95-percentiles of the *E. coli* data (utilising face values of the monthly minimum, arithmetic mean and maximum data) (**Figure 5-4**). Sites with microbial counts above EU environmental standards are S00, S01, S07 and S09, though variability across those six years is high.

Only one of 12 sites (S03) recorded 95-percentiles values consistently below 250 cfu/100 ml (approximating EU 'excellent' classification). Out of the remaining 11 sites, only one site (S05) recorded 95-percentiles values below 500 cfu/100 ml (approximating EU 'good' classification) and one site (S04) was borderline around this threshold (see

Figure **5-5**). All other sites recorded 95-percentile values above 500cfu/100ml (approximating EU "poor" classification).

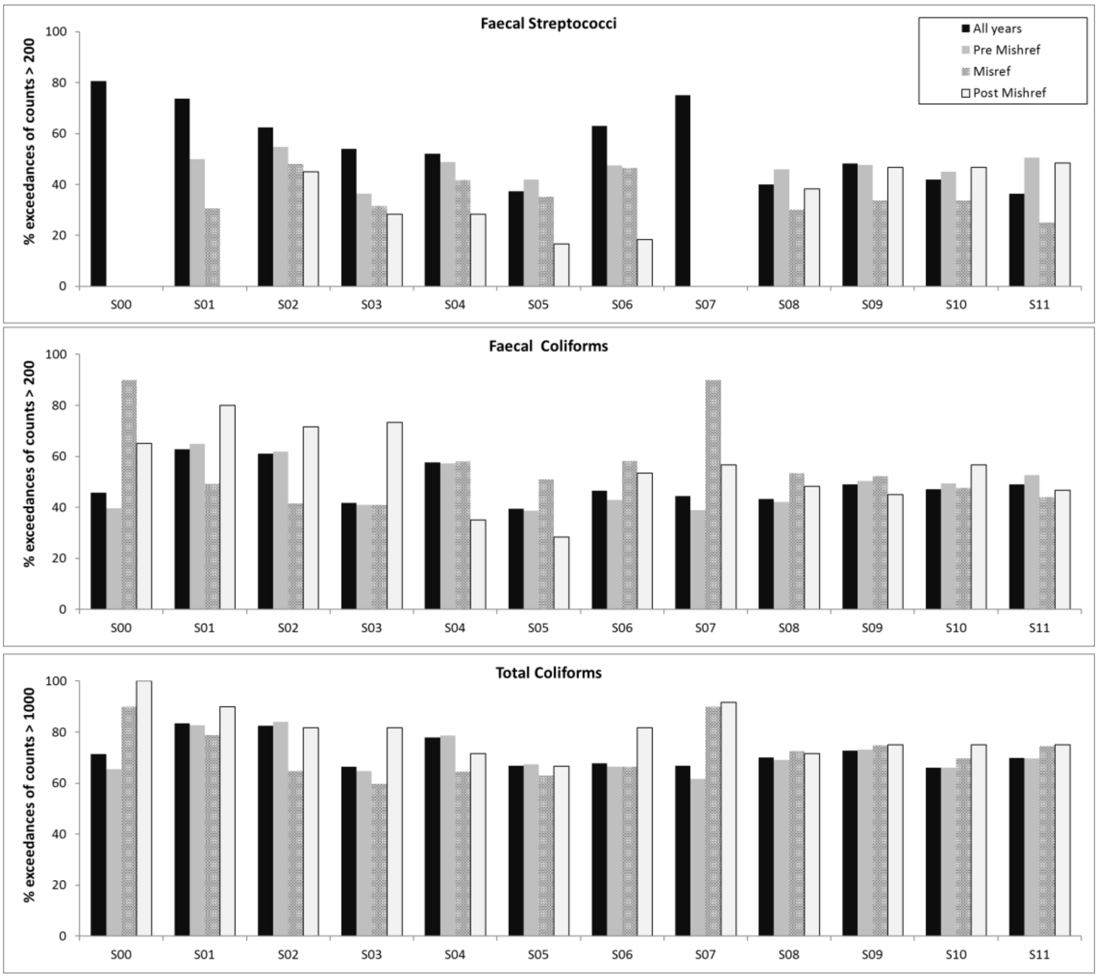


Figure 5-3: Exceedances (expressed as a percentage) of faecal streptococci as assessed against current EPA guidelines (EPA, 2001) Thresholds for faecal streptococci are also set against the mandatory guidelines for the European Union Bathing Water Directive (76/160/EEU). The percentage exceedances are calculated from the number of data points, collected monthly between 1988 to 2015, that have exceeded either a threshold for poor water quality for faecal streptococci (counts/100ml > 200), faecal coliforms (counts/100ml >200) and total coliforms (counts/100ml >1000).

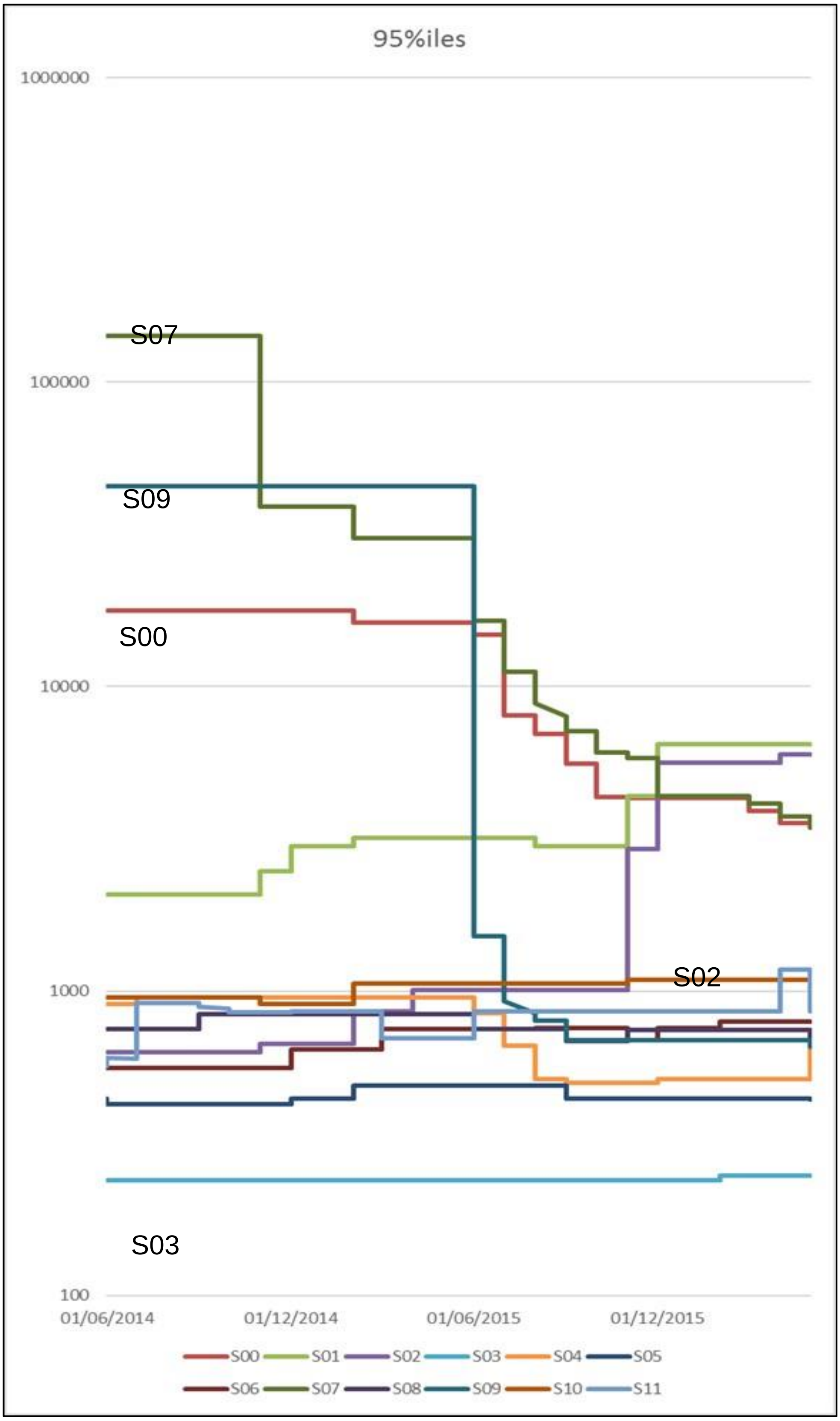
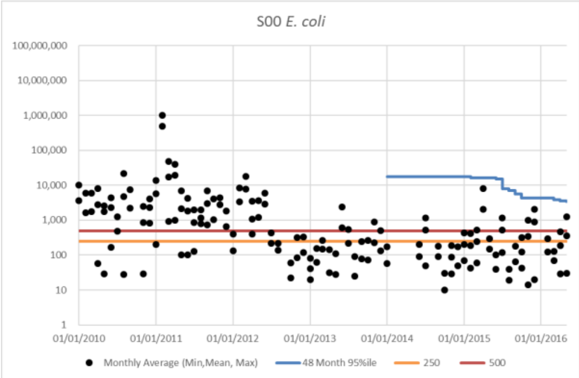
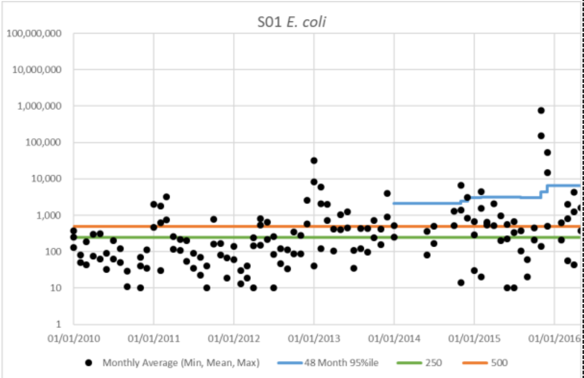
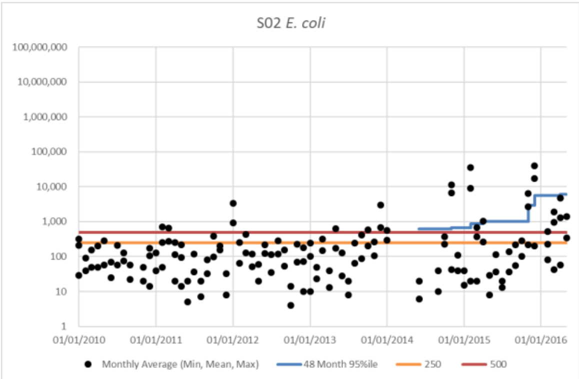
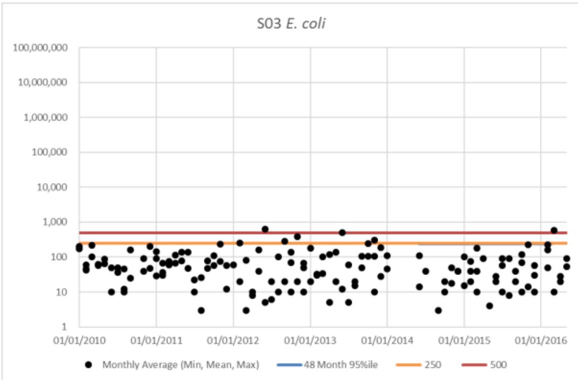


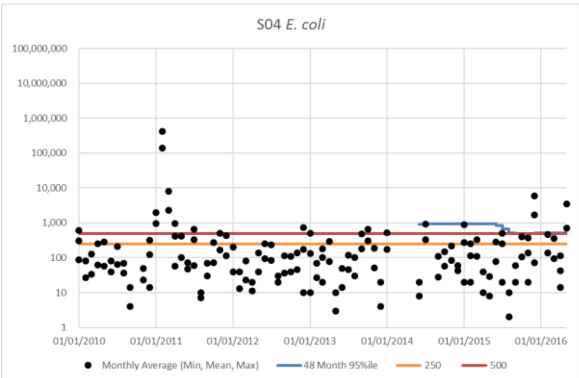
Figure 5-4: Rolling 48 month 95th percentiles of *E. coli* data by site as an indication of variability.

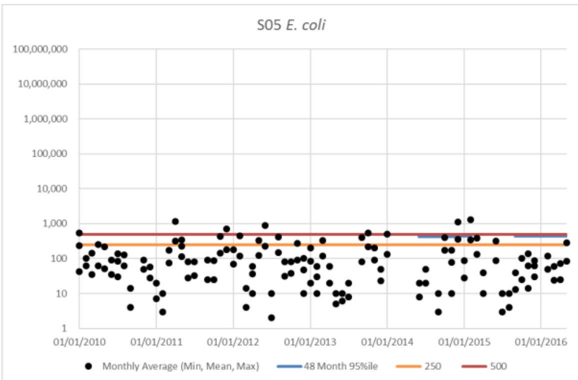

S00 *E. coli*
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
Monthly Average (Min,Mean, Max)
48 Month 95%ile
250
500


S01 *E. coli*
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
Monthly Average (Min, Mean, Max)
48 Month 95%ile
250
500


S02 *E. coli*
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
Monthly Average (Min, Mean, Max)
48 Month 95%ile
250
500


S03 *E. coli*
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
Monthly Average (Min, Mean, Max)
48 Month 95%ile
250
500


S04 *E. coli*
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
Monthly Average (Min, Mean, Max)
48 Month 95%ile
250
500


S05 *E. coli*
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
01/01/2010
01/01/2011
01/01/2012
01/01/2013
01/01/2014
01/01/2015
01/01/2016
Monthly Average (Min, Mean, Max)
48 Month 95%ile
250
500

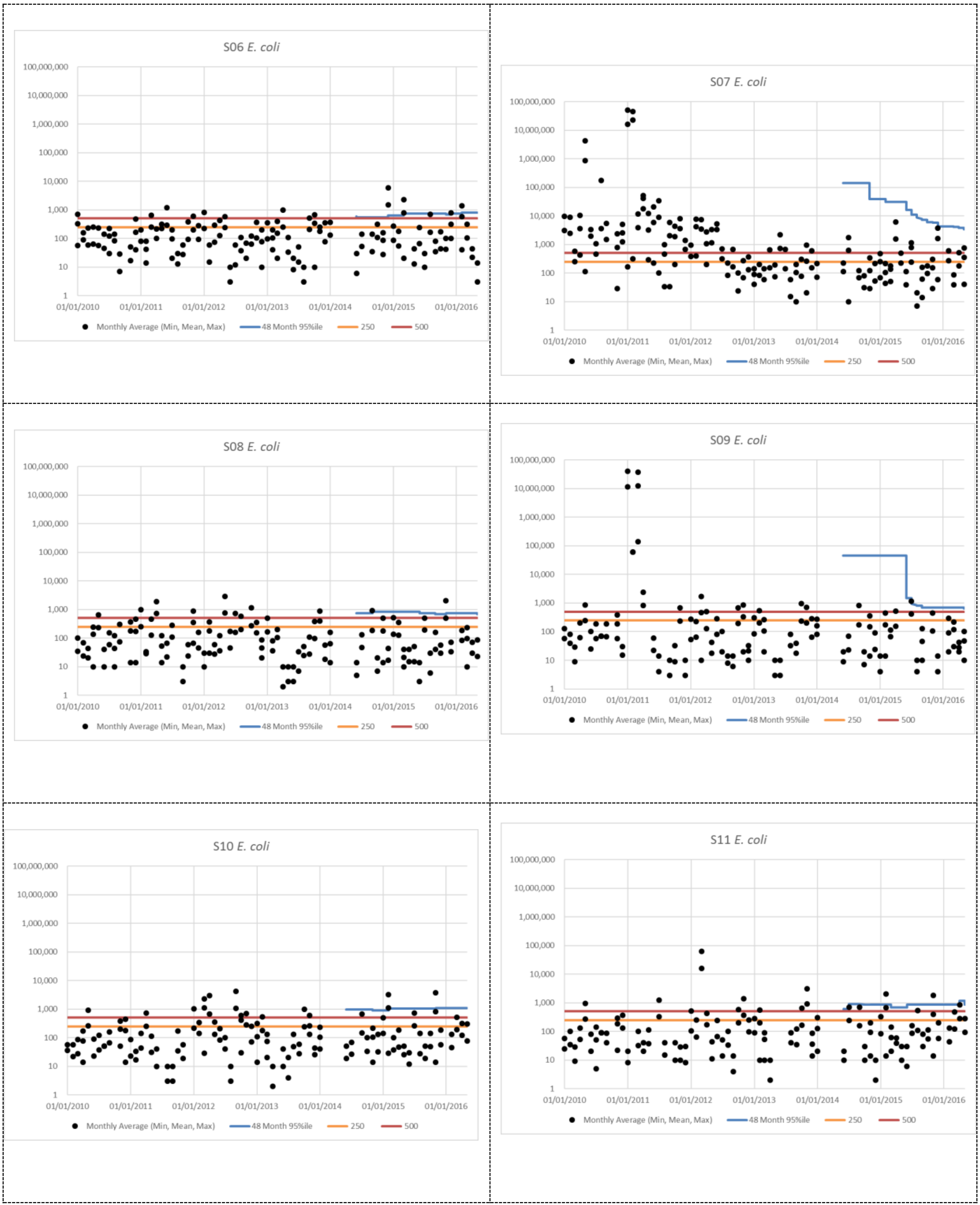


Figure 5-5: Monthly average values for *E. coli* counts reported as a minimum, mean and maximum value for each S site. Additionally, the rolling 48-month (equivalent to four years' data) 95-percentiles of the E. coli data (log 10) are shown as a blue line. Thresholds of 250cfu/100ml and 500 cfu/100ml are also provided as yellow and red lines.

5.6.1.3 Assessment approach and findings

A comparison of the number of times the monthly maximum values of *E.coli* have exceeding EU bathing water 'excellent' threshold level of 250 *E. coli* 100 ml and "good" threshold of 500 *E.coli*/100ml between 2010 and 2016 is given in **Error! Reference source not found.**. Frequency of the assessment outcomes is presented as counts and a percentage frequency based on a total of 82 samples over 6 years.

EPA microbial monitoring data were compared against Revised Bathing water Directive (rBWD) thresholds for Faecal Streptococci and *E.coli.* Values are calculated as annual measurements of 80th, 90^{th} and 95^{th} percentile of samples meeting a required threshold. Both mean and maximum measures failed compliance guidelines for every site (below excellent) and four sites (S00, S01, S02, S07) failed against imperative guidelines (below good). The rBWD provide a useful guide to an assessment of microbial water quality based on accepted international standards and show that the quality of water is impacted significantly by sewage run-off.

Reviewing this historic data set highlights the widespread microbial water quality failures across a number of sites around the coastline of Kuwait. Sites S00 and S07 stand out as due to continued breaches of microbial thresholds. During the Mishref sewage crisis, large volumes of untreated sewage entered the sea from a number of outfalls. It is interesting to note that for all sites, with the exception of S00 and S07 during and after the Mishref crisis, exceedances for faecal coliforms for pre (mean - 48.4% +/- 2.7 SE), during (mean – 49.6% +/- 3.6 SE), and post (mean - 55.5% +/- 4.2 SE) Mishref, increased only slightly during and after the Mishref crisis (Figure 5-3). The mean exceedance for faecal streptococci across all sites (omitting S00 and S07) slightly increased from pre - Mishref (mean – 46.8% +/- 1.8 SE), during (mean - 35.6% +/- 5.9 SE) to post Mishref (mean - 31.7% +/- 4.1 SE), indicating a more permanent issue of impacted water quality from sewerage outfalls across the whole monitoring area. Other sites that were directly impacted by releases of sewage related to the Mishref crisis (S04, S05 and S06) did not reflect the higher percentage exceedances associated with S07 and S00 during the period of the crisis. This is thought to be associated with the direct management action, which included dosing the raw sewage with hypochlorite during the period of the crisis. Overall, exceedances of thresholds directly associated with sewage contamination can be seen as a problem that impacts the majority of the coastline close to residential population centres. Anthropogenic pressures, such as those associated with the Mishref crisis are providing additional point sources of contamination into an already contaminated environment.

time period: 2012-2016	(a) Maximum monthly values												
		S00	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11
Guideline compliance													
90% of samples meet the value of 100 Int. enterococci per 100ml, AND at least 80% of samples meet the value of 100 *E.coli* per 100ml.													
Faecel Strep	90th % ile	1740	804	1420	292	498	360	430	1644	324	524	404	352
E. coli	80th % ile	1172.6	2492	968	440	484	374.8	500	1128.2	500	491.4	664	584
Imperative compliance													
At least 95% of samples meet the value of 2000 *E.coli* per 100ml.													
E. coli	95th % ile	7470	24380	6610	727	908	778	1260	5860	1082	920	3140	1948.7

time period: 2012-2016	(b) Mean monthly values												
		S00	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11
Guideline compliance													
90% of samples meet the value of 100 Int. enterococci per 100ml, AND at least 80% of samples meet the value of 100 *E.coli* per 100ml.													
Faecel Strep	90th % ile	896.4	372	516	106.4	177.2	110	143.4	844	120	160	149.4	105
E. coli	80th % ile	488.4	784	339.4	173.6	137.8	120	174.4	573.4	161.6	158.8	237.6	169
Imperative compliance													
At least 95% of samples meet the value of 2000 *E.coli* per 100ml.													
E. coli	95th % ile	2627.3	6330.1	7080.6	390.9	326.1	223.5	508.9	2790	354.2	307.3	994.1	597.3

Table 5-5: EPA microbial monitoring data compared against Revised Bathing water Directive thresholds for Faecal Streptocci and *E.coli*. Values are calculated as the 4 year rolling mean of the measurements of the 80th, 90th and 95th percentile value of samples meeting a required threshold. Both the maximum value (a) and the mean values (b) measures failed compliance guidelines for every site (below excellent) and S00, S01, S02 and S07 failing imperative compliance.

5.6.1.4 Conclusions

Applying European Union revised Bathing Water Directive (rBWD) assessment on the EPA monitoring data shows clearly that all sites have some degree of contamination, and no site is meeting the compliance guidelines (Table 5-5) and four sites (S00, S01, S02, S07) are not meeting the imperative guidelines. Noncompliance with the imperative guidelines would typically result in beach closures, however, additional monitoring data would need to be applied for a full rBWD assessment to be carried out. However, we can take from these initial results that there are chronic contamination issues in the coastal waters and urgent action is required to address this ongoing issue.

It should be a priority to report and disseminate these important findings to EPA senior management, and where appropriate the general public (e.g. via public advisory notice boards at sampling location close to recreational beaches), who may be exposed to the sewage through recreational activities, such as bathing and jet skiing. It is recommended that the EPA consider undertaking annual microbial assessments that would allow them to easily classify each coastal area monitored, applying regional or international standards in a similar way as used by the EU Bathing Water Directive.

This assessment also highlighted the urgent need for the EPA to develop a system for collating, and regularly assessing, the microbial water quality data it currently collects. Future recommendations would be that the analysis of non-summarised results is undertaken to evidence changes in recreational water quality over time and provided a better assessment of trend and statistically significant differences in results between sites, periods of monitoring for individual sites. Information on censored data would also facilitate further assessment of the data. Time of sampling should be appended to future data to allow correlation of results with environmental variables such as tides. It will be appropriate to review the particular indicators monitored in terms of current relevance of each test organism and overall numbers of parameters monitored and sampling frequency for a given resource to provide an efficient, fit for purpose programme, moving into the future. Information to be derived from future Kuwaiti coastal water characterisation studies and international developments in best-practise for monitoring recreational waters should also inform future state of the seas reporting.

5.6.2 Food Health: Contaminants in seafood

5.6.2.1 Background

Seafood (that is finfish (vertebrates) and shellfish (invertebrates)) represents an important source of protein as aquatic animals contain a high level of protein (17-20%), with an amino-acid profile like that of meat from land animals. The consumption of seafood provides several health attributes due in large part to the presence of long-chain omega-3 polyunsaturated fatty acids. Fish, however, contain other nutrients (e.g. protein, selenium, iodine, vitamin D, choline, and taurine) that may also contribute to the health benefits of fish. Counter to the benefits of fish consumption, sources of fish taken from locations that are contaminated may also represent a toxicological risk. To ensure that the benefits of seafood consumption far outweigh any concerns regarding environmental contamination it is important to establish or adopt appropriate quality standards for potential contaminants of concern and to set management targets to reduce the levels of contaminants in each dietary source and/or manage its availability and level of consumption.

Establishing suitable monitoring programmes to measure key groups of contaminants in seafood is an essential part of any strategy to manage their presence and level and to ensure high quality is achieved or maintained. As marine organisms accumulate contaminants either directly or indirectly through the water and sediment the presence and concentration of contaminants in seafood is directly linked to the management of pollution sources and inputs. Although contaminants may accumulate and magnify in fish and those that are higher in the food chain the presence of contaminants exceeding levels of concern in seafood indicates that at least in some localised marine areas chemical quality standards have been failed.

Managing the marine environment to ensure low contaminant levels in locally caught seafood is therefore important to Kuwait to maintain its own traditional sources of seafood which contribute to a healthy diet, the local economy and demonstrate good stewardship of the resource.

The main evidence of chemical contamination in locally caught seafood in Kuwait is derived from the scientific literature, but includes reports from the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), US Environmental Protection Agency and European Food Safety Authority. A survey conducted as part of a Doctoral thesis on mercury intake from seafood and risk to the Kuwait population is also referenced. The data sourced in these references was primarily related to the Kuwaiti consumption of fish and to contaminant concentrations present in locally sourced seafood. However, some reference is also made for comparative purposes to similar data collected from other parts of the Arabian Gulf.

5.6.2.2 Current State of knowledge:Kuwait

Fish provide an important source of protein, minerals, vitamins, and trace elements to the diet in Kuwait. Consumption of fish therefore offers many dietary benefits. Dependent upon the presence and concentration in fish tissue of contaminants derived from the aquatic environment, consumption of fish may also represent a degree of risk. Health benefits and risks from consumption of fish vary per species consumed, size, its origin, the amount consumed and the group of the consumers (FAO, 2011). The coastal status of Kuwait means that fish consumption forms an important component of diet with some early studies indicating average consumption of 70 – 80 g of fish per head per day (Al-Yakoob et al., 1995). Studies focussing on high consumption groups, specifically fishers have quoted a value of up to 250 g of fish /per meal consumed (Majed and Preston, 2000). A more recent study in 2011 (for which surveys were conducted in 2007) reported a range of fish consumption values for different groups in the Kuwaiti population. Consumption rates for the above studies are summarised in Figure 5-6.

Figure 5-6: Mean per capita consumption rates of fish and shellfish determined in dietary surveys for different groups within the Kuwaiti population

Food type	Population group	Mean per capita Consumption rate g/day	Reference
Fish	Total (3626 responses)	35	2011 Mey-Akashah
Fish	All Men (Men 37-92)	49 (59)	2011 Mey-Akashah
Fish	All Women (Women 32-82)	25 (32)	2011 Mey-Akashah
Fish	Fishermen	250 (per meal)	2000 Majed and Preston
Fish	Average	69.7 g/day	Al Yakoob et al., 1995

For the Kuwaiti population the consumption rate values for fish provide indicative figures for use in estimating potential uptake of contaminants that may be present in seafood. Using these consumption figures any potential concerns regarding the quality of seafood may be determined based on the most current contaminant data for seafood harvested from the marine environment of Kuwait and for seafood available through local markets.

Acceptable levels of contaminants in food including fish (Table 5-8) have been determined over many years by the Joint Expert Committee on Food Additives (JECFA) which is an international expert scientific committee that is administered jointly by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO).

Contaminant levels in foodstuffs are usually set as Provisional Tolerable Daily Intake (PTDI) or weekly (PTWI) or monthly (PTMI) intake. Whether any given threshold is exceeded is dependent on the level of contaminants in a food source and upon the rate of consumption both of which are influenced by regional factors.

Due to the intrinsic hazardous properties of some chemicals i.e. high toxicity and persistence and other properties such as carcinogenicity they may represent a higher risk when present in the human diet and so maximum values are set for them. Under European Legislation Commission Regulation (EC) No 1881/2006 sets maximum limits for certain contaminants in foodstuffs: Substances with maximum levels set for fishery products are the metals, lead, cadmium, mercury (Table 5-6, Table 5-7,

Table **5-8**) and organic chemicals dioxins or dioxin-like polychlorinated biphenyls (Table 5-9) and polycyclic aromatic hydrocarbons (PAHs) (Table 5-10).

Table 5-6: WHO/JECFA advisory limits for tolerable intake for various contaminants of food

Substance	Recommended limits
methylmercury	PTWI of 1.6µg/kg bodyweight per week
Dioxins and dioxin-like PCBs	COT[3] set tolerable intake (TDI) -2 pg WHO-TEQ[4]/kg bw per day (2001)
Cadmium:	PTMI: 25 µg/kg bw/month
Cadmium:	PTWI 7 µg/kg
Lead	25 µg/kg bw/week
Mercury (inorganic)	PTWI: 4 µg/kg bw
Tin:	PTWI 14,000 µg/kg bw
Copper:	200 µg/kg bw/day
Iron	PMTDI: 800 µg/kg bw/d,
Zinc:	PMTDI 300-1000 µg/kg bw/d
PAH	Mean: 0.004 µg/kg bw per day; high: 0.01 µg/kg bw per day (estimates for benzo[a]pyrene as a marker for polycyclic aromatic hydrocarbons (PAHs))

[3] COT is The Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment and is an independent scientific committee that provides advice to the UK Food Standards Agency
[4] TEQ – Toxic Equivalents – the potency of dioxins is expressed relative to that of a toxicologically well-characterised dioxin 2,3,7,8-tetrachlorodibenzo-p-dioxin

Table 5-7: Maximum limits in fishery products set under EC 1881/2006 for lead

Foodstuff	Maximum level mg/kg wet wt
Muscle meat fish	**0.3**
Crustaceans: muscle meat from appendages and abdomen (excluding cephalothorax of crustaceans). In case of crabs and crab-like crustaceans (*Brachyura and Anomura*) muscle meat from appendages.	**0.5**
Bivalve molluscs	**1.5**

Table 5-8: Maximum limits in fishery products set under EC 1881/2006 for cadmium

Reference	Foodstuff	Maximum level mg/kg wet wt
3.2.12	Muscle meat of fish[5,6], excluding species listed in points 3.2.13, 3.2.14 and 3.2.15	**0.05**
3.1.13	Muscle meat of the following fish[5;6] mackerel (Scomber species), tuna (*Thunnus* species, *Katsuwonus pelamis*, *Euthynnus* species), bichique (*Sicyopterus lagocephalus*)	**0.1**
3.2.14	Muscle meat of the following fish[1,2]: bullet tuna (*Auxis* species)	**0.15**
3.2.15	Muscle meat of the following fish[5,6]: anchovy (Engraulis species) swordfish (*Xiphias gladius*) sardine (*Sardina pilchardus)*	**0.25**
3.2.16	Crustaceans: muscle meat from appendages and abdomen (excludes cephalothorax of crustaceans). In case of crabs and crab-like crustaceans (Brachyura and Anomura) muscle meat from appendages	**0.5**
3.2.17	Bivalve molluscs	**1.0**

[5] where fish are intended to be eaten whole maximum applies to whole fish,
[6] does not include fish liver

Table 5-9: Maximum limits in fishery products set under EC 1881/2006 for mercury and WHO maximum limit for methyl mercury (1990)

Reference	Foodstuff	Maximum level mg/kg wet wt
3.3.1	Fishery products and muscle meat of fish[1,2], excluding species listed in 3.3.2.	**0.5**
3.3.1	The maximum level for crustaceans applies to muscle meat from appendages and abdomen (excludes cephalothorax of crustaceans). In case of crabs and crab-like crustaceans (Brachyura and Anomura) it applies to muscle meat from appendages.	**0.5**
3.3.2	Muscle meat of the following fish[1,2]: anglerfish (*Lophius* species) Atlantic catfish (*Anarhichas lupus*) bonito (*Sarda sarda*) eel (*Anguilla* species) emperor, orange roughy, rosy soldierfish (Hoplostethus species) grenadier (*Coryphaenoides rupestris*) halibut (*Hippoglossus hippoglossus*) kingklip (*Genypterus capensis*) marlin (*Makaira species*) megrim (*Lepidorhombus* species) mullet (*Mullus* species) pink cusk eel (*Genypterus blacodes*) pike (*Esox lucius*) plain bonito (*Orcynopsis unicolor*) poor cod (*Tricopterus minutes*) Portuguese dogfish (*Centroscymnus coelolepis*) rays (*Raja* species) redfish (*Sebastes marinus, S. mentella, S. viviparus*) sail fish (*Istiophorus platypterus*) scabbard fish (*Lepidopus caudatus, Aphanopus carbo*) seabream, pandora (*Pagellus* species) shark (all species) snake mackerel or butterfish (*Lepidocybium flavobrunneum, Ruvettus pretiosus, Gempylus serpens*) sturgeon (Acipenser species) swordfish (*Xiphias gladius*) tuna (*Thunnus* species, *Euthynnus* species, *Katsuwonus pelamis*)	**1.0**
WHO 1990	Fish	**0.3**

Table 5-10:Maximum limits in fishery products set under EC 1881/2006 for dioxins and dioxin-like PCBs

Foodstuff	Sum of dioxins (WHO-PCDD/ F-TEQ) (32)	Sum of dioxins and dioxin-like PCBS (WHO-PCDD/F-PCB-TEQ) (32)	Sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180 (ICES – 6) (32)
Muscle meat of fish and fishery products and products thereof[1], with the exemption of: — wild caught eel — wild caught fresh water fish, except for diadromous fish species caught in fresh water — fish liver and derived products — marine oils The maximum level for crustaceans applies to muscle meat from appendages and abdomen (excludes cephalothorax of crustaceans). In case of crabs and crab-like crustaceans (Brachyura and Anomura) it applies to muscle meat from appendages.	3.5 pg/g wet wt	6.5 pg/g wet wt	75 ng/g wet wt
Muscle meat of wild caught eel (*Anguilla anguilla*) and products thereof	3.5 pg/g wet wt	10 pg/g wet wt	300 ng/g wet wt
Fish liver and derived products thereof except for marine oils referred to in point below	-	20 pg/g wet wt	200 ng/g wet wt
Marine oils (fish body oil, fish liver oil and oils of other marine organisms intended for human consumption)	1.75 pg/g fat	6.0 pg/g fat	200 ng/g fat

Table 5-11: Maximum limits in fishery products set under EC 1881/2006 for PAHs

PAH	Foodstuff	Maximum level ug/kg	PAH
6.1	Benzo(a)pyrene,benz(a)anthracene, benzo(b)fluoranthene and chrysene.	Benzo(a)pyrene	benzo(a)- pyrene+ benz(a)anthracene+benzo(b)fluoranthene and chrysene[7]
6.1.6	bivalve molluscs (fresh, chilled or frozen)	**5.0**	**30.0**

International and National data on tolerable contaminant intake levels in fish and fishery products and associated maximum levels described above (Table 5-6) provide an initial point of reference for comparison to available contaminant data for fish and shellfish from the Kuwait marine environment. Where data have been gathered to assess dietary intake of contaminants by the Kuwaiti population this is likely to include fish and shellfish from the wider region as well as international sources. Dietary sources of contaminants will therefore also be present in fishery products not from Kuwait territorial waters and may also originate from other dietary or environmental sources all of which can influence decisions on acceptable contaminant levels in locally sourced fish.

Data on metal concentrations recorded for fish and shellfish from the Kuwait marine environment are shown in Table 5-12. In a survey of a point-source metal contamination from desalination/power plant wastewater discharge in Kuwait Bay during 1999-2000 total mercury tissue concentrations in the non-commercial bivalve *Aminantis umbonella* collected at potentially contaminated sites in Kuwait Bay were over ten times higher than the EC maximum (Tarique et al., 2013) and reference site values were on the EC limit. Other earlier studies for which fish were collected from between Uuha and the Faylakah Islands showed elevated total and methyl mercury tissue concentrations for muscle tissue that were above EC maximum limits for one of the seven species assessed the Hamoor, *Epinephelus coioides* (Majed and Preston, 2000). Contaminant data for muscle tissue samples collected from smooth tooth black tip shark *Carcharhinus leiodon* caught as bycatch during 2011, most probably from locations in northern Kuwait waters, also showed total mercury concentrations that exceed EC maximum limits (i.e. mean 4.37 range 1.1-9.5 mg kg^{-1} wet weight n=7). However, measured lead and cadmium concentrations were below EC

[7] Lower bound concentrations are calculated on the assumption that all the values of the four substances below the limit of quantification are zero.

maximum limits. Recent studies in other parts of the Arabian Gulf on another shark species, the whitecheek shark, *Carcharhinus dussumieri*, do not show any exceedance of maximum limits for metals including mercury (Adel et al., 2016). Similarly, more recent studies for parts of the Northern Gulf (Mosa Bay) show total mercury in tissue of five commercial species of fish, *Liza abu*, 1.172 µg g^{-1} *Sparidentex hasta*, 0.445 µg g^{-1} for *Acanthopagrus latus*, 0.390 µg g^{-1} for *Thunnus tonggol*, and 0.360 µg g^{-1} for *Fenneropenaeus indicus*) were below the total mercury WHO guideline of 0.5 mg kg^{-1} wet weight (Mortazavi and Sharifian, 2011). Contaminant data from some early studies also show levels of lead that are likely to exceed EC 1881/2006 limits (i.e. 0.3 mg lead kg^{-1} wet weight). Data reported indicate that for muscle tissue samples for three of the species sampled near the Al-Ahmadi area, *Valamugil schelli*, *Triachanthus biaculatus* and *Sphyraena obtusata* lead tissue levels expressed as dry weights are likely to exceed the equivalent wet weight standard (Bu-Olayan and Subrahmanyam, 1996). However, for the same study for samples collected from the Kuwait City area within Kuwait bay showed no muscle tissue metal concentrations including lead that exceeded EC limits. Relatively few studies report cadmium tissue concentrations for Kuwait waters. However, samples of a non-commercial bivalve *Aminantis umbonella* collected in Kuwait Bay between 1999-2000 had cadmium concentrations that were almost twice the EC maximum (Tarique et al., 2013). A study in 2014 of four locations, one in Kuwait Bay and four along the cities Eastern coastline measured metal concentrations in muscle tissue of Giant sea catfish (*Arius thalassinus*) and confirmed that concentrations of mercury, lead and cadmium were below EC maximum limits (Al-Zaidan et al., 2014). Samples of Rock oyster *Saccosterea cucullata* and Venus clams *Circentia callipyga* collected from coastal sites during the same survey but in both 2013 and 2014 also showed tissue concentrations for the same metals that were below EC maximum limits (KEPA, Mishref data). For the studies of metal contamination in fish tissue described above several key commercial species typically had the highest measured levels and these are shown in Table 5-13.

Various petroleum hydrocarbons including aliphatic and polycyclic aromatic hydrocarbons (PAHs), have been measured in biota from the Kuwait marine environment and the tissue concentration data for various species are shown in Table 5-14. The studies reported in Table 5-14 indicate that there is some potential for the concentration of the four PAHs identified in EC Commission Regulation No 1881/2006 (i.e. the sum of benzo[a]pyrene, benz[a]anthracene, benzo[b]fluoranthene and chrysene) in commercial fish and shellfish to exceed acceptable dietary levels. It should be noted that the limits in the guidance relate to smoked fish and seafood products rather than PAHs accumulated from the environment but are used here as a point of reference. It is notable that several species in which the sum of the four PAH concentrations exceed EC 1881/2006 are sampled from other areas of the Arabian Gulf. Other studies sampling fish from the Kuwait marine environment from Kuwait Bay and Auha in winter and summer periods showed that for some species i.e. the tonguesole *Liza klunzinguri*, significantly higher tissue concentrations of PAHs are present during the summer period (Beg et al., 2009). However, these latter studies did not show

PAH levels of concern for dietary intake during summer or winter in any of the species sampled.

Polychlorinated dibenzo para dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are a group of structurally and chemically related compounds commonly referred to as dioxins. These organic compounds are persistent and toxic and therefore represent a threat both to the environment and potentially to the food chain. Some polychlorinated biphenyls (PCBs) which have similar toxic properties to PCDDs are also included under the term "dioxins". Some 419 types of dioxin-related compounds have been identified but only about 30 of these are considered to have significant toxicity, with 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) being the most toxic. Because many dioxin-like chemicals may be present in each tissue sample the potency of the mixture is usually evaluated using toxic equivalents (TEQ). In this approach each dioxin-like chemical is judged in terms of toxicological equivalence to TCDD and the individual TEQ values are summed to derive an overall equivalence for a tissue sample. Based on these TEQ values WHO (2005) has set maximum limits for different foodstuffs including fish and fish products. Maximum values for TEQ are set (WHO, 2005) for the sum of polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), and separately for the sum of dioxins, furans and dioxin-like polychlorinated biphenyls (PCBs), defined as the sum of PCDDs, PCDFs and PCBs. A third maximum value is set for the sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180 referred to as the ICES-6. A survey of foods including fish that are available in Kuwaiti Supermarkets (Husain et al., 2014) used a bioassay technique (DR-Calux) to measure TCDD toxic equivalent values in food samples. The data for 18 unidentified fish samples indicates bioassay equivalent (BE) toxic equivalents of 0.1-0.9 pg DR-CALUX-BEQ g^{-1} wet weight against a maximum limit of 6.5 (WHO-TEQ g^{-1} fresh weight in fish, 2005). A study in 2014 (Al-Zaidan et al., 2015) sampled Giant sea catfish (*Arius thalassinus*) from four locations, one in Kuwait Bay and four along the cities Eastern coastline. A series of analyses of tissue samples were conducted including the measurement of PCBs in liver tissue. The summed values of the ICES-6 PCBs are used to define a maximum limit of 200 ng g^{-1} wet weight of fish liver for human consumption (WHO, 2005). Liver samples from the four sample sites at which liver samples were analysed were below the WHO maximum (range 53.5 -114.3 ng g^{-1} wet weight liver). Samples of rock oyster Saccosterea cucullata and Venus clams Circentia callipyga were also collected from coastal sites during the same survey but in both 2013 and 2014 and showed tissue concentrations of the ICES-6 PCBs that were around a third or less of the EC maximum limits (KEPA, Mishref data). During a study conducted in 2005 de Mora et al., (2010) also measured PCBs in the flesh of Venus clam collected from three sites around the coast of Kuwait, Doha bay, Al Bida'a and Khiran. During this earlier period samples from all sites were 2-3 orders of magnitude below the maximum limit of 75 ng g^{-1} wet weight for ICES-6 PCBs for fishery products. Tissue samples of the Spangled Emperor fish or Hamoor *Epinephelus coioides* also sampled during this survey were similarly very low and hence below this maximum limit of 75 ng g^{-1} for all three sample sites. Brominated diphenyl ethers were also measured in

Hamoor tissue in this latter study and were found to be very low - ranging from below detection to 4.8 ng g^{-1} in liver tissue

Table 5-12: Measured concentrations for a range of metals in fish and shellfish sampled in Kuwait Bay and wider Arabian Gulf (values underlined and in bold exceed either maximum limits or are at a level that is likely to exceed WHO/JECFA advisory limits if consumed

Substance	Species	Tissue concentration	Location	Reference
Cr, Cu, Fe, Ni, Pb, V, Zn (µg/g) (dry weight)	Range fish species Caught in fish traps	Cr (21.9-60.3); Cu (16.1 96.2) Fe (28.5-76.7); Ni (0.5-20.4); Pb(0.1-1.2);V(0-4.6); Zn(7.8-81.3)	Kuwait City area,	Bu-Olayan and Subrahmanyam 1996
Cr, Cu, Fe, Ni, Pb, V, Zn(µg/g) (dry weight)	Range fish species Caught in fish traps	Cr (6.2-68.5); Cu (6.4-82.6) Fe (5.32-113.6); Ni (0.6-14.8); **Pb** (0.2-**14.6**); V (0-15.6); Zn (7.6-67.4)	Al-Ahmadi area.	Bu-Olayan and Subrahmanyam 1996
Pb, Ni, V ug/g (1995-96) (dry weight)	7 species fish, 2 species shrimp	Fish Pb(0.08-0.16);Ni(0.15-0.69);V(0.48-1.02)	Local fish market - Nov, 95 to June 96	Bu-Olayan, Al-Yakoob, 1998
Total Hg and MeHg (µg/g) dry and wet weight (ratio 0.25)	7 fish species edible muscle	(factor 0.25 dry to wet weight) 0.002-**0.98** total Hg and <0.00025- **0.82** **MeHg** wet weight	between Uuha and Faylakah Islands.	Majed and Preston, 2000
Cd, Cr, Cu, Hg, Ni, Pb, V and Zn (wet weight)	Bivalve *Aminantis umbonella* Non commercial	**Cd** (0.4-**4.9** mg/kg); Cr (3.0-6,7); **Cu** (2.6-**6.4**); **Hg** (0.5-**6.5** mg/kg); Ni(2.6-6.2); Pb(0.3-**2**);V(0.3-0.7); Zn(83-102)	Kuwait Bay	Tarique *et al*., 2013
Ni, Cu, Zn,As, Cd, Pb, Se, Mn, Fe, Hg (mg/kg) wet wt (muscle)	Giant sea catfish (*Arius thalassinus*)	Cr (0.01-0.88); Ni (<0.012-0.45); Cu (7.1-32); As (13-21); Cd (<0.004); Pb(<0.007-<0.017);Se(0.33-0.41); Mn (0.13-0.22); Fe(4.7-8.1); Hg(0.13-0.29)	5 stations located within Kuwait Bay	Al-Zaidan *et al*, 2015

Table 5-13: Measured concentrations for a range of metals in commercial fish species sampled in Kuwait Bay and wider Arabian Gulf (values underlined and in bold exceed either maximum limits or are at a level that is likely to exceed WHO/JECFA advisory limits if consumed

Substance	Species	Tissue concentration	Location	Reference
Pb (µg/g) (dry weight)	*Gastrophysus lunaris* (Fugul) highest lead	1.2 (µg/g) unlikely an issue	Kuwait City area,	Bu-Olayan and Subrahmanyam 1996
Pb (µg/g) (dry weight)	*Valamugil schelli* (Maid) *Triachanthus Biaculeatus* (Chlaib-el-dhow) *Sphyraena obtusata* (Jidd)	2.8 µg/g 5.3 µg/g 14.6 µg/g	Al-Ahmadi area.	Bu-Olayan and Subrahmanyam 1996
Pb, Ni, V (µg/g) (1995-96) (dry weight)	Zobaidy (highest value for Pb of 6 fish species) Nakroor (highest value for Ni and V of 6 fish species) Shrimp two species (*Penaeus semisulcatus*) (*Metapenaeous affinis*.)	Pb (0.16) Ni (0.31) V (1.48) Ni (0.68) V (0.69)	procured from local fish market during Nov, 95 and Jun,96	Bu-Olayana, Al-Yakoob, 1998
Total Hg and MeHg (µg/g) dry and wet weight (ratio 0.25)	Hamoor (*Epinephelus coioides*) Khubbat (*Scoberomorus guttas*)	Highest values for these species for T-Hg and MeHg both exceeded standard values	between Uuha and Faylakah Islands.	Majed and Preston, 2000

Table 5-14: Measured concentrations for a range of Total Petroleum hydrocarbons (TPHs) icommercial fish species sampled in Kuwait Bay and wider Arabian Gulf (values underlined and in bold exceed either maximum limits or are at a level that is likely to exceed WHO/JECFA advisory limits if consumed (an approximate factor of 0.25 dry to wet weight has been assumed)

Substance	Species	Tissue concentration	Location	Reference
PAHs seafood 14 compounds ng/g dry weight	7 fish two species shrimp	Highest total 4 PAHs (EC 2006) 24.7 and highest BaP maximum 5.33 both in one sample of Nuwaiby *otolithes argentus*	Local fish market	Saeed *et al*., 1995
Total PAH[8] ng/g dry weight	Silver Pomfret *pampus argentus* Jinga shrimp *meta penaeus affinis* other Kuwait and Gulf species	**141.9 4-PAH (EC 2006)** **138.5 4-PAH** **Range 31.9-89.8 4-PAH** **Range 39.6 -247 4-PAH**	Kuwaiti fish markets	Alomirah *et al*., 2009
TPH and µg/g parent PAH[2] ng/g dry weight	Venus clam (*Circentia callipyga*)	15 TPH; 37 PAH 40 TPH; 88 PAH 20 TPH; 15 PAH (TPH equiv, ROPME oil)	Doha Bay, Al-Bida'a and Khiran,	de Mora *et al*., 2010
TPH and µg/g parent PAH[9] ng/g dry weight	Hamoor (*Epinephelus coioides*)	2.7 TPH; 3.5 Parent PAH 2.3 TPH; 2.9 Parent PAH	Khor Abdullah and Fahaheel	de Mora *et al*., 2010

5.6.2.3 Assessment approach and findings

Data on contaminant concentrations from the tissues of fish and shellfish sampled from Kuwaiti waters can be compared to international standards set for seafood intended for human consumption. Standard values include maximum recommended values in the edible tissue of seafood and recommended time based consumption limits.

[8] Total PAH includes: naphthalene, phenanthrene, benzo[a]anthracene, fluoranthene, pyrene and chrysene other Low and high molecular weight PAHs <0.3 ng/g

[9] Parent PAH includes three to six ring parent polycyclic aromatic hydrocarbons (m/z: 178 (phenanthrene/anthracene), 202, (pyrene/fluoranthene); 228 (benzo[a]anthracene/chrysene); 252 (benzofluoranthenes, benzo[e]-pyrene, benzo[a]pyrene; 276 (indeno[1,2,3-cd]pyrene, benzo[ghi]perylene).

Of the chemicals that have been analysed in seafood, total mercury and methyl mercury have been detected above acceptable maximum concentrations in several early studies. Total mercury concentrations in the non-commercial bivalve *Aminantis umbonella* collected at sites in Kuwait Bay during 1999-2000 were over ten times higher than the EC maximum (Tarique et al., 2013) and reference site values were on the EC limit. Samples of fish tissue collected from different species sampled between 1996 and 1998 also showed elevated total mercury concentrations (Majed and Preston, 2000). However, only one of the seven fish species sampled, the Hamoor (*Epinephelus coiodes*) showed concentrations of both total and methyl mercury that exceeded the EC maximum. Samples from shark a higher predatory species sampled in northern Kuwait waters in April 2011 also showed elevated total mercury above the Commission Regulation (EC) No 1881/2006 maximum. However, more recently tissue samples collected from the Giant catfish (*Arius thalassinus*) from locations within and external to Kuwait Bay had total mercury concentrations that were around a half of the EC maximum. Tissues of Rock oyster and Venus clam collected during the same survey period at coastal sites around Kuwait have very low total mercury concentrations in their tissue around fifty times below the EC maximum (KEPA, Mishref data). For some fish species sampled in 1995 in the Al-Ahmadi area (Bu-Olayan et al., 1996), tissue concentrations of lead exceeded EC maximum levels. However, samples from a local fish market in 1995 and 1996 which included one of the most commonly consumed species showed relatively low concentrations of lead (Bu-Olayan and Yakoob, 1998). For cadmium one of the higher priority metals, there are fewer reported data. Cadmium concentrations in the non-commercial bivalve *Aminantis umbonella* were almost twice the EC maximum in samples collected in Kuwait Bay between 1999-2000 (Tarique et al., 2013). More recent data for the Giant sea catfish *Arius thalassinus* sampled from within Kuwait Bay in April 2014 showed cadmium muscle tissue concentrations an order of magnitude below the EC maximum (Al-Zaidan et al., 2015). Tissues of Rock oyster and Venus clam collected during the same survey period at coastal sites around Kuwait also had very low cadmium concentrations in their tissue and all sample sites had concentrations below the EC maximum (KEPA, Mishref data). Cadmium concentrations in shark sampled in Northern Kuwaiti waters in 2011 were also below EC maximum limits for fish muscle (Moore et al., 2015). Other metals are not regularly monitored and reported but data for copper and zinc are reported for fish sampled near Kuwait City and Al-hamdi areas in 1995 (Bu-Olayan et al., 1996) and for shellfish from Kuwait Bay in 1999-2000 (Tarique et al., 2013) and copper also for fish sampled in Kuwait Bay in 2014 (Al-Zaidan et al., 2015). By comparison to data for the North Sea and Mediterranean (Robinson et al., 2016) the copper and zinc concentrations for shellfish are in the same order of magnitude but have a higher range and the fish data show concentrations of copper an order of magnitude higher and zinc in a similar but higher range. A comparison of tissue concentrations for copper and zinc in shark species between Kuwaiti, Northern Arabian Gulf, and European waters shows similar concentrations of copper and higher concentrations of zinc (Adel et al., 2016). For other contaminants notably PAHs there is some evidence from Kuwait market collected samples in 2005 to suggest that fish tissue may just exceed EC maximum concentrations (Alomirah et al., 2009). Data for fish and shellfish collected in 2005 from the coast of Kuwait, Doha bay, Al Bida'a and Khiran did not show any concentrations that exceeded the maximum limit of 75 ng/g wet weight for ICES-6 PCBs Mora et al., (2010).

5.6.2.4 Conclusions

Relative to world data and based on the data reviewed, seafood consumption may be considered high to very high amongst the Kuwait population. However, consumption patterns across the population vary and this will influence those groups which are most at risk from eating seafood with higher levels of chemical contaminants. Data indicate localised areas of contamination, and in some cases this is clearly linked to historic industrial discharges, particularly for mercury. The presence of elevated total and methyl mercury concentrations in some higher predator species suggests a potential longer term issue for consumption of high risk species. Recent data suggest that concentrations of mercury, lead and cadmium may be at acceptable levels in several seafood species but there is insufficient data to judge how far these data might be generalised to the most common food species consumed. Copper and zinc concentrations in sampled fish from Kuwait waters are moderately high and the trend for these metals is important to consider as they have many potential diffuse sources. For organic chemicals, PAHs and PCBs recent limited data suggest that they are below levels of concern in fish tissue but wider spatial data, across species and trend data are needed to improve confidence in this judgement. There are few existing data for other chemicals e.g. polybrominated dipheylethers (PBDEs) but these indicate that levels of these may be low. However, in terms of potential for accumulation in the marine foodchain, PBDEs and other chemicals of emerging concern internationally should be considered in terms of their relevance for inclusion in future trend monitoring for Kuwait seafood species.

6 Pollution

6.1 Introduction

Pollution is broadly defined as the introduction of hazardous substances (e.g. chemical contaminants) to the environment leading to adverse change. This can include all human inputs to the marine environment such as chemicals, but also litter and energy in the form of noise and thermal inputs. Hazardous substances can enter the marine environment from both natural sources (in the case of metals and polycyclic aromatic hydrocarbons (PAHs), for example) and as a result of human activities. The main routes through which hazardous substances can enter the marine environment include waterborne discharges to coastal areas (e.g. effluent discharges) and via the atmospheric deposition into the sea. The relative importance of these will vary between substances depending on their individual properties and subsequent behaviour once in the marine environment. The degree and mode of toxicity will vary between hazardous substances, and the risk they pose need to be considered at both an environmental (risk for toxicity to aquatic-dwelling organisms) and human (seafood consumers) health perspective. Although they would be covered by this definition it should be noted that inputs of nutrients are considered separately in the Eutrophication and Harmful Algal Blooms Theme (chapter 8) and aspects of pollution leading to adverse effects on human health (water microbial contamination) are considered separately under the Water Quality for Human Health Theme (chapter 5), therefore this section focuses on the environmental impacts of marine pollution and the risk chemical contamination poses to human health, via the consumption of contaminated seafood.

6.2 Drivers and pressures for environmental pollution

The State of Kuwait has witnessed major economic, social and industrial development following the discovery and exploitation of its vast oil reserves (Al-Abdulghani et al., 2013). Similar to other countries, which comprise the Gulf Co-operative Council (GCC), the rapid expansion of Kuwait's industrial sector has mainly occurred around its coasts (Al-Rifaie et al., 2007; Al-Abdulghani et al., 2013). As a consequence, a variety of pollutants are discharged directly into the marine environment, including petroleum hydrocarbons, trace metals, nutrients (from raw domestic sewage), and contaminated brine from desalination plants, which are essential for freshwater production in the region (Readman et al., 1992; Al-Ghadban et al., 2002; Al-Sarawi et al., 2015). Analysis of sediment and biota have shown the marine environment around Kuwait to be contaminated with a range of aliphatic and polycyclic aromatic hydrocarbons (PAHs) and organochlorinated contaminants (Beg et al., 2009; de Mora et al., 2010; Al-Sarawi et al., 2015). Power generating industries and desalination plants are also known to be point sources of contamination and elevated levels of heavy metals, which in some instances exceeded human consumption safety limits, have been observed in clams (*Amiantis umbonella*) collected from Kuwait Bay (Tarique et al., 2012; Tarique et al., 2013). A large number of industrial outfalls, storm water culverts and earth channels are situated along the coastline of Kuwait and discharge directly into the sea. It is known that these release raw sewage and untreated industrial water to the marine environment (Ghannoum et al., 1991; Al-Ghadban et al., 2002; Bu-Olayan and Thomas, 2014; Saeed et al., 2012; Lyons et al., 2015).

Past events, such as the 1991 Gulf War, have further contributed to environmental pressures associated with rapid industrialization. During this period, it is estimated that 9 - 10.8 million barrels of oil were released into the coastal waters of Kuwait from sabotaged tankers and pipelines at the Al-Ahmadi terminal (Al-Abdali et al., 1996; Readman et al., 1996). As a consequence, the environment was exposed to an array of contaminants, which included petroleum hydrocarbons from burning oil wells and polychlorinated biphenyls (PCBs) and heavy metals from damaged industrial facilities (Massoud et al., 1998; Al-Sarawi et al., 2002). In recent years, environmental disasters, such as the Mishref pumping station breakdown, have also contributed to the degradation of Kuwait's marine environment (Saeed et al., 2012). The Mishref pumping station malfunctioned in August 2009, resulting in the discharge of around 150,000 m^3 day^{-1} of raw sewage directly into the sea for several years. The discharge occurred via three main outfalls at Al-Bidda, Al-Khitabi and Al-Messela, impacting beaches in a number of areas important for tourism and residential housing. Monitoring undertaken by EPA during this period indicated that approximately 20 km of coastline was affected, with water quality and bacterial indicators greater than permitted guidelines (EPA 2001). These impacts are exacerbated by other sources of marine pollution that include atmospheric fallout from dust storms and particulate matter transported from the Shatt Al-Arab river (Al-Ghadban et al., 2002; Al-Ghadban and El-Sammak, 2005). It is also known that natural oil seepage occurs at a number of sub-sea locations and these are also thought to be important point sources of contamination at various locations around the coast (Al-Ghadban et al., 2002).

6.3 Data sources.

A survey conducted by the EPA collected sediments from twenty-nine locations situated within Kuwait Bay (including Sulaibikhat Bay) and along the Gulf coastline towards the Shuaiba Industrial Area (SIA) to the south of the city. Sediments were analysed for PAHs, metals and an array of organohalogen compounds. Samples were collected during 2013/2014 using a hand-held van veen grab deployed from a combination of research vessels provided by the EPA, Kuwait Institute of Scientific Research (KISR) and Public Authority for Agriculture and Fish Resources (PAAFR). Full details of the sampling and analytical methods employed are provided in Annex 6.1. Other data sources include the EPA's own water quality monitoring programme (Figure 6-1) (metals and total petroleum hydrocarbons) along with reports and peer-reviewed publication from a variety of external organisations (e.g. KISR and Kuwait University)

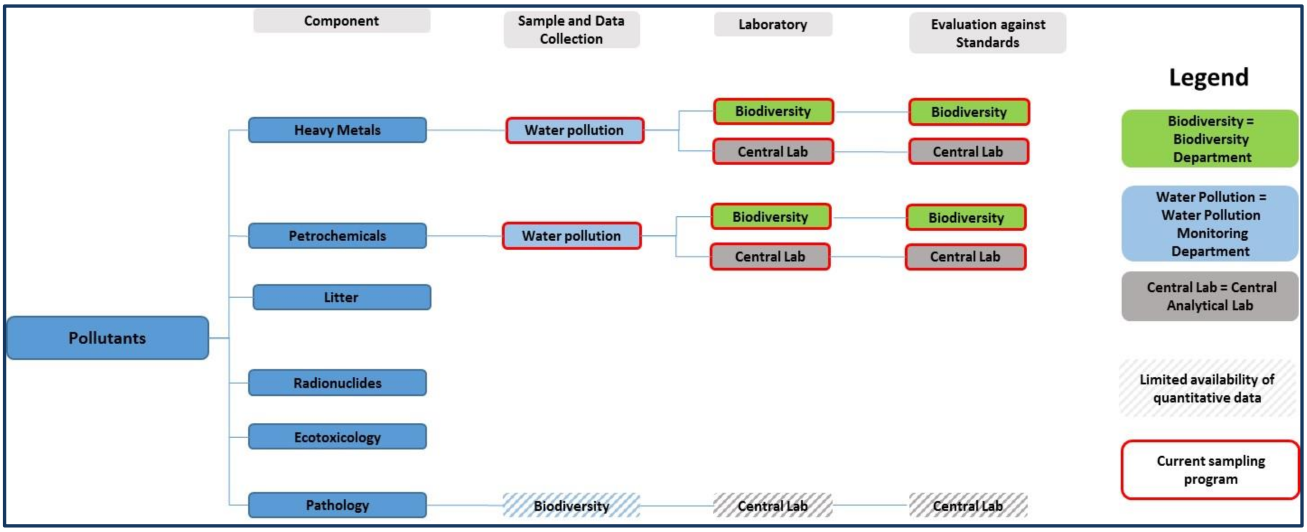


Figure 6-1: Data sources used in SOMER assessment that are available from current Kuwait EPA monitoring programs

6.4 Assessment process for environmental pollution

The main objective for environmental pollution assessment is "marine ecosystem components and processes are not adversely impacted by contaminants" Thus the overall objective is simple, however complex assessment based on measures of different environmental pollution across water, sediment and biota (Figure 6-2).

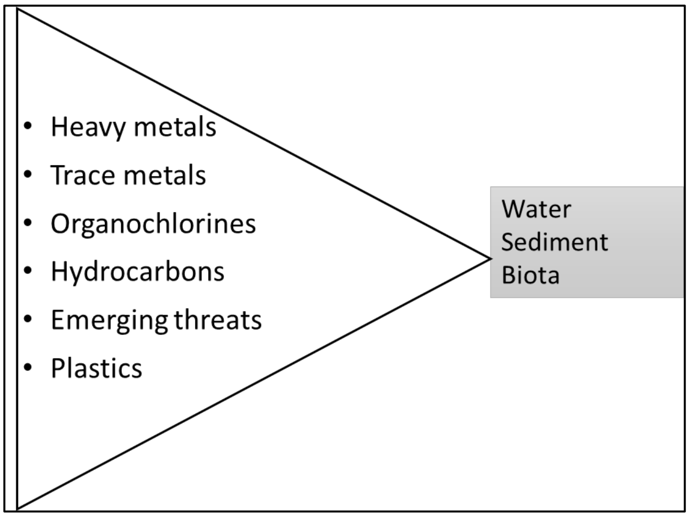


Figure 6-2: List of environmental pollutants across water, sediment and biota.

These objectives are tested against a set of pollutant criteria for water, sediment and biota. Many of the environmental standards for the pollution objectives have not been set for Kuwait marine waters, and in some cases, international standards have been applied as per a Type 1 assessment (Table 2-3). In other cases, given a lack of information around the appropriate environmental standards for the pollution objective, an assessment of available data against historical trends has been presented as per the Type 2 assessment (Table 2-3). A summary of how the overall assessment has been applied is shown in Figure 6-3.

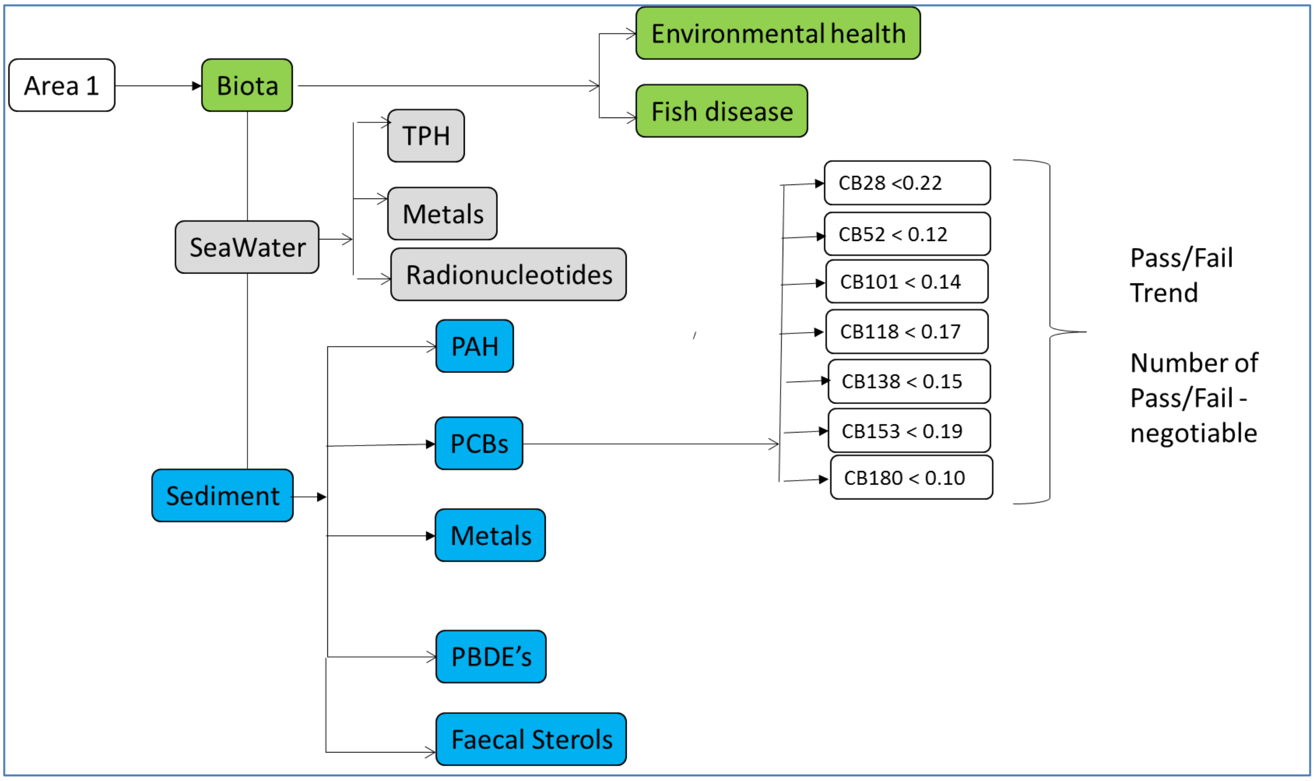


Figure 6-3: Description of the assessment process for environmental pollution. Where available and applicable, the concentrations of the pollutants were compared against environmental standards. However, in the instances of no environmental standards being applicable, the assessment was based on a quantitative assessment of the data and the identification of trends.

6.5 Summary of outcomes

Pollution in Kuwait has been a chronic issue over many years, with long term records showing persistent contamination of sediment, water and biota. An assessment of available EPA water contamination data (30-year data set for metals and petroleum hydrocarbons), from the national monitoring program demonstrated that no biologically significant change in water contamination was detected over the time series available, indicating that from a perspective of metal and petroleum hydrocarbon contamination the situation has not deteriorated over time. For sediment contamination by metals, PAHs and PCBs, current levels of contamination posed little toxicological risk to marine biota inhabiting the areas sampled. Indeed, for those chemicals assessed, the levels of contamination detected would indicate that in general Kuwait's marine environment is relatively unpolluted when compared with other industrialised regions of the world. Where detected hot spots of chemical contamination were restricted to locations associated with industry, such as the Shuaiba Industrial Area (SIA). Assessment of current status is given as good, with trajectory of change to be low and medium confidence in final outcome (Table 6-1). The analysis of chemical contamination in biota along with the levels of contaminant associated disease in fish supports these findings with levels generally indicative of unpolluted environments (Section 5.6.2).

Pollution due to sewage discharges continues to be a persistent threat to Kuwait's marine environment. As detailed in section 5.6., microbial water quality counts regularly breach regional water quality guidelines and indicate that raw and partially treated sewage effluent is regularly being discharged from a number of locations around the coast. This is attributed to the failure of the sewage treatment network to keep pace with demands for capacity driven by rapid population growth, which has almost trebled over the last 30 years. The analysis of faecal sterols in sediments (section 6.6.8) further provides proof that the environment is regularly impacted by sewage discharges with high levels of contamination found along the Gulf coast and Kuwait Bay, In particular evidence of high levels of sewage pollution where associated with Doha Bay and Sulaibikhat Bay, both located in Kuwait Bay. Sulaibikhat Bay was heavily impacted with raw sewage originating from a number of illegal discharges in the area, including the Al-Ghazali storm drain. These discharges of sewage are also known to contain a complex mixture of chemical contaminants and these have been shown to be both directly toxic to marine species and also contain endocrine disrupting properties (section 6.6.9)

Table 6-1: Overview of the pollution assessment for Kuwait Marine waters.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
Environmental Pollution						
Status assessment is Good. Assessment of the current status is given as GOOD, with the trajectory of change predicted to be stable with high confidence in these assessments of state and trajectory. An assessment of long-term water contamination data from the EPA national monitoring program has demonstrated that no biologically significant change in water contamination was detected over the time series available, indicating that from a perspective of metal and petroleum hydrocarbon contamination, the situation has not deteriorated over time. An assessment of the available long term data also indicates that, in general, metals and petroleum hydrocarbon in water are below levels thought to pose a toxicological threat. For sediment contamination by metals, PAHs and PCBs, current levels of contamination posed little toxicological risk to marine biota inhabiting the areas sampled. The levels of contamination detected indicate that, in general, Kuwait's marine environment is relatively unpolluted when compared with other industrialised regions of the world. Hot spots of contamination have been identified, but these are restricted to locations associated with industry. However, faecal sterol data highlights that sewage contamination is widespread in coastal areas across the whole of Kuwait. Discharges of sewage can contain a complex mixture of chemical contaminants and these have been shown to be both directly toxic to marine species and also contain endocrine disrupting properties. In conclusion, the analysis of chemical contamination in biota along with the levels of contaminant associated disease in fish supports the conclusion of GOOD status with levels generally indicative of unpolluted environment. However, pollution due to sewage discharges continues to be a serious and persistent threat to Kuwait's marine environment. This is an area that requires urgent investigation as continued sewage discharges could impact on the current good status particularly in coastal areas and contamination hotspots.						
ENVIRONMENTAL POLLUTION	Water	Total Petroleum Hydrocarbons (TPH)	● (green)	➡	■■■	Status assessment is GOOD, as concentrations of TPH in water samples from the EPA monitoring stations are all below the national environmental standards. Confidence is high with data indicating improvements at some locations.
		Heavy metals < thresholds	● (green)	➡	■■■	Status assessment is GOOD, as concentrations of metals in water samples from the EPA monitoring stations are generally below the national environmental standards. Confidence is high with data indicating improvements at some locations.
	Ecotoxicology	Toxicity/endocrine disrupting chemicals	● (red)	?	■	Status assessment is POOR due to toxic and endocrine disrupting chemicals having been detected in effluents discharged into Kuwait's marine environment. There is evidence that water collected from Kuwait Bay can pose a toxic threat to sensitive marine species. However, the dataset is very limited, so low confidence in the assessment.
	Sediment	PAH	● (green)	?	■■	Status assessment is GOOD as, in general, the concentrations of PAHs in sediment samples collected from Kuwait's waters were below international sediment quality guidelines, and are not thought to pose a toxic risk to marine species. The only identified area considered to be contaminated was around the Shuaiba Industrial Area. Trajectory unknown and medium confidence.
		PCB	● (green)	⬆	■■	Status assessment is GOOD. The status is considered to be improving with medium confidence. There is a low level of PCB contamination in Kuwait's marine sediments and current levels are not thought to pose a toxicological risk. The only marine area considered to be contaminated is associated with the Shuaiba Industrial Area. Sediment cores analysed from sites in Kuwait Bay indicate that peak PCB contamination occurred in the early 1990's and levels have since fallen.
		Metals	● (orange)	➡	■■	Status assessment is MODERATE. Current levels are above the background concentrations previously proposed for the region. However, assessment criteria developed in other regions (e.g. Europe and North America) are not suitable for use in the Arabian Gulf. Further work is required to develop regional specific sediment quality guidelines. Until then it will be difficult to assess the toxicological risk current levels contamination pose.
		PBDE	● (green)	?	■	Status assessment is GOOD, but unknown trajectory for future state. In global terms the concentrations of PBDEs reported for Kuwait's marine environment are low, with values often an order of magnitude below those reported for other industrialised regions. The only hotspots identified were associated with sediments sampled close to the Shuaiba Industrial Area and a site located in western Kuwait Bay (Doha Bay). However, the dataset is limited, so confidence in the assessment is low.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
POLLUTION	Sediment	Faecal sterols	●	⬇	■■■	Status assessment is POOR, and the predicted trajectory is that it will continue to decline. Assessment made with high confidence due to the data availability and focused studies. There is wide spread sewage contamination of Kuwait's coastal marine environment. Hotspots are located at multiple points around the coast with highly contaminated areas identified in Kuwait Bay (including Doha and Sulaibikhat Bay), and residential areas along the Gulf coast. Multiple studies conducted both by the EPA and KISR support this assessment.
	Biota	Chemical contamination	●	?	■	Status assessment is GOOD as, in general, concentrations of contaminants in fish and shellfish collected from Kuwaiti waters appear to be below concentartions thought to pose a toxicological threat to marine species. However the data limited to a small number of studies so trajectory unknown and confidence low.
		Fish health	●	?	■	Status assessment is GOOD. A survey of fish health indicates that fish residing in Kuwaiti waters contain a low prevalence of disease and pathologies associated with contaminant exposure. However, the dataset is limited to a small number of fish species, so low confidence in the assessment.

6.6 Environmental Pollution indicator assessments

6.6.1 Seawater contamination: Total Petroleum Hydrocarbons (TPH)

6.6.1.1 Background

Total Petroleum Hydrocarbons (TPH) is a mixture of chemicals that are natural components of oil and coal. They are one of the most widespread organic pollutants in the marine environment, entering the sea from industrial activities, operational and accidental oil spills from shipping, atmospheric fallout and riverine inputs (e.g. Shatt Al Arab). Although TPHs can be produced through natural processes, they can also arise from man-made activities. Sources include incomplete combustion of organic material and those which arise from a petrogenic origin (e.g. crude oils or refinery products). Despite the large number of hydrocarbons found in petroleum products and the widespread nature of petroleum use and contamination, only a relatively small number of the compounds are well characterized for toxicity. The health effects of some fractions can be well characterized, based on their components or representative compounds (e.g., light aromatic fraction-BTEX-benzene, toluene, ethylbenzene, and xylenes). However, heavier TPH fractions have far fewer well characterized compounds. Systemic and carcinogenic effects are known to be associated with petroleum hydrocarbons.

6.6.1.2 Current state of Knowledge Kuwait

Apart from specific events related to the Gulf War, the introduction of pollutants from the oil industry appear relatively low. The levels of total petroleum hydrocarbons (TPHs) were observed to remain relatively stable between 1988 and 1995 at a number of sites, which encompassed the whole of the Kuwait coast line. While values recorded peaked in 1991-1992 (8 – 22 µg l^{-1}) they were still considered to be within background levels (Al-Majed and Faraj, 1996; Al Ghadban et al., 2002). Higher values have been reported by Bu-Olayan et al., (1998) who, between 1993-1994 observed PAHs (expressed as chrysene equivalents) ranging from 21 to 320 µg l^{-1} across a number of sites along the length of the Kuwait coastline. However, direct comparison of these studies is difficult due to differences in the sites sampled and analytical methodologies employed. While reports on the concentrations of TPHs and metals predominated the literature, only a few studies to date have focused on the toxic nC6 to nC14 volatile liquid hydrocarbon (VLH) fractions of crude oil. VLH comprises hydrocarbon compounds such as benzene, xylenes and toluene, and can account to up to 40% of components of crude oil (Saeed et al., 1999a). Information on seawater contamination by VHL is particularly pertinent to the marine environment of Kuwait as they are known to co-distil with drinking water during the process of desalination (Ali and Riley, 1990). Saeed et al., (1999a) reported concentrations of VLH in coastal seawater to be within the range 307 – 5017 ng l^{-1}, with benzenoids constituting 65% of the total VLH recorded. Work examining the contribution power and desalination plants make to the values detected was undertaken at Doha and Ras Al-Zor (Saeed et al., 1999b). Levels close to the intake and outfall pipes around the Doha power/desalination plant ranged from 307 to 7811 ng l^{-1}, while further south at Ras Al Zor values ranged from 465 to 4652 ng l^{-1}. Benzenoids (76-84%) dominated the makeup of the VLH, followed by n-alkanes (12-22%) and cycloalkanes (2-4%) (Saeed et al., 1999b).

6.6.1.3 Assessment approach and findings

A current assessment of hydrocarbons data from seven shoreline (S-sites) and 13 coastal sites (Z-Sites) was carried out to investigate if they are at concentrations that may cause harm to the marine environment around the Kuwaiti coast. To establish if concentrations were above levels that may cause harm, set Ambient Seawater Quality Criteria (ASQC) were used as assessment criteria. The ASQC for hydrocarbons are set at 5 ppm or 5000 µg l^{-1} (EPA, 2001). To compare the hydrocarbons simply the Risk Characterisation Ratio (RCR) was used as described by Nicolaus et al. (2015). In summary, the RCR is the ratio between the Measured Environmental Concentration (MEC) and the ASQC. If the RCR is above 1, then the determinant failed the particular ASQC and this determinant may cause harm to the environment. Not a single station failed the assessment criteria over the whole data set, indicating that pollution from hydrocarbons is not a problem in Kuwaiti waters. The trend assessment also indicated a downward trend at 13 stations of which four were significant (Table 6-2).

6.6.1.4 Discussion and Conclusions

As previous studies suggested, TPH are not a fundamental issue in the Kuwaiti marine environment, as concentrations are below set environmental assessment criteria. The downward trends observed in the current study are also very encouraging and follow up studies should be considered to monitor if these continue. An upward trend was observed at station S04 (Al-Sha'ab) and further investigations should take place to see if increases are happening there in the future as some trace elements like Ar, Cu and Pb also increased at this site.

Table 6-2: Summary results of status and trend assessment for Total Petroleum Hydrocarbons. Status assessment: Green- result of last sampled year below ASQC; Trend Assessment was carried out if three or more years were sampled: positive value shows an increase; negative value shows a decrease; bold indicates a significant trend.

Station	Total Petroleum Hydrocarbons	Last year sampled
S00	-0.02	2010
S01	-0.41	2010
S02	NA	NA
S03	NA	NA
S04	0.29	2010
S05	0.01	2010
S06	NA	NA
S08	-0.16	2010
S09	NA	2007
S11	-0.37	2010
Z00	**-0.29**	2014
Z01	**-0.29**	2014
Z02	**-0.23**	2014
Z03	-0.08	2014

Station	Total Petroleum Hydrocarbons	Last year sampled
Z04	-0.12	2014
Z05	0.07	2014
Z06	0.09	2014
Z07	-0.04	2014
Z08	**-0.25**	2014
Z09	-0.09	2014
Z10	-0.1	2014
Z11	-0.01	2014
Z12	-0.09	2014

6.6.2 Seawater contamination: Metals

6.6.2.1 Background

The State of Kuwait has witnessed major economic, social and industrial development following the discovery and exploitation of its vast oil reserves (Al-Abdulghani et al., 2013). Similar to other countries, which comprise the Gulf Co-operative Council (GCC), the rapid expansion of Kuwait's industrial sector has mainly occurred around its coasts (Al-Rifaie et al., 2007; Al-Abdulghani et al., 2013). As a consequence, a variety of contaminants have been discharged directly into the marine environment, including metals (Al-Sarawi et al., 2015). Metals are released into the marine environment, from both anthropogenic and natural inputs and are strongly affiliated with particulate matter (Zhang et al., 2007). Many metals (e.g. copper, zinc, chromium) occur naturally in the environment and even without inputs from industry, significant concentrations would occur owing to the underlying natural geology of the region. In many cases where metals occur in naturally high concentrations, local species will have adapted to tolerate the elevated background levels.

6.6.2.2 Current state of Knowledge Kuwait

Effluent discharges into Kuwait's marine environment come from a number of industrial and domestic sources and inputs span most of the county's 195 km of coastline. The highest density of these point sources of contamination is associated with populated areas around the city or with industrial centres such as Doha and Shuaiba (Al-Ghadban et al., 2002). Sea water metal contamination, linked to the oil production/refining and desalination industries, have been the focus of a number of studies, including those conducted following the 1991 Gulf War. Bu-Olayan et al., (1998) ranked total mean seawater metal concentrations (Zn 3.6 – 9.4 (range) > V 1.6 – 8.2 > Ni 1.2 – 4.7 > Pb 0.4 – 3.6 > Mn 0.4 – 8.5 > Cu 0.6 – 2.2 > Cr 0.5 – 1.2 > Cd 0.2 – 0.7 µg L^{-1}), with variation in contamination observed across sites spanning the whole coastline of Kuwait attributed to point source inputs. Similar seawater concentrations were reported by Bu-Olayan et al., (2001a) who observed mean values (0.1 – 7 µg L^{-1}) of trace metals (Cu, Fe, Zn, Ni, Pb, Co) at a series of sites across Kuwait Bay and along the eastern coastline. Al-Sarawi et al., (2002a) carried out a detailed survey of water and suspended particulate samples collected from 24 locations within Sulaibikhat Bay. Seasonal differences were observed with elevated levels of trace metals detected in the summer months. Mean concentrations (total 48 samples) of dissolved phase trace metals were Cu 4 (range: 0.7 – 20), Fe 100 (50 – 120), Zn 36 (10 – 98), Ni 1 (<LOD – 5), Pb 2 (0.1 – 9), V 14 (5 – 50), Cr 1 (0.3 – 7), and Mn 3 (0.2 – 7) µg L^{-1}. Higher concentrations were found associated with particulate matter collected from the water column, with mean concentrations of Cu 90 (range: 12 – 210), Fe 28,000 (10600 – 49,000), Zn 351 (128 – 545), Ni 37 (3 – 160), Pb 70 (<LOD – 151), V 98 (<LOD – 171), Cr 152 106 – 208), and Mn 55 (25 – 89) µg g^{-1}. Similarly, Bu-Olayan and Thomas (2014) reported high Zn, Cr and Cu concentrations in wastewater drain outfall samples, which were attributed to the effluents discharged from power plants, automobiles, paint industries, lubricants and domestic wastes from residential areas.

6.6.2.3 Assessment approach and findings

A current assessment of 7 trace elements (cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni) and vanadium (V)) from ten shoreline (S-sites) and 13 coastal (Z-sites) sites was carried out to investigate if they are at levels that may cause harm to the marine environment around the Kuwaiti coast. This monitoring was undertaken as part of the EPA water quality monitoring programme, which has been conducted at some locations since 1984.To establish if concentrations were above levels that may cause harm, set Ambient Seawater Quality Criteria (ASQC) were used as assessment criteria (Table 6-3). To compare the seven trace elements simply with one another the Risk Characterisation Ratio (RCR) was used as described by Nicolaus et al. (2015). In summary, the RCR is the ratio between the Measured Environmental Concentration (MEC) and the ASQC. If the RCR is above 1, then the determinant failed the particular ASQC and this determinant may cause harm to the environment. Table 6-4 gives an overview of all the determinants and sites that failed the ASQC since 1984. It can be seen that Cu and Pb were reasons of concern in the recent past at shoreline stations, while coastal sites indicate failures for Cd, Hg and Fe. Interestingly, only Fe failed the environmental standard in the last sampled year at the coastal Z02 Al-Doha site. Nevertheless, this result should be treated with caution as it was the only sample analysed so far in 2016 (Table 6-4, Table 6-5). Looking at the trend assessment, in total 29 significantly negative trends were observed across the board for trace elements. Only coastal sites observed significant downward trends, while shoreline sites showed some increases, mainly for Cd, Fe and Pb at stations S01, S05 and S11 (Al-Salam, Ras Al-Ardh and Al-Fahaheel, respectively). The most significant decreases were observed for Hg at 11 out of 13 coastal sites. A detailed overview of the status and trend assessment can be found in Table 6-5.

Table 6-3: Ambient Seawater Quality Criteria (SQC), taken from EPA (2001).

Determinant	Chemical symbol	Maximum limit (µg $L^{-1)}$
Cadmium	Cd	0.7
Copper	Cu	15.5
Iron	Fe	91.3
Lead	Pb	12
Mercury	Hg	0.37
Nickel	Ni	20
Vanadium	V	9.7

Table 6-4: All stations samples since 1984 that failed the Ambient Seawater Quality Criteria for trace elements. RCR-Risk Characterisation Ratio is the ratio between the Measured Environmental Concentration (MEC) and the Ambient Seawater Quality Criteria. If the RCR is above 1, than the determinant failed the particular ASQC and this determinant may cause harm to the environment.

Station	Year	Determinant	MEC Mean ($\mu g\ L^{-1}$)	SE	MEC Max ($\mu g\ L^{-1}$)	N	RCR Mean	SE
S01	2010	Cu	22.8	20.4	104.6	5	1.5	1.3
S04	2010	Cu	16.4	12.1	64.5	5	1.1	0.8
S04	2010	Pb	12.6	8.9	47.1	5	1.1	0.7
S05	2010	Cu	23.5	20.3	104.6	5	1.5	1.3
Z00	1991	Fe	110.8	*	110.8	1	1.2	*
Z00	2002	Cd	0.9	0.0	1.0	4	1.2	0.1
Z01	2002	Cd	1.0	0.5	2.6	4	1.5	0.8
Z01	2004	Hg	0.4	0.3	2.0	6	1.1	0.9
Z02	1997	Cu	18.2	15.8	97.3	6	1.2	1.0
Z02	2003	Cd	1.3	1.0	5.2	5	1.9	1.4
Z02	2016	Fe	91.4	*	91.4	1	1.0	*
Z04	2002	Cd	1.1	0.4	2.2	4	1.6	0.5
Z05	2002	Cd	1.2	0.4	2.4	4	1.7	0.6
Z06	2002	Cd	0.7	0.1	0.9	4	1.0	0.1
Z07	2002	Cd	1.2	0.2	1.8	4	1.7	0.3
Z08	2002	Cd	0.8	0.1	1.0	4	1.1	0.2
Z09	1991	Hg	0.4	0.1	0.5	2	1.1	0.1

Station	Year	Determinant	MEC Mean ($\mu g\ L^{-1}$)	SE	MEC Max ($\mu g\ L^{-1}$)	N	RCR Mean	SE
Z10	2002	Cd	1.1	0.4	1.9	3	1.5	0.6
Z11	2002	Cd	0.9	0.3	1.6	3	1.3	0.5
Z11	2007	Cd	0.8	0.5	1.7	3	1.1	0.7
Z12	2002	Cd	1.0	0.4	1.4	2	1.5	0.6
Z12	2007	Cd	0.9	0.5	1.9	3	1.3	0.7

6.6.2.4 Discussion and Conclusions

The current study highlights that trace element concentrations are on the downward trend at coastal sites (Z-sites), but shoreline stations (S-sites) have shown increases over the last sampling years going back to 2006, which may be of concern. Nevertheless, the status assessment has highlighted that all sampled stations for the different trace elements are below the assessment criteria apart from Fe at the Z02 station (Al-Doha) which indicates that the water quality in regard to trace elements is in a satisfactory state. Further sampling is advised, especially at stations where an upward trend has been observed to ensure the water quality is not deteriorating over time (ATSDR, 2016).

Table 6-5: Summary results of status and trend assessment for metals. Status assessment: Green- result of last sampled year below ASQC; Red- result of last sampled year above ASQC; Trend Assessment was carried out if three or more years were sampled: positive value shows an increase; negative value shows a decrease; bold indicates a significant trend.

Station	Ar	Cd	Cu	Fe	Pb	Hg	Ni	V	Zn	Last year sampled
S00	0.47	0.18	0.27	-0.05	0.09	0.175	0.2	0.13	NA	2010

Station	Ar	Cd	Cu	Fe	Pb	Hg	Ni	V	Zn	Last year sampled
S01	0.37	0.3	0.24	0.02	0.26	0.1	0.19	-0.14	NA	2011
S02	NA	NA	NA	NA	NA	NA	NA	NA	NA	2011
S03	NA	NA	NA	NA	NA	NA	NA	NA	NA	2011
S04	0.35	-0.02	0.25	0.19	0.26	0.08	0.34	0.13	NA	2011
S05	0.27	0.16	0.24	0.21	0.12	0.13	0.15	-0.02	NA	2011
S06	NA	NA	NA	NA	NA	NA	NA	NA	NA	2011
S08	NA	-0.18	0.09	0.19	0.2	0.04	-0.29	-0.08	NA	2010
S09	NA	NA	NA	NA	NA	NA	NA	NA	NA	2007
S11	0.49	0.36	0.04	0.09	0.28	-0.02	-0.14	0.07	NA	2010
Z00	-0.09	-0.09	-0.06	**-0.25**	-0.12	-0.16	**-0.19**	**-0.22**	NA	2015
Z01	-0.01	**-0.18**	0.01	-0.03	0.05	-0.13	-0.09	**-0.17**	NA	2016
Z02	-0.04	-0.06	-0.02	0.06	-0.06	**-0.29**	-0.05	-0.03	NA	2016

Station	Ar	Cd	Cu	Fe	Pb	Hg	Ni	V	Zn	Last year sampled
Z03	-0.09	**-0.33**	-0.09	-0.11	**-0.2**	**-0.5**	-0.05	-0.08	NA	2016
Z04	-0.06	-0.14	-0.11	-0.04	0.03	**-0.4**	-0.07	-0.05	NA	2016
Z05	-0.04	**-0.34**	-0.12	-0.11	-0.06	**-0.38**	-0.13	-0.13	NA	2016
Z06	-0.03	**-0.18**	0.04	0	0.13	**-0.32**	-0.11	-0.09	NA	2016
Z07	0	**-0.38**	-0.02	-0.17	0.13	**-0.32**	-0.02	**-0.3**	NA	2015
Z08	0.05	**-0.17**	0.12	-0.06	0.22	**-0.34**	-0.14	-0.17	NA	2015
Z09	0.06	-0.1	-0.03	0	0.1	**-0.29**	-0.12	**-0.3**	NA	2015
Z10	0.07	-0.13	**-0.27**	0.08	0.02	**-0.35**	**-0.23**	**-0.41**	NA	2015
Z11	0.04	0.06	-0.07	0.06	0.07	**-0.31**	-0.18	**-0.26**	NA	2015
Z12	0.07	0.05	0.05	0.05	0.14	**-0.25**	0	-0.16	NA	2015

6.6.3 Ecotoxicology and chemical screening of water samples

6.6.3.1 Background

Waste effluents from industry and domestic sewage are thought to make up the key components of marine pollution around Kuwait (Al-Ghadban et al., 2002; Al-Abdulghani et al., 2013; Al-Sarawi et al., 2015; Devlin et al., 2015). In particular, sewage contamination, both from illegal discharges or authorised releases, has been documented as being of particular concern (Lyons, et al., 2015; Saeed et al., 2012). Other effluents from power stations, desalination plants and industrial or commercial processes also reach the marine environment from various outfall around the coastline of Kuwait. Due to these various inputs, the waters of Kuwait Bay and the Gulf coast are subject to a constant stream of complex effluents varying in volume, constituents and flow. The problems associated with understanding the overall effect of these mixed effluents were recognised by the early 1990s (Matthiessen et al., 1993) as research showed that effluents from sewage treatment plants may also, through various chemical pollutants, demonstrate endocrine disruption effects (Desbrow et al., 1998; Harries et al., 1996; Jobling et al, 1998). These effects can be caused by natural steroids and also by industrial chemicals acting as endocrine disruptors (Aerni et al, 2004; Thomas et al, 2004). Interest in what is in these complex effluents has widened and a wide range of pharmaceutical and personal care product compounds have now been identified in the receiving waters (Prasse et al., 2010). The presence of pharmaceuticals is of particular concern, as they are designed to have specific biological effects and low concentrations, and so are thought to pose high risk to organisms in receiving waters (Gaw et al., 2014). Such effluents contain a complex mix of potential hazardous substances and current chemical monitoring programmes are only capable of measuring a relatively small proportion of the total contaminants present. Predicting the risk such complex mixtures pose to both environmental and human health has been one of the key issues facing environmental managers in the 21st century (Backhaus and Karlsson, 2014; Backhaus et al, 2011). Effective biological assays can provide data on the overall effects of a complex mixture, and help to target impacted sites without any pre-knowledge of what chemicals might be present. Finding the right combination of suitable biological and chemical analysis can give the capability to monitor for both specific and unknown pollutants. One effective screening assay for effluent based contamination is the yeast estrogen screen (YES) (Routledge and Sumpter, 1996). This is a tool for investigating the potential for steroid and steroid mimicking chemicals to be present in environmental samples, and gives a measure of the overall effect of active steroid-like chemicals. It is a widely accepted bioassay and has been used in many countries to look at contamination in effluents, rivers, estuaries and marine areas (Balaam et al, 2010; Galluba and Oehlmann, 2012; Thomas et al., 2004). In addition, the general toxicity of effluent samples can be effectively assessed using various invertebrate bioassay tests. One such test commonly employed in environmental surveys is the 48hr oyster embryo bioassay, which has shown to be a sensitive indicator of both seawater and effluent toxicity (Thain, 1991; Lyons et al., 2013).

6.6.3.2 Current state of Knowledge Kuwait

It is known that Kuwait's marine environment is subject to pressures arising from both industrial and sewage effluents. However, to date little work has been conducted to assess the toxicological risk these may pose to both environmental and human health. The only published work to date used a microbial based toxicity test (MicroTox^{TM}) to identify areas of Kuwait Bay and the Northern Gulf where extracts obtained from sediment samples elicited a toxic response (Beg and Al-Ghadban, 2003).

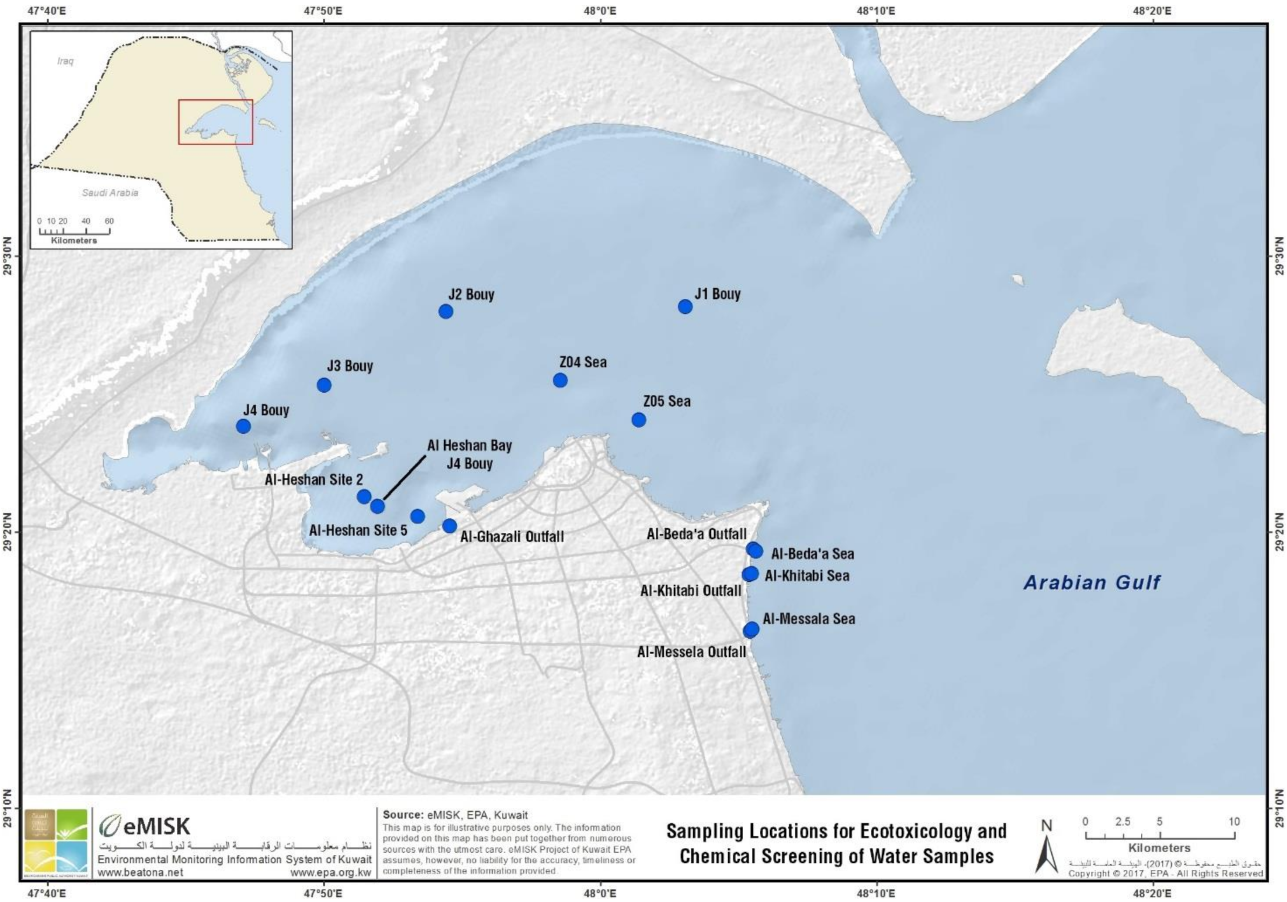


Figure 6-4: Sampling locations for ecotoxicology and chemical screening of water samples

6.6.3.3 Assessment approach and findings

Samples were collected to assess the potential toxicological and endocrine disrupting risks posed by effluents currently discharging into Kuwait's marine environment. A series of water and effluent samples were collected from a number of sites known to be impacted by effluent discharges to establish if such a threat exists. Water samples were screened using a GC–MS target based screening approach, to identify the main pollutants present and assessed for both toxic and endocrine disruption potential using bioassays. During April 2014 a total of sixteen water samples were collected from four known point-sources of effluent input, Al Ghazali, Salmiya, Al Bedaa and Al Messela, and from twelve other sites located offshore in Kuwait Bay and along the Gulf coastline adjacent to the city (Figure 6-4). Approximately 2.5

litres of water or effluent were collected at each site using either a stainless steel bucket or Winchester bottles to collect samples from immediately beneath the water surface. All samples were stored in 2.5 litre amber Winchester bottles prior to extraction and analysis. The Winchesters were transported back to the EPA laboratory, where they were immediately prepared for vacuum extraction. Full details of the analytical and toxicological protocols are provided in Annex 6.2 Ecotoxicology and chemical screening of water samples

Oyster embryo bioassay

The Oyster embryo screen was run on a subset of the samples, selected to represent the breadth of expected site characteristics (Figure 6-5). These included outfalls associated with Al Bedaa, Salmiya and the Al Messela districts. In addition historic EPA smart buoy locations in Kuwait Bay (known as J-buoy sites) were also examined. In particular the J5 buoy was selected as it is located in the entrance Sulaibikhat Bay close to the Al Ghazali outfall, so would be expected to be impacted by this known point source discharge. Under normal (unpolluted) conditions normal oyster development should be greater than 80%. The two control samples run as part of this study achieved this value, demonstrating that the bioassay was meeting internationally specified quality criteria (Thain, 1991). Sites sampled in the middle of Kuwait Bay (J1 Buoy and J2 Buoy), displayed mild toxicity with normal development falling to just over 60%. Higher toxicity was seen at the outfall locations and the J5 Buoy and Salmiya, where in some instances no normal oyster development was observed. This clearly demonstrates that effluents entering the sea at these points pose a direct toxic treat to the marine environment. Of particular concern were the elevated level of toxicity at both the J5 Buoy and Salmiya, which are several hundred meters removed from point sources of pollution and indicate that the influence extended from the source of impact at these locations.

Endocrine disruption bioassays

Data from the YES bioassay are shown in Figure 6-6. The YES data displayed a positive response in a number of the samples. This indicates that chemicals present in these samples have endocrine disrupting activity. The clearest evidence of endocrine disrupting activity was observed at the Al Ghazali and Al Messela outfalls. Responses indicating higher concentrations of endocrine disrupting chemicals were also observed at sites on in Kuwait Bay (J-Buoy sites), Sulaibikhat Bay (Al Hesah Sites 2, 5) and those along the Gulf coast (Al Bedaa sea). It is uncommon to find these sort of effects in open water marine samples because the amount of dilution available is usually enough to drive all responses below the limits of detection.

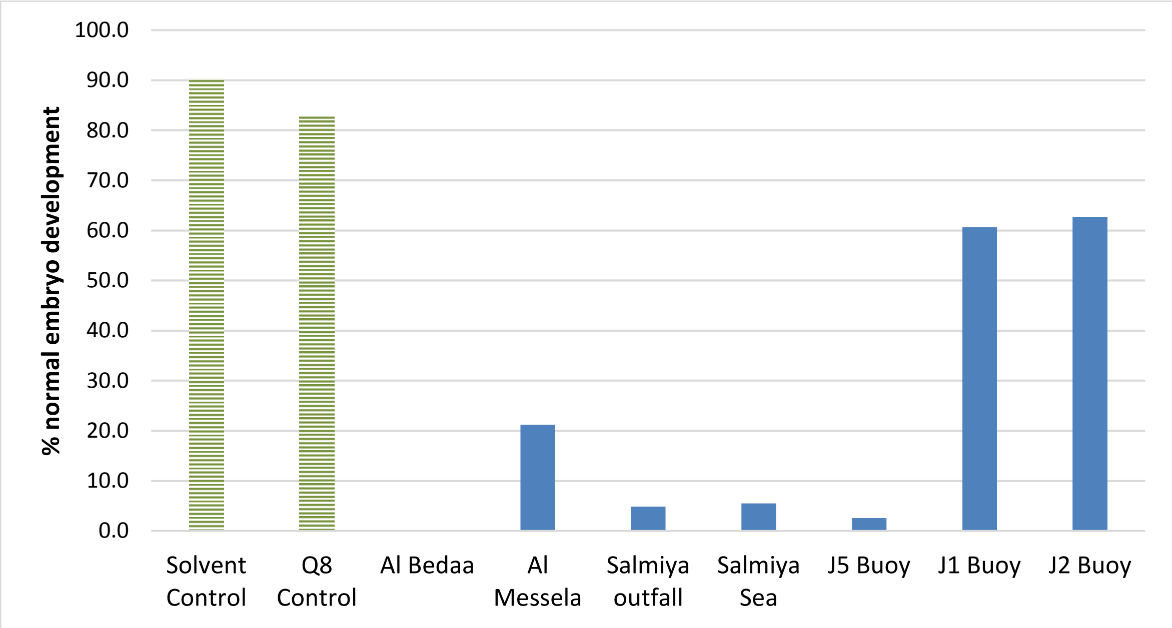


Figure 6-5: Oyster embryo development screen. Y-axis represents percentage of embryos developing normally. Solid bars represent results from sites of interest. Striped bars indicate control sample results (>80% normal development indicating a valid test)

Chemical contaminant screening

The samples were also run through a chemical screening procedure (Table 6-6). The approach compares samples against a library of over 1000 different chemical pollutants. Sites have been grouped together as the offshore J-Buoy sites, the Mishref outfalls, the enclosed Sulaibikhat Bay sites and the unlicensed Al Gahazali outfall on its own. The J-buoy sites and Sulaibikhat Bay registered 19 chemicals of interest. Al Ghazali on its own had a list of 78 detectable chemicals. The tables describe the potential uses for the chemicals, which allow a certain amount of speculation as to how the chemicals arrived in the effluent. Various chemicals were observed at the different sites including caffeine, parabens, bromoform, PAHs and flame retardants. As a marker of sewage contamination cholesterol was the largest contaminant by concentration, which was picked up at high concentrations at the Al Ghazali outfall. Amongst the known endocrine disrupting chemicals found, Al Ghazali sites showed Bisphenol A, and several phthalates at microgram (µg) per litre concentrations. The outfalls at Al Bedaa, Salmiya and Al Messela had similar levels of two phthalates, whilst some of the J Buoy sites had varying levels of phthalates, or Bisphenol A. 17-a-Ethinyl estradiol, found in most sewage effluents due to use of the contraceptive pill, did not appear on the list of chemicals detected, but is highly potent even at ng/l levels which would not be picked up by the rapid screening tool deployed here. Other common human steroids such as 17-β estradiol, estrone and estriol are also likely to be present in the effluents in low concentrations, adding to the levels of effect detected by the YES bioassay.

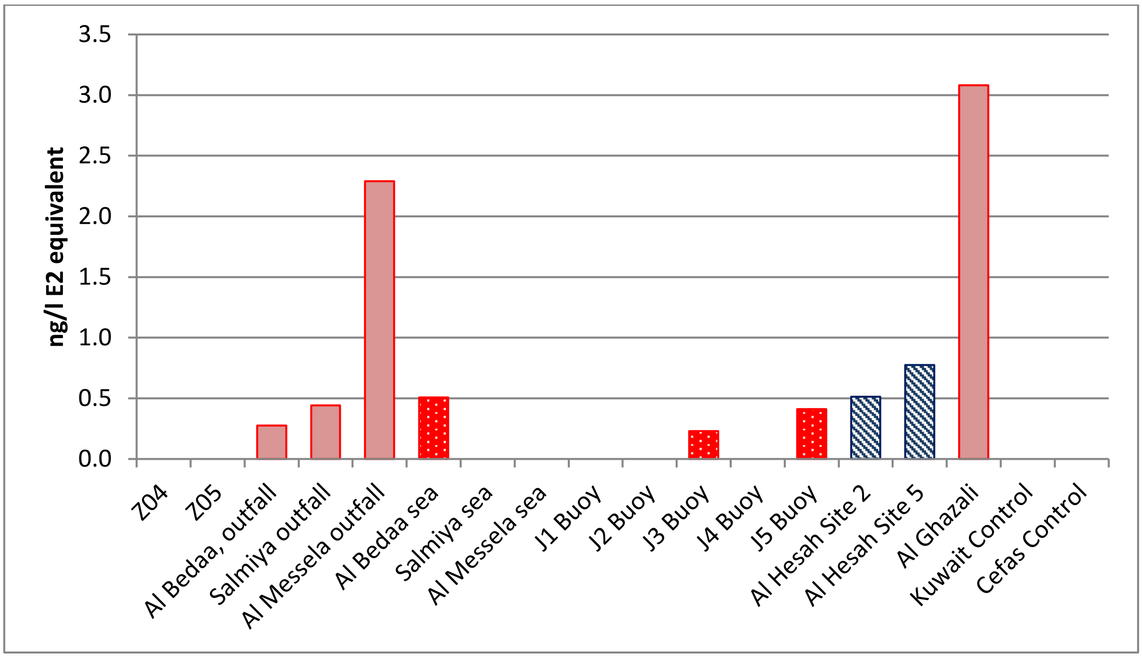


Figure 6-6: Response for samples tested using the Yeast Estrogen Screen. The vertical scale represents the amount of E2 in ng/l required to produce a response similar to that cause by the sample. Solid orange data bars represent the concentration in outfalls. Blue diagonally striped bars represent near shore samples. Red spotted bars indicate open water samples. No bar = no response detected.

CAS number	Name	Approximate concentration μg/l	Possible use
75252	Bromoform	0.04–0.48	Volatile solvent
74953	Dibromomethane	0.01–0.05	Volatile solvent
99763	Methylparaben	0.1–2.3	Antifungal preservative in cosmetics
120478	Ethylparaben	0.8	Antifungal preservative in cosmetics
88755	2-Nitrophenol	0.01–0.02	Manuf dyes, paint coatings, rubber coatings and fungicides
119619	Benzophenone	0.05	Fixative for heavy perfumes
142916	Isopropyl palmitate	7.5	Widely used in cosmetics and personal care products
5466773	Octyl-methoxycinnamate	0.02	Personal care products, sun blocker
118605	2-Ethylhexyl salicylate	0.1–9.7	Used in cosmetics and sunscreens to absorb UVB
6197304	Octocrylene	0.13–9.9	UV-filter
88040	Chloroxylenol	0.06	Biocide/antiseptic
131113	Dimethyl phthalate	0.06	Additives for plastics known as phthalates
3622842	Benzenesulfonamide, *N*-butyl-	0.14–0.3	Intermediate for the synthesis of dyes, photochemicals and disinfectants
80057	Bisphenol A	0.03	In the manufacture of epoxy resins and polycarbonates for food packaging
77907	Tributyl acetylcitrate	0.05	Plasticizer or carrier solvent permitted in the field of food additive, food contact material as well as for polymers especially for cellulosics
10323	1 Bis(2-ethylhexyl) adipate	0.06–0.13	Plasticizer
10544500	Sulphur (S8)	0.03	Acaricide/insecticide
58082	Caffeine	0.04–0.37	Psychoactive stimulant drug
57885	Cholesterol	7.3	Waxy steroid of fat that is manufactured in the liver or intestines

Table 6-6: Open water J-buoy sites 1–4. Chemicals identified by GC–MS residue scans. Listed chemicals are toxic, carcinogenic, indicators of other pollutants, indicators of industrial process wastes, pharmaceuticals or personal care products.

6.6.3.4 Conclusions

These two bioassay tests employed show definite differences between the sites and between control samples and contaminated sites. The oyster embryo test results represent the effects of chemicals which have both toxic and developmental impacts on this very sensitive life stage. This could include any number of the chemicals identified as being present by the chemical screen, as pharmaceuticals, agricultural chemicals, plasticisers and petrochemicals all contain chemicals implicated in developmental abnormality. With the YES screen, it has been well established since the 1990s that domestic and industrial sewage effluents potentially contain a number of chemicals which can bind to and activate parts of the endocrine system, such as the estrogen receptors used in this test. Several of the sites are at or very close to sewage effluent outfalls, so the source of these chemicals and the route they take to get into the environment are clear and would be expected to affect both the oyster and YES screens. Of more concern are the estrogenic and developmental/toxic responses seen in samples, such as those taken from the J Buoy sites in open water section of Kuwait Bay. The dilution factor of any effluent stream would be expected to be very high at this point, making detection of any but the most highly contaminated effluents very unlikely. The concentrations found were low ng/l, but this high when compared to other studies reporting on open water marine locations (Atkinson et al, 2003; Beck et al, 2006).

6.6.4 Sediment contamination: Polycyclic aromatic hydrocarbons (PAHs)

6.6.4.1 Background

Polycyclic aromatic hydrocarbons (PAHs) are natural components of oil and coal and are also formed during the combustion of fossil fuels and organic material. They are one of the most widespread organic pollutants in the marine environment, entering the sea from industrial activities, operational and accidental oil spills from shipping, atmospheric fallout and riverine inputs (e.g. Shatt Al Arab). Although PAHs can be produced through natural processes, they can also arise from man-made activities. Sources include incomplete combustion of organic material and those which arise from a petrogenic origin (e.g. crude oils or refinery products). PAHs from combustion sources mainly comprise the heavier, parent (non-alkylated) aromatic hydrocarbons, whereas those of petrogenic origin include alkylated, 2- and 3-ring PAHs formed as a result of diagenetic processes. Assessment of the PAH profile, including PAH ratios such as the phenanthrene/anthracene or fluoranthenene/pyrene ratio can give an indication of the source of the PAHs (e.g. petrogenic or combustion). PAH properties will vary considerably depending on molecular weight of the compound (governed by the number of aromatic rings the PAH possesses). Low molecular weight PAHs are potentially toxic to marine animals, while high molecular weight PAHs can be carcinogenic and have been shown to induce tumours in a number of fish species. There are marked differences in the behaviour of PAHs in the marine environment, which is dependent on their molecular weight. The low molecular weight (LMW) compounds are water soluble, whereas the high molecular weight (HMW) compounds are relatively insoluble and hydrophobic, and attach readily to particulate matter within the water column. As a consequence, sediment will act as a sink for PAHs in the marine environment.

6.6.4.2 Current state of Knowledge Kuwait

Studies investigating the contamination of sediments by both Total Petroleum Hydrocarbons (TPH) and PAH have been extensive, particularly in the period immediately following the

1991 Gulf War (Fowler et al., 1993; Readman et al., 1996; Metwally et al., 1997; Massoud et al., 1998). Surveys conducted immediately after the cessation of hostilities indicated that TPH and PAH contamination was evident up to approximately 400 km from the sources of oil that had been deliberately released into the environment (Readman et al., 1996). In subsequent surveys conducted between 1992 and 1993, these levels decreased by around 50%, with some small localised increases attributed to the resumption of industrial activity following the cessation of hostilities (Fowler et al., 1993; Readman 1996; Al-Omran and Rao, 1997). Even at the heavily contaminated sites of Al-Bedaa and Az-Zor the concentrations of TPH (range: 40 - 240 µg g^{-1} dw) were relatively low when compared to contaminated sites in Europe and North America (Simpson et al., 1996; Woodhead et al., 1999). Other studies have reported similar findings, with contamination mainly localised around the Shuaiba Industrial Area (SIA), whereas other locations were considered to reflect background values for the region (Metwally et al., 1997). These findings supported the work undertaken by Massoud et al., (1998) who surveyed the whole Arabian Gulf and categorised the majority of Kuwait's offshore sediments to be only slightly contaminated with TPHs (15-50 µg g^{-1} dw), when compared to unpolluted locations (TPHs 10-15 µg g^{-1} dw). More recent studies have reported hydrocarbon contamination from ten locations within Kuwaiti territorial waters (de Mora et al., 2010). Conducted under the auspices of the Regional Organisation for the Protection of the Marine Environment (ROPME) and as part of a larger regional investigation, the study observed concentrations of TPH ranging from 2 to 251 µg g^{-1} dw, with hotspots of contamination documented in Sulaibikhat Bay (western Kuwait Bay), Ras Al Zour and Fahaheel.

The hot spot of contamination around the SIA has been studied in detail to obtain information about the specific PAHs contaminating the sediment Beg et al., (2003). Particularly high levels of contamination were observed across a number of transects close to Shuaiba Harbour, with total PAH concentrations ranging from 201 – 1333 µg kg^{-1} dw. Such values are considerably higher than those reported at other locations around Kuwait (Saeed et al., 1999; de Mora et al., 2010). Interestingly, this research noted that high molecular weight PAHs dominated the profiles at sites around the SIA, which differs when compared with the dominance of low molecular weight PAHs at sites in and around Kuwait Bay (de Mora et al., 2010). At the most contaminated sites concentrations of individual PAHs including phenanthrene (maximum value recorded: 165 µg kg^{-1}), fluoranthene (maximum value recorded: 293 µg kg^{-1}) and benzo[a]pyrene (maximum value recorded: 95 µg kg^{-1}), exceeded international sediment quality guidelines (CCME, 1999; Beg et al., 2003). Wider spatial surveys of sediment PAH contamination have documented ∑PAH concentrations ranging from 12 to 1670 µg kg^{-1} dw (de Mora et al., 2010). The study by de Mora et al., 2010 noted that the highest concentrations were observed at Ras Al Zour and Sulaibikhat Bay, though this study did not include sites adjacent to the SIA.

6.6.4.3 Assessment approach and findings

Results from the sediment analysis for TPC and PAHs are presented in

Table 6-7 and Figure 6.7. The concentration of THC recorded in the present study (range: 4.2 – 744 µg g^{-1} dw) match those previously reported for the region (Fowler et al., 1993; Readman et al., 1996; Metwally et al., 1997; de Mora et al., 2010). The findings confirm that TPC is mainly restricted to the sites close to the SIA (C24, 105 µg g^{-1} dw and C26 744 µg g^{-1} dw). At the remaining locations the concentration of TPC ranged from 4.2 to 41 µg g^{-1} dw, which closely match the findings of Massoud et al., (1998) who undertook an extensive survey of the whole Arabian Gulf and categorised the majority of Kuwait's offshore sediments to be only slightly contaminated with TPHs (15-50 µg g^{-1} dw).

Summed PAH concentrations (∑PAH total of 30 compounds including parent and alkylated hydrocarbons) were compared at all the sites (

Table 6-7;Figure 6-7). The highest ∑30PAH concentration was observed in sediment collected at site C26 with 1,290 ng g^{-1} dw. This site is close to the SIA and analysis releveled it was composed of approximately 70% PAHs derived from combustible sources. The next highest value observed in this current survey was found at sample site C24 (also close to the SIA), with a ∑30PAH concentrations of 192 ng g^{-1} dw. Similar values were found at sample site C1 (Doha Bay), with∑30PAH concentration of 190 ng g^{-1} dw. However, the PAH profile at this location indicated that approximately 70% of the hydrocarbons analysed originated from an oil source. Two previous studies also documented individual and ∑PAH concentrations in marine sediments collected in Kuwaiti waters (Beg et al., 2003; de Mora et al., 2010). While the constituent ∑PAHs differed slightly between studies the general levels of contamination were considered similar with 5.65 – 1333.6 ng g^{-1} dw and 12 to 1670 ng g^{-1} dw reported by Beg et al., (2003) and de Mora et al., (2010) respectively. Again, and similar to the data presented in the current study, the most contaminated sites were those close to the SIA. Such values are still relatively low when compared to other industrialised locations around the world where ∑PAH concentrations at impacted sites can exceed 40,000 ng g^{-1} dw (Woodhead et al., 1999; Nicolaus et al., 2015).

Internationally recognised sediment quality guidelines (SQGs) can be used to assess the potential toxicological impact of the concentrations of PAHs detected in Kuwaiti marine sediments. For the purpose of the assessment here the Effects Range Low (ERL) / Effects Range Medium (ERM) methodology, as proposed by NOAA were applied (Long et al., 1995; Long and MacDonald 1998). In a regulatory context, where SQGs are to be used as informal (non-regulatory) benchmarks to aid in the interpretation of sediment chemistry (Long et al., 1995), this becomes complicated when a large number of individual PAH compounds are determined, as is usually the case. This has led to separate ERL/ERM derived SQGs being set for "Low molecular weight (LMW) PAHs" and "High molecular weight (HMW) PAHs" (Gorham-Test, 1999). In this context, LMW PAH includes the 2- and 3-ring PAH compounds naphthalene, monomethyl naphthalenes, acenaphthene, acenaphthylene, fluorene, phenanthrene and anthracene, primarily oil-derived compounds; HMW PAH includes the 4- and 5-ring PAH compounds fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[a]pyrene and dibenz[a,h]anthracene, primarily combustion-derived compounds.

Although a wider suite of PAHs is determined routinely for both licensing and monitoring purposes, these can be considered as toxicity markers for the PAHs as a whole. The ERL and ERM concentrations applied are given in

Table 6-7. The ERL and ERM values for LMW PAH are lower than those for HMW PAH as they have a higher acute toxicity. Using this approach, no site in this study breached the ERL or ERM values and therefore it is proposed that in relation to PAH contamination no adverse effects to marine biota is expected.

6.6.4.4 Conclusions

The results confirm previous studies that indicate that PAH contamination is not wide spread in Kuwait's marine environment. Hotspots of contamination occur close to the SIA. However, the concentration of PAHs at all the sites examined are thought to be low when compared to other regions globally. All the concentrations measured were below international SQGs and are not thought to pose any toxicological risk to exposed marine species.

Site	TPC µg g^{-1} dw	∑LMW ng g^{-1} dw	∑HMW ng g^{-1} dw	∑30PAH ng g^{-1} dw	% oil	% combustion
C1	39.0	13.2	15	190.1	72	28
C2	20.0	8.5	13	102.9	57	43
C3	18.0	5.6	6	29.2	39	61
C4	23.0	10.8	14	58.7	44	56
C5	32.0	13.6	17	101.0	60	40
C6	13.0	3.4	11	50.9	56	44
C7	4.2	6.3	3	45.9	74	26
C8	13.0	8.7	5	74.7	71	29
C9	19.0	7.4	10	85.0	60	40
C10	27.0	8.3	11	89.6	58	42
C11	30.0	8.7	9	91.7	63	38

Site	TPC µg g^{-1} dw	∑LMW ng g^{-1} dw	∑HMW ng g^{-1} dw	∑30PAH ng g^{-1} dw	% oil	% combustion
C12	15.0	4.5	6	53.7	58	42
C13	9.0	4.2	4	66.1	57	43
C14	12.0	7.8	7	75.4	57	43
C15	9.1	6.5	1	18.1	89	11
C16	17.0	7.8	2	36.5	79	21
C17	10.0	8.3	5	74.0	65	35
C18	32.0	6.9	5	45.9	65	35
C19	15.0	9.0	7	73.9	63	38
C20	12.0	3.4	3	34.3	56	44
C21	7.0	4.2	3	40.7	59	41
C22	19.0	8.4	7	78.3	60	40
C23	41.0	8.3	18	115.7	45	55
C24	105.0	7.7	43	192.4	33	67
C25	17.0	3.7	54	140.8	28	72
C26	744.0	36.2	277	1286.0	35	65
C27	32.0	21.2	22	122.0	45	55
C28	29.0	10.2	6	97.7	67	33
C29	4.7	1.9	2	12.9	40	60
Assessment criteria						

Site	TPC µg g^{-1} dw	∑LMW ng g^{-1} dw	∑HMW ng g^{-1} dw	∑30PAH ng g^{-1} dw	% oil	% combustion
ERL	-	552	1,700	-	-	-
ERM	-	3,160	9,600	-	-	-

Table 6-7: Total petroleum content (TPC), Low Molecular Weight (LMW: naphthalene, methyl naphthalene, acenaphthylene, acenapthene, fluorene, phenanthrene, anthracene) and High Molecular Weight (HMW: fluoranthene, pyrene, benz[a]anthracene, chrysene, benzo[a]pyrene, ibenz[a,h]anthracene) PAHs and ∑PAH concentrations from marine sediments around Kuwait. ERL and ERM taken from Gorham-Test, (1999).

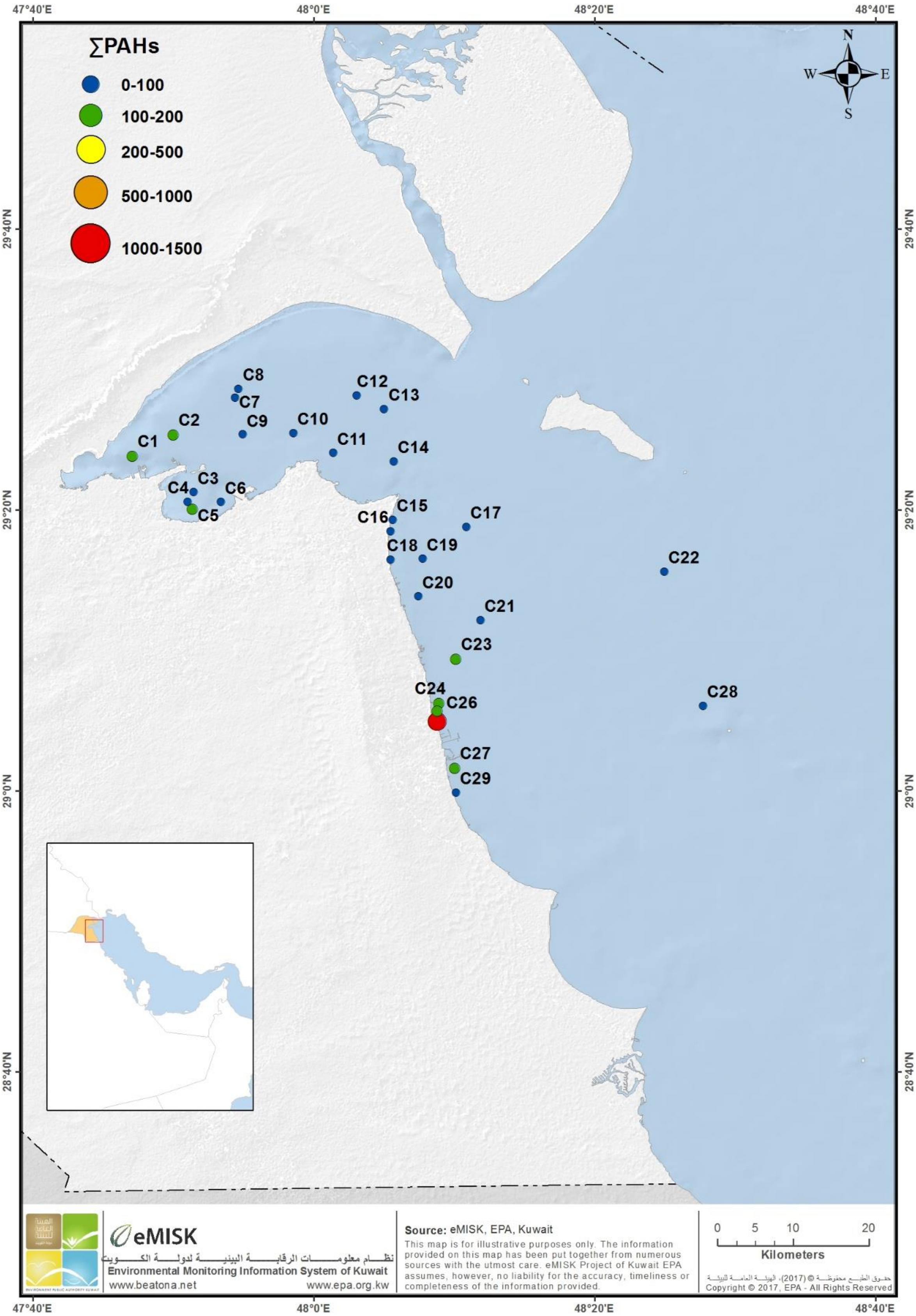


Figure 6-7: 30PAH sediment concentrations from locations around Kuwaiti's marine environment (ng g-1 dry weight).

6.6.5 Sediment contamination: Polychlorinated biphenyls (PCBs)

6.6.5.1 Background

Polychlorinated biphenyls (PCBs) are a group of 209 man-made chemical compounds which were mainly used in electrical equipment until their manufacture was banned in the mid-1980s because of environmental and biological concerns about their toxicity and accumulation (OSPAR, 2008). It has been estimated that globally 1.3 million tonnes of PCB compounds have been produced (Breivik *et al.*, 2007). PCBs are chemically inert and stable when heated. These properties contribute greatly to PCBs having become environmental contaminants which are regulated by the Stockholm Convention of Persistent Organic Pollutants (POPs). The chemical inertness and heat stability properties that make PCBs desirable for industry also protect them from destruction when the products in which they are used are discarded. Such properties also enable PCB residues to persist in the marine environment, where once associated with fine particulate matter that can be transported on the wind or ocean currents. PCBs are known to bioaccumulate with the highest concentrations found at the top of the food chain. Studies have shown PCBs to be associated with toxic effects in marine mammals, including reproductive impairment, development and immuno-toxicity and cancers. Therefore, while the ban on their use and manufacture has led to large reductions in releases they remain an environmental pollutant of concern. Remaining sources include electrical and hydraulic equipment containing PCBs, waste disposal, redistribution of historically contaminated marine sediments.

6.6.5.2 Current state of Knowledge Kuwait

Only a limited number of studies have previously attempted to study the levels of PCB contamination in Kuwait's marine environment. Intensive sampling has been conducted around the Shuaiba Industrial Area (SIA) where the concentration of ∑PCBs varied by two orders of magnitude across the survey location, ranging from 0.40 to 81.7 ng g^{-1} dw (Gevao et al., 2006). These were deemed to be comparable to other international studies of industrialised coastal sediments reviewed by the authors. The study also indicated that the highest values were associated with sample locations close to water effluents originating from industries based in the SIA, suggesting that inputs from the port and not atmospheric deposition of PCBs may be the most significant source of contamination in this area of Kuwait (Gevao et al., 2006). The depositional history of PCB sediment contamination has also been studied in a number of cores collected from Sulaibikhat Bay (located in Kuwait Bay). The data, which reflected sediment deposition over 37 ± 5 year period, demonstrated a peak in ∑PCB concentrations around 1991, after which values fall by 15x to the current sediment-water interface concentrations of around 2 ng g^{-1} dw (Gevao et al., 2012). The 1991 peak was attributed to the sudden input of PCBs following the destruction of a number of PCB-laden electrical transformers that occurred towards the end of the Gulf War. Declines after this date would match the findings of other international studies which have linked such reductions to the global bans placed the manufacture and use of PCBs. A more recent study conducted under the auspices of ROPME has examined sediment PCB contamination at a number of locations within Kuwait's marine waters. ∑PCB concentrations of 0.1 – 5 ng g^{-1} dw were reported by de Mora et al., (2010) and these were considered to be generally low by global standards. With respect to chlorinated hydrocarbons derived from industrial sources, relatively high levels of PCBs (based on the sum of Aroclors) were observed at only a few stations such as those near Doha Bay (2 ng g^{1} dw) and Sulaibikhat Bay (8 ng g^{1} dw). The concentrations of PCBs in the sediments from all other locations were not exceptional, and comparable to levels reported elsewhere in the region (Fowler, 2002; de Mora et al., 2004).

6.6.5.3 Assessment approach and findings

PCB concentrations were measured in sediment samples from monitoring stations throughout Kuwait's marine environment (

Table 6-8 Figure 6-8). Concentrations of PCB contaminants in the sediment were compared with various action limits, to investigate whether any adverse effects in benthic biota were likely to be expected as a consequence of their presence at levels detected with Kuwaiti sediments. The data was assessed against two sets of assessment criteria: The Background Assessment Criteria (BAC) and the Environmental Assessment Criteria (EAC). The EAC values were set so that concentrations below the EAC should not cause chronic effects in sensitive marine species and present no significant risk to the environment. BACs are used to assess whether concentrations are close to zero for man-made substances (OSPAR, 2008). When undertaking this analysis, PCB concentrations were normalised (2.5%) against the <2mm total organic carbon (TOC) content

∑ICES 7 CBs concentrations ranged from <0.7 to 42 ng g^{-1} dw, with concentrations at most stations <1 ng g^{-1} dw. The three highest concentrations of 42, 7.3 and 2.1 ng g^{-1} dw were at the closely grouped stations C24, C26 and C25, adjacent to the SIA a 'known' contaminated site in Kuwait and confirming previous findings (Gevao et al., 2006). The only other result >1 ng g^{-1} dw was at C18, where the ∑ICES 7 CBs concentration was 2.2 ng g^{-1} dw. Generally, PCB concentrations were very low, with 20 out of 29 stations below the limits of quantification (LOQs).

Using the assessment approach as adopted in the OSPAR guidelines the concentrations below BACs would be considered to have high (excellent) environmental status. Concentrations significantly below EACs could be considered to have good environmental status and those above, a poor environmental status (OSPAR, 2008). A site is deemed to have poor environmental status if more than one ICES7 CB congeners fails its respective EAC. Within the current data set examined in this SOMER report 26 out of 29 stations were below BAC for all 7 PCB congeners. The exceptions were C18 and C26, which had a few congeners between BAC and EAC, and C24 which was above EAC for CB101 and CB118. According to the OSPAR guidelines, most stations had 'good' environmental status for all

ICES 7 CBs and 'good' status overall, except station C24, which had 'poor' environmental status for CB28 and CB118 and therefore 'poor' status overall (Figure 6-8).

6.6.5.4 Conclusions

The results confirm previous studies that indicate that PCB contamination is not wide spread in Kuwait's marine environment. At the majority of sites examined (28/29) it is thought than no adverse effects due to PCB contamination is expected. The only site where PCB contamination is of concern is close to the SIA, which confirms the findings of previous work.

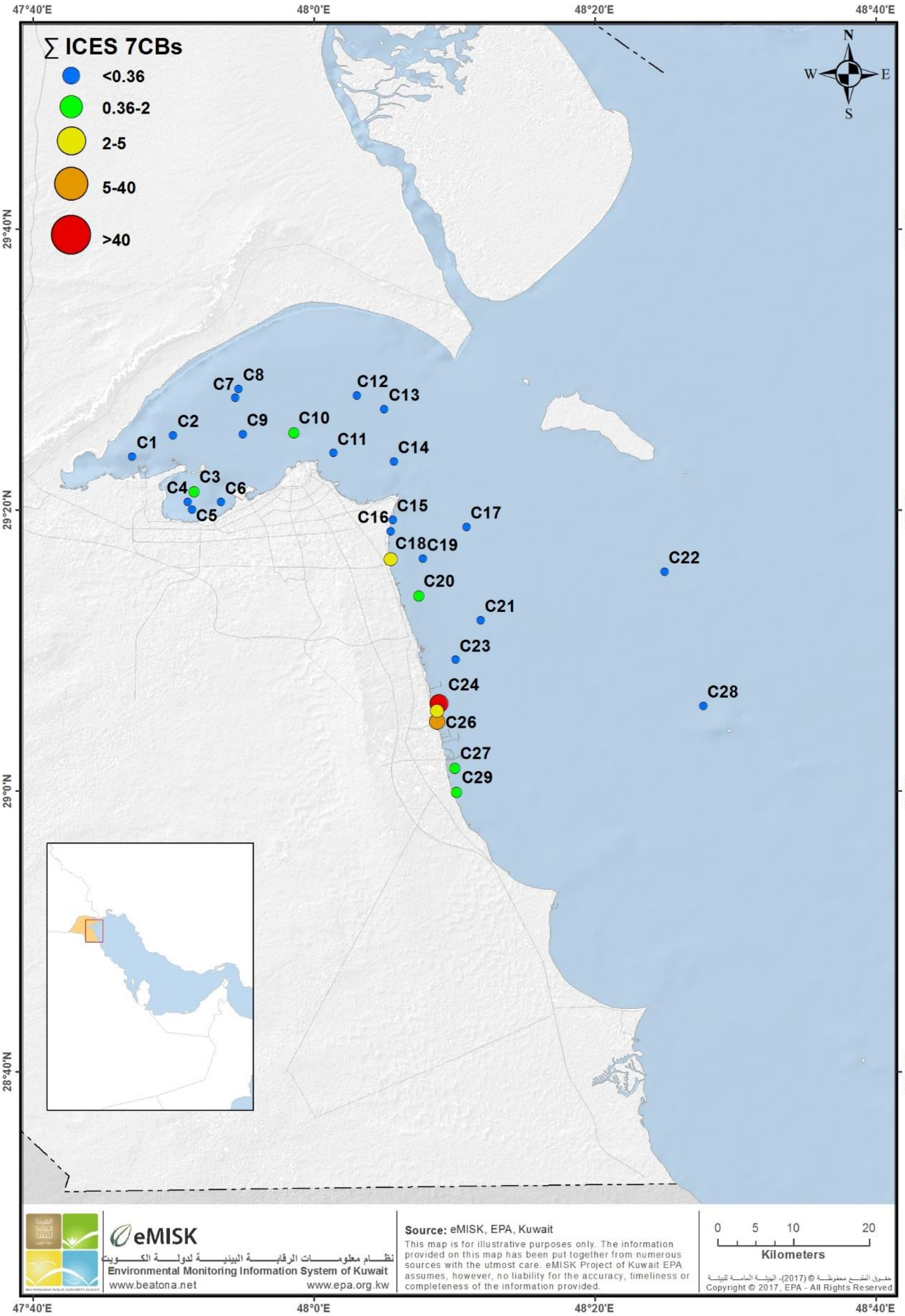


Figure 6-8: Spatial distribution of ∑ICES 7CBs. Concentrations are expressed as ng g^{-1} dw basis normalised to 2.5% TOC content and assessed against Environmental Assessment Concentrations (EAC).

Site name	CB #28	CB #52	CB #101	CB #118	CB #153	CB #138	CB #180	∑25 PCBs
C1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C3	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	<0.1	1.31
C4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C7	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C8	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C9	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C10	<0.1	<0.1	0.13	0.12	0.16	0.23	0.18	2.0
C11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C13	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.366
C14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C15	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C17	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C18	<0.1	<0.1	0.36	0.27	0.55	0.5	0.4	4.23
C19	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C20	<0.1	<0.1	<0.1	<0.1	<0.1	0.14	<0.1	1.34
C21	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25

Site name	CB #28	CB #52	CB #101	CB #118	CB #153	CB #138	CB #180	∑25 PCBs
C22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C23	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C24	<0.1	1.97	6.87	5.33	10.08	9.8	7.81	78.4
C25	<0.1	0.17	0.47	0.38	0.35	0.52	0.16	3.76
C26	<0.1	0.34	0.93	0.83	1.82	1.89	1.44	14.07
C27	<0.1	<0.1	<0.1	<0.1	<0.1	0.16	<0.1	1.36
C28	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.25
C29	<0.1	<0.1	<0.1	<0.1	<0.1	0.14	<0.1	1.34
Assessment criteria								
BAC	0.22	0.12	0.14	0.17	0.15	0.19	0.1	-
EAC	1.7	2.7	3.0	0.6	7.9	40	12	-

Table 6-8: OSPAR assessment criteria for ICES 7CBs in sediments. ICES 7CBs: CB28, 52, 101, 118, 153, 138 & 180) and ∑25 PCBs (sediment (ng g^{-1} dry weight (dw), normalised to 2.5% TOC)

6.6.6 Sediment contamination: Metals

6.6.6.1 Background

The State of Kuwait has witnessed major economic, social and industrial development following the discovery and exploitation of its vast oil reserves (Al-Abdulghani et al., 2013). Similar to other countries, which comprise the Gulf Co-operative Council (GCC), the rapid expansion of Kuwait's industrial sector has mainly occurred around its coasts (Al-Rifaie et al., 2007; Al-Abdulghani et al., 2013). As a consequence, a variety of contaminants have been discharged directly into the marine environment, including metals (Al-Sarawi et al., 2015). Metals are released into the marine environment, from both anthropogenic and natural inputs and are strongly affiliated with particulate matter (Zhang et al., 2007). Sediment bound contamination has been shown to affect the water quality and resulting impacts have been documented in a range of marine invertebrate and vertebrate species (Leung et al., 2005; Damiano et al., 2011). Many metals (e.g. copper, zinc, chromium) occur naturally in the environment and even without inputs from industry, significant concentrations would occur owing to the underlying natural geology of the region. In many cases where metals occur in naturally high concentrations, local species will have adapted to tolerate the elevated background levels.

6.6.6.2 Current state of Knowledge Kuwait

In a comprehensive study undertaken to assess the impact of the 1991 Gulf War, attempts were made to develop estimates of natural background levels (upper permissible limits) of trace metal concentrations in the fine faction (63µm) of Arabian Gulf sediments. Using data collected from both surface grab samples and sediments cores from 71 sites across the whole Gulf, guideline background levels were established for: zinc (Zn) 30-60, lead (Pb) 15-30, Cadmium (Cd) 1.2-2.0, nickel (Ni) 70-80, magnesium (Mn) 300-600, iron (Fe) 10,000-20,000, vanadium (V) 20-30, and copper (Cu) 15-30 µg g^{-1} dw (Al-Abdali et al., 1996). Work to characterise metal contamination has been undertaken along a series of stations extending from Kuwait Bay and down along the coast south towards the border with Saudi Arabia (Metwally et al., 1997). The highest levels of Ni (range: 12 – 253 µg g^{-1} dw), Pb (range 72 -261 µg g^{-1} dw) and V (range: 25 – 179 µg g^{-1} dw) were observed close to industrial centres around Doha, Fintas and Shuaiba. Concentrations of all three of these metals levels fell considerably at sites removed from any known point sources of pollution (Metwally et al., 1997). Higher levels of metal contamination in samples collected from Kuwait Bay were reported by Beg et al., (2003). This was attributed to an influx of contamination via the Shatt Al-Arab, following the draining of marshes in Iraq to the north. Al-Sarawi et al., (2002) carried out an assessment of trace metal pollution in bottom sediments collected from Sulaibikhat Bay, located in the south western corner of Kuwait Bay. Analysing samples collected over both summer and winter periods Al-Sarawi et al., (2002) documented mean values of Cu 27, Fe 24,900, Zn 73, Ni 13, Pb 6, V 68, Cr 56, and Mn 187 µg g^{-1} dw. The findings were similar to other data for the region and the concentrations of Cr, Pb, and Mn were all within their natural background levels (Al-Abdali et al., 1996). However, at certain locations within Sulaibikhat Bay the levels of Cu, Zn, Fe, and V were considered to be indicative of polluted sediment (Al Sarawi et al., 2002). The authors attributed this to the recent increase and diversification of the anthropogenic inputs impacting this area, which includes illegal sewage discharges and an outfall from a major desalination facility. A further detailed study of trace metal contamination in Sulaibikhat Bay has been recently undertaken, during which thirty four sites were examined for particle size analysis, calcium carbonate and total organic carbon (TOC) content, along with the determination of eight trace metals (Alshemmari et al., 2010). The levels recorded ranged across the Sulaibikhat Bay (Hg 0.1-1.4, As 1-7, Cd 2-4, Co 4-20, Cr 65-190, Cu 10-100, Ni 25-130, Zn 10-290 and Pb 2-32 µg g^{-1} dw). While some of the concentrations recorded were clearly within the natural background levels previously reported by Al-Abdali et al., (1996), the authors assessed the values obtained against a number of published sediment quality guidelines (SQGs) from Canada, USA and Sweden. Their analysis concluded that levels of As, Co and Pb were below any concentration thought to pose a toxicological threat to species living in Sulaibikhat Bay. Whereas at certain sites within the bay levels of Hg, Zn, Cu and Cr exceeded at least one of the SQGs applied (Alshemmari et al., 2010). However, the validity of using SGQs developed in other regions (such as Effects Range Low (ERL) and Effects Range Median (ERM) proposed by Long et al., (1998) still need to be validated as in certain cases the background concentrations for the region as proposed by Al-Abdali et al., (1996), actually exceed the established SQG criteria.

Previous work has investigated specific issues related to metal pollution in Kuwait Bay. Inventories of the total (T-) and methyl (Me) Hg contamination in the bay has been undertaken by both Al-Majed and Preston, (2004) and Bou-Rabee et al., (2006). These studies focused on sediment contamination resulting from inputs from a salt and chlorine plant (SCP) situated in Shuwaikh Port. It was estimated that during its operational life (1964-1985) approximately 20 tonnes of mercury was discharged into the coastal zone around the port area. In addition, there were airborne releases recorded from the plant (estimated to be 400 kg) and other local sources of Hg pollution, such as untreated sewage, which discharged directly into Kuwait Bay. Al-Majed and Preston, (2004) undertook an extensive spatial survey of surface and core sediment samples, which encompassed 103 different locations around Kuwait Bay. The study identified hot spots of T-Hg contamination (>180 ng g^{-1} dw) close to the former SCP outfall, with concentrations falling away to relatively low concentrations <30 ng g^{-1} dw at the northern side of the bay (Al-Majed and Preston, 2004). The presence of hot spots close to the former SCP outfalls in surface sediments was assumed to be due to remobilisation of historic contamination by dredging and mine sweeping activity (Bou-Rabee et al., 2006). Similar patterns were observed for MeHg, although the ratio of T-Hg to MeHg decreased with increasing distance from the SCP outfall. Analysis of several sediment cores indicated that historic contamination was mainly restricted to sites close to the Shuwaikh Port area, with the highest concentrations corresponding to peak production of the SCP during the mid-1980s. Calculations made by the authors on the upper 40 cm of sediments from Kuwait Bay estimated a total of ~22.5 tonnes of T-Hg and ~80 kg MeHg to be present in the area studied, which correlated well with the known inputs over the life time of the plants operation (Al-Majed and Preston, 2004).

6.6.6.3 Assessment approach and findings

The concentration of trace metals Cr (108.2 – 429.0 µg g^{-1} dw), Ni (86.2 – 169.3 µg g^{-1} dw), Cu (21.7 – 53.4 µg g^{-1} dw), Zn (55.3 – 140.7 µg g^{-1} dw), As (3.1 – 7.4 µg g^{-1} dw), Cd (<0.178 – 0.5 µg g^{-1} dw), Pb (9.7 – 32.2 µg g^{-1} dw) and Hg (<0.097 - <0.236 µg g^{-1} dw) were assessed against the Background Assessment Concentrations (BACs) and Effects Range Low/Effects Range Median (ERL and ERM) concentrations (Table 6-9; Figure 6-9). BACs were developed by the Oslo and Paris Commission (OSPAR) for testing whether concentrations are near background levels (OSPAR, 2008) and ERL/ERM concentrations, which were developed for the US EPA, are founded on a large database of sediment toxicity and benthic community information (Long et al., 1995; Long and McDonald, 1998). The ERL/ERM methodology derives SQGs representing, respectively, the 10th and 50th percentiles of the effects dataset. This approach is a reasonably conservative one, and has been partially validated using North American field data. Concentrations below the ERL rarely cause adverse effects in benthic marine organisms. All stations depicted levels of Ni above the ERM concentrations. This observation indicates either the mineralogical background is naturally high in Ni or the sampling area is highly enriched with Ni due to surrounding industrial activities over the years. Station C16 showed Cr concentration above ERM level, this station is situated north of a known sewage outfall. The remaining stations exhibited levels of Cr above ERL concentration but remained below ERM level. Most of the stations that showed levels of Cu above ERL (but below ERM concentration) are located by the shoreline. There appears to be a decreasing gradient in concentrations as the stations are further offshore, indicating a possible dilution effect from industrial activities. The majority of the stations recorded levels of Zn and Cd below the OSPAR BACs, with a few stations depicting levels below ERL concentrations. Interestingly, levels of As and Pb were below OSPAR BACs for all stations. Concentrations of Hg were below the method limit of detection for all stations, indicating levels of Hg either below ERL or below OSPAR BACs. In general, no difference was observed when concentrations recorded from stations located near industrial areas (e.g. C1, C24-C27) were compared against levels of metals from residential areas (e.g. C15-C18).

Previous studies have used sediment core data to estimate the natural background levels of metals present in different regions of the Gulf's marine environment (Al-Abdali et al., 1996). Using this approach, background levels were proposed for: Zn 30-60, Pb 15-30, Cd, 1.2-2.0, Ni 70-80, Mn 300-600, Fe 10,000-20,000, V 20-30, and Cu 15-30 µg g^{-1} dw (Al-Abdali et al., 1996). The levels of sediment contamination by metals in this present study are similar to those previously reported for Kuwait's marine environment. For example, the concentrations of metal reported by Metwally et al., (1997) included hot spots of contamination around known anthropogenic inputs (Ni range: 12.3 – 235.6; Pb range 71.55 -261.4 and V range: 24.8 – 179.41 µg g^{-1} dw). Al-Sarawi et al., (2002) and Alshemmari et al., (2010) carried a similar assessment of trace metal pollution in bottom sediments collected from of Sulaibikhat Bay, which corresponds to sites C3-C6 in the present study. Broadly similar concentrations of metals were again reported and while the authors noted that concentrations of some metals were clearly within the natural background levels, as previously reported by Al-Abdali et al., (1996), the values of others exceeded a number of published SQGs (Alshemmari et al., 2010).

6.6.6.4 Conclusions

The data present along with that of Alshemmari et al., (2010) highlights the caution that must be applied when applying commonly used SQGs, such as ERLs and ERMs proposed by NOAA (Long and McDonald, 1998) or Interim Sediment Quality Guideline (ISQG) and Probably Effect Levels (PEL) proposed by CCME (1999). For selected metals the background concentrations for the region as proposed by Al-Abdali et al., (1996), actually exceed the established ERL/ERM or ISQG/PEL criteria. For example, in the current study the values of Ni recorded across the whole of Kuwait range from 86.2 – 169.34 µg g^{-1}, which exceeds the ERL (20.9 µg g^{-1}) and ERM (51.6 µg g^{-1}) SQGs. However, the proposed background concentration for Ni for the Gulf has been set at 70–80 µg g^{-1}, which clearly is above both the ERL and ERM threshold. A similar situation also occurs for Cu and Cd, where proposed background concentrations exceed the ERL and/or ISGL. Therefore, until a fully validated series of region specific guidelines are developed the current ERLs/ERMs or ISQG/PEL should purely be used to indicate levels below which biological effects are not thought to occur and any exceedances need to be investigated further taking into account natural background levels of contamination and the sensitivity of resident marine species.

Table 6-9: Levels of metal contamination (μg g^{-1} dw) in marine sediments collected from Kuwait. Assessments conducted alongside OSPAR BAC (OSPAR, 2008), ERLs/ ERM (Long and MacDonald, 1998) and ISQG/PEL (CCME, 1999) criteria.

Site name	Cr	Ni	Cu	Zn	As	Cd	Pb	Hg
C1	212.6	169.1	49.5	123.1	6.9	0.5	14.3	<0.109
C2	148.6	169.3	44.0	111.5	4.9	0.3	13.8	<0.106
C3	241.3	142.2	34.6	100.0	4.9	0.3	10.8	<0.113
C4	267.2	126.2	29.5	91.6	3.6	0.2	11.8	<0.113
C5	176.7	122.3	30.4	90.8	4.0	0.3	11.3	<0.104
C6	162.1	138.2	41.7	108.9	4.5	0.3	13.8	<0.113
C7	181.4	166.5	31.9	87.3	5.4	0.3	10.5	<0.102
C8	157.9	142.1	27.3	67.5	4.2	0.3	13.8	<0.222
C9	154.6	157.5	37.9	103.9	4.0	0.3	12.6	<0.108
C10	182.4	159.0	34.0	99.7	4.9	0.2	12.7	<0.12
C11	202.5	147.4	29.7	92.4	5.3	0.3	12.3	<0.102
C12	152.6	145.3	26.8	81.1	4.6	0.3	10.3	<0.108
C13	144.0	127.8	22.6	66.8	4.2	0.2	12.6	<0.204
C14	159.8	148.1	23.9	69.4	5.0	0.3	9.7	<0.097
C15	183.6	144.7	53.4	140.7	7.2	<0.391	15.9	<0.235
C16	429.0	121.8	34.7	98.4	5.4	0.3	15.3	<0.113
C17	140.6	135.8	25.4	67.6	4.2	0.2	12.9	<0.213
C18	171.6	140.1	33.8	90.8	4.2	0.3	13.0	<0.114

Site name	Cr	Ni	Cu	Zn	As	Cd	Pb	Hg
C19	154.2	147.4	28.0	85.7	3.8	0.2	11.0	<0.112
C20	155.2	142.3	49.6	108.9	3.4	0.2	14.9	<0.113
C21	145.9	119.7	21.7	55.3	5.3	0.2	11.8	<0.214
C22	125.3	129.5	24.6	66.5	3.1	<0.192	13.7	<0.23
C23	148.8	161.6	30.4	85.1	4.9	0.3	11.8	<0.112
C24	144.7	122.4	39.6	90.3	3.5	<0.178	19.1	<0.213
C25	135.1	120.6	38.7	82.4	5.2	0.2	33.2	<0.236
C26	108.2	86.2	41.1	80.9	5.2	0.2	20.7	<0.228
C27	135.1	124.6	51.9	94.2	7.4	0.2	29.8	<0.235
C28	143.7	149.9	29.2	74.7	3.7	0.3	12.6	<0.229
C29	228.0	109.2	28.3	78.7	4.4	<0.183	17.4	<0.219
Assessment criteria								
Regional background	-	70-80	15-30	30-60	-	1.2-2.0	15-30	
OSPAR BAC	81	36	27	122	25	0.31	38	0.07
ERL	81	20.9	34	150	8.2	1.2	46.7	0.15
ERM	370	51.6	270	410	70	9.6	218	0.71
ISQG	52.3	-	18.7	124	7.24	0.7	30.2	0.13
PEL	160	-	108	271	41.6	4.2	112	0.7

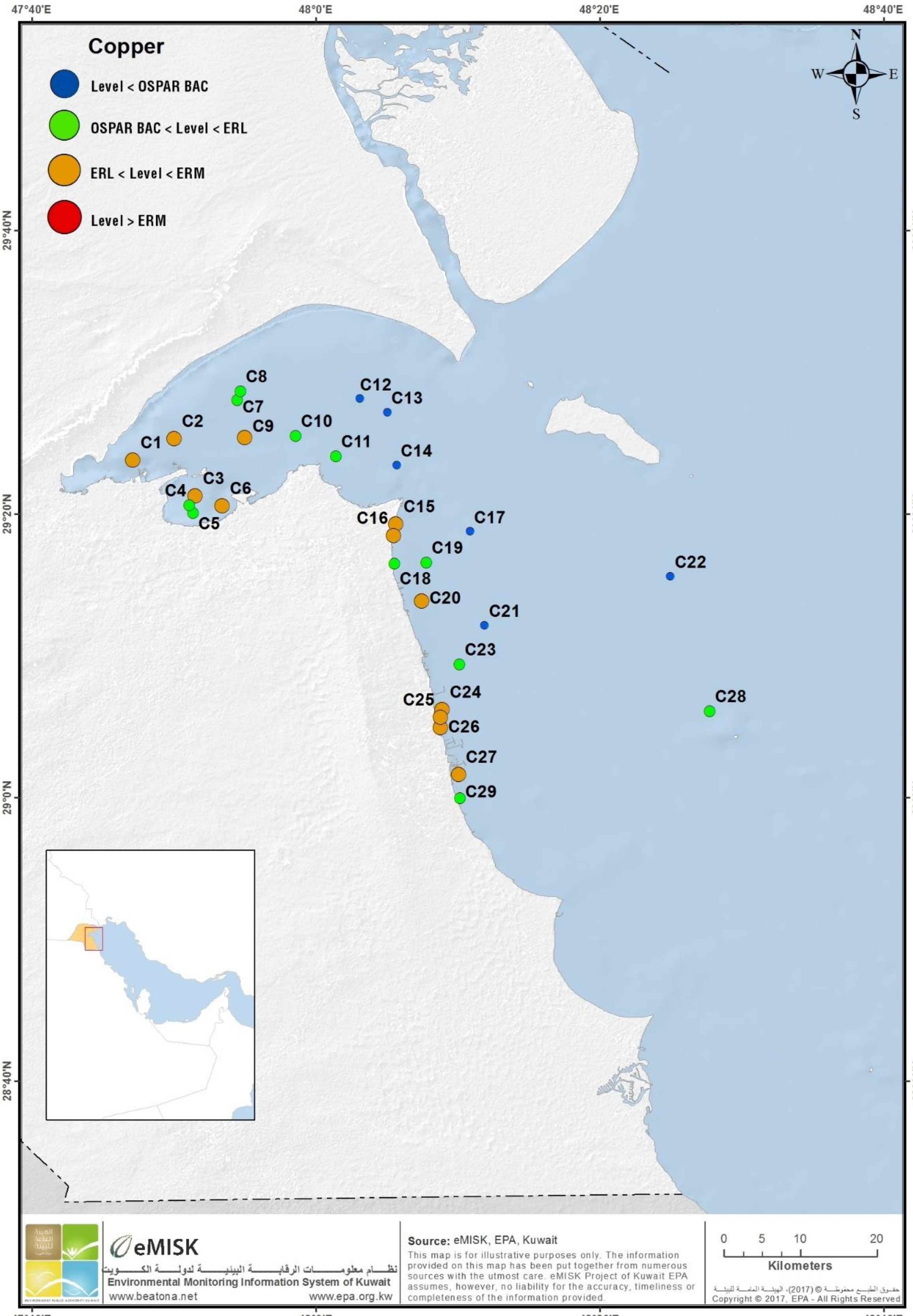


Figure 6-9: Spatial distribution of metals. Concentrations are expressed as µg g^{-1} dw basis.

6.6.7 Sediment contamination: Polybrominated diphenyl ethers (PBDEs),

6.6.7.1 Background

Polybrominated diphenyl ethers (PBDEs), are a group of 209 different man-made compounds, which have mainly been used as flame-retardants in plastics, furniture, textiles and electronic products. Three major commercial PBDE products have been produced, pentaBDE, octaBDE and decaBDE, which contain mixtures of different PBDEs. Globally DecaBDE is the most widely used PBDE. They may enter the environment via emissions from manufacturing processes, recycling wastes, run-off from waste disposal sites and evaporation from various products that contain PBDEs. Their occurrence is now widespread and they have been detected in all aquatic and terrestrial departments. Recent research has also documented their presence in remote regions (far from direct sources of input), such as the Canadian Artic, which indicates long-range transport in the air. PBDE are known to have effects on the nervous, immune and endocrine systems in birds and mammals. Due to their persistence they have the potential to accumulate in the flesh of fish and shellfish. In regions such as the Europe, penta- and octaBDE have been banned or restricted since 2004, while similar management measurers came into force for decaBDE in 2008. Since 2009 they have also been included in the Stockholm Convention.

6.6.7.2 Current state of Knowledge Kuwait

Data on sediment contamination by PBDEs are extremely scarce within Kuwait and the wider Gulf region. The data available in Kuwait is restricted to a handful of studies (Gevao et al., 2006; Gevao et al., 2014). These compounds are of environmental concern due to their persistence, high lipophilicity and resistance to degradation (Allchin et al., 1999). As such they quickly bind to suspended particles upon entering the marine environment and are transported to bottom sediments where they may enter the aquatic food chain and pose a toxicological risk (Gevao et al., 2006a; Gevao et al., 2009). PBDEs share many characteristics with other persistent organic pollutants (POPs), including PCBs. The first study of its kind conducted in Kuwait was undertaken by Gevao et al. (2006), who documented the degree of PBDE contamination in a series of transects close to the Shuaiba Industrial Area (SIA). Data indicated that BDE 153, 154 and 183 were the most dominant forms of PBDEs detected with BDE 183 typically accounting for 60% of the congener mix. Values of PBDEs ranged from 0.1 to 4 ng g^{-1} dw. A further study, covering offshore sediment samples locations along with those within Kuwait Bay, reported a generally lower level of PBDE contamination (Gevao et al., 2014). The analysis of core samples taken at the entrance to Kuwait Bay demonstrated that detectable levels of PBDE first appeared above background concentrations in the mid-1950s with peak inputs associated with periods of military conflict (Gevao et al., 2014).

6.6.7.3 Assessment approach and findings

Studies conducted by the EPA indicate that the Σ11 PBDE concentrations (excluding BDE 209) ranged from 0.2 to 0.35 ng g^{-1} dw, with the highest concentration again at C26, located adjacent to the SIA (Table 6-10; Figure 6-10). The next highest concentrations at C13, C1 and C24 were all around 0.15 ng g^{-1} dw. Elsewhere PBDE concentrations were also generally very low, with 17 out of 29 stations containing levels below the limit of quantification (LOQ) of the methods employed. BDE209 concentrations ranged from 0.1 to 8.9 ng g^{-1} dw, with the highest concentration at C1, and other high values of 7.9 and 5.7 ng g^{-1} dw at the SIA 'hotspot' sites C26 and C24.

Table 6-10: PBDE sediment contamination (ng g^1 dw). ∑11 BDEs combination of BDE# 17, 28, 47, 66, 85, 99, 100, 138, 153, 154, 183. Where value was below limit of quantification (LOQ) a value of ½ LOQ was used to calculate ∑11 BDEs.

Site Code	BDE 17	BDE 28	BDE 47	BDE 66	BDE 85	BDE 99	BDE 100	BDE 138	BDE 153	BDE 154	BDE 183	∑11 BDEs	BDE 209
C1	<0.04	<0.04	0.049	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.22	8.879
C2	<0.02	<0.02	0.023	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.12	0.801
C3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	0.977
C4	<0.02	<0.02	0.024	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.12	1.479
C5	<0.02	<0.02	0.036	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.14	1.254
C6	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	1.173
C7	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	<0.1
C8	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	<0.1
C9	<0.02	<0.02	0.024	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.12	1.073
C10	<0.02	<0.02	0.021	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.12	0.829
C11	<0.02	<0.02	0.025	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.13	0.82
C12	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	0.471
C13	<0.02	<0.02	<0.02	0.052	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.15	0.177

Site Code	BDE 17	BDE 28	BDE 47	BDE 66	BDE 85	BDE 99	BDE 100	BDE 138	BDE 153	BDE 154	BDE 183	∑11 BDEs	BDE 209
C14	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	0.264
C15	<0.02	<0.02	0.024	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.12	<0.1
C16	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	0.546
C17	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	<0.1
C18	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	1.028
C19	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	1.01
C20	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	0.458
C21	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	<0.1
C22	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	0.13
C23	<0.02	<0.02	0.024	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.12	0.998
C24	<0.02	<0.02	0.042	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.14	5.7
C25	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	0.43
C26	0.147	<0.02	0.086	<0.02	<0.02	<0.02	<0.02	0.036	<0.02	<0.02	<0.02	0.35	7.92
C27	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	<0.1
C28	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	<0.1
C29	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.11	1.15

6.6.7.4 Conclusions

In global terms the concentrations of PBDEs reported for Kuwait's marine environment are low with values often an order of magnitude below those reported for locations in Northern Europe (Allchin et al., 1999), Japan (Watanabe and Sakai, 2003) and China (Luo et al., 2007). Where hotspots of contamination are detected they are associated with known point sources of contamination (e.g. SIA). However, BDE209 was also elevated at other locations around the coast (e.g. Doha Bay) and are new ‘hotspots’ for the region requiring further study.

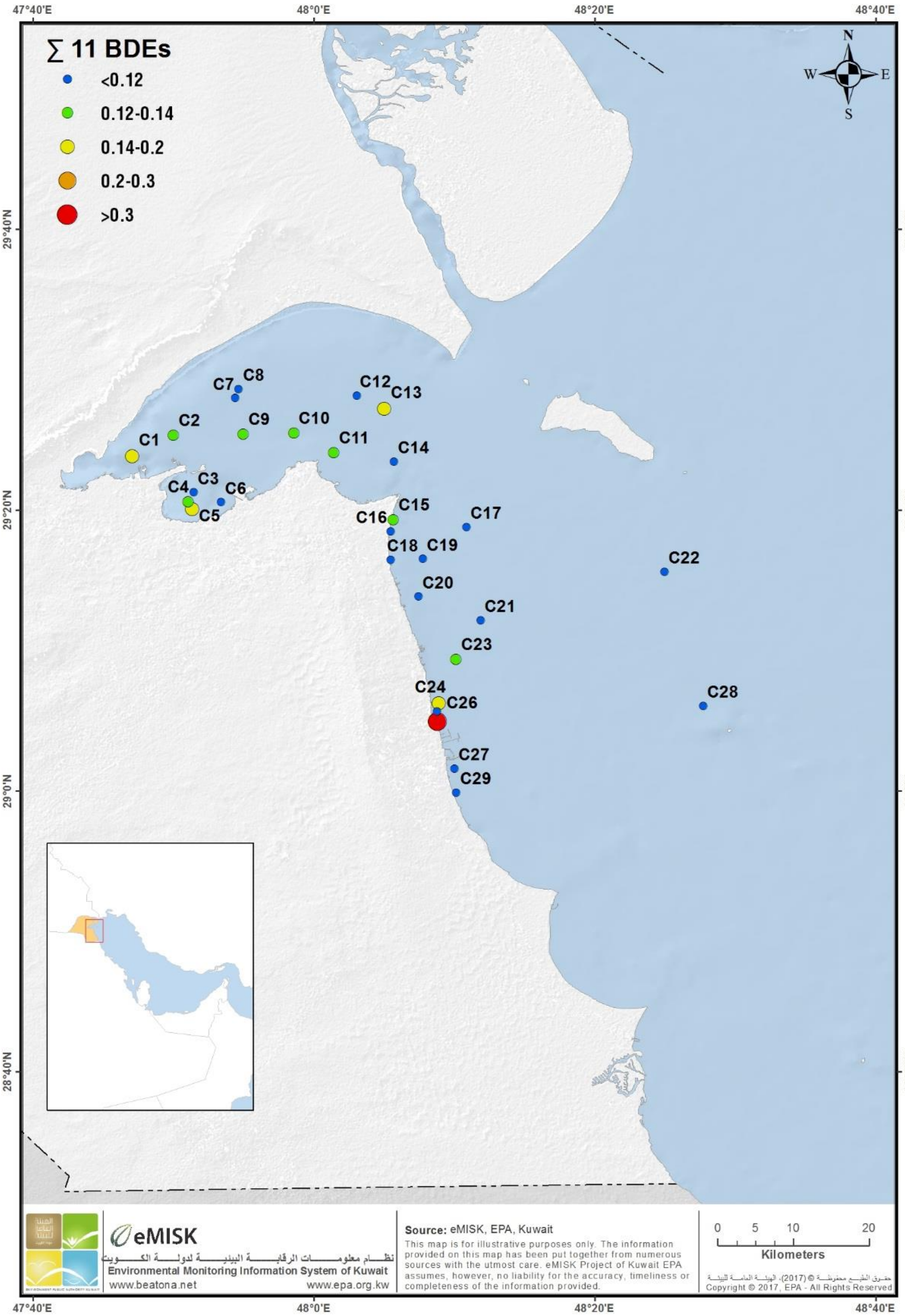


Figure 6-10: Spatial distribution of ∑11 BDEs. Concentrations are expressed as ng g^{-1} dw basis

6.6.8 Sediment: Faecal sterols

6.6.8.1 Background

Sewage and industrial contamination are key issues in the management of water quality in Kuwait's marine waters (Al-Ghadban et al., 2002; Al-Abdulghani et al., 2013). Recently, there has been interest in the use of biological and chemical markers to help quantify sewage pollution in coastal marine waters (González-Oreja and Saiz-Salinas, 1998; Readman et al., 2005; Adnan et al., 2012). One of these chemical markers is coprostanol (5β-cholestan-3β-ol), which comprises 40%-60% of the total sterols in human faecal waste, and has been used widely around the globe as a marker of sewage contaminated (Al-Omran, 1998; Readman et al., 2005; Reeves and Patton, 2005; Adnan et al., 2012; de Abreu-Mota et al., 2014). Coprostanol like many other faecal sterols is hydrophobic, readily associating with particulate matter in sewage effluent, and consequently is incorporated into bottom sediments (Tolosa et al., 2014). Studies have demonstrated that coprostanol concentrations correlate well with coliform bacteria, especially in sewage contaminated environments (Isobe et al., 2002). Under anoxic conditions coprostanol is relatively persistent and any decline will invariably be associated with sediment transport. In tropical waters coprostanol, along with other selected sterols, are considered to be a more robust and reliable marker of sewage pollution than faecal coliform enumeration (Carreira et al., 2004; Adnan et al., 2012; Tolosa et al., 2014). To gain a full understanding of sewage input and source, the analysis of coprostanol is also assessed in relation to other sterols. For example, epicoprostanol, an isomer of coprostanol, can be used as a marker to indicate the level of treatment or age of the faecal matter (Readman et al., 2005; Martins et al., 2014; Tolosa et al., 2014). This compound is a by-product of sewage treatment systems and will only occur in low concentrations if the sewage is not treated or only partially treated, increasing in anoxic environments such as sewage sludge (Martins et al., 2014). Ratios, such as the coprostanol/cholesterol index can also be used to assess the degree of sewage pollution (Leeming et al., 1996; Isobe et al., 2002).

6.6.8.2 Current state of Knowledge Kuwait

A large proportion of Kuwait's population is situated along its coastal margin. This has led to the accumulation of high levels of bacterial contamination (e.g. faecal coliforms and faecal streptococci) associated with discharges of domestic sewage (Lyons et al., 2015). Results indicate that bacterial counts regularly breach regional water quality guidelines and at some locations may pose a threat to human health (see **Error! Reference source not found.**). Faecal sterols have previously been used to identify widespread sewage contamination of coastal locations close to effluent outfalls (Saeed et al., 2012; Saeed et al., 2015).

6.6.8.3 Assessment approach and findings

The spatial distributions of sterols in marine sediments from Kuwait are displayed in Table 6-10.

Detectable concentrations of coprostanol were recorded in all sediment samples analysed, with values ranging from 29 to 2420 ng g^{-1} dw. A number of authors have previously attempted to set thresholds for coprostanol in sediments and it has been proposed that levels between 10-100 ng g^{-1} dw are indicative of uncontaminated environments, values greater than 100 ng g^{-1} dw indicate sewage contamination, while those in excess of 500 ng g^{-1} dw signify gross sewage pollution (Grimalt et al., 1990; Gonzales-Oreja and Saiz-Salins 1998; Tolosa et al., 2014). Of the 29 sites sampled 3 exceeded the 500 ng g^{-1} dw coprostanol threshold, indicating significant sewage pollution at these locations (Table 6-11, Figure 6-11Figure 6-7). Sites C1, in Doha Bay (1880 ng g^{-1} dw), C5 (601 ng g^{-1} dw) and C6 (2420 ng g^{-1} dw) in Sulaibikhat Bay are all close to known sewage inputs. In particular, C5 and C6 are located close to an area known to contain a number of illegal sewage discharges, such as the Al-Ghazali storm drain. A further 6 sites breached the 100 ng g^{-1} dw threshold (105 – 329 ng g^{-1} dw), including C3 and C4 also situated in Sulaibikhat Bay. The sites breaching the 100 ng g^{-1} threshold in Kuwait Bay (C9, C10, C11), were up to 10 km offshore and are far from any obvious point sources of pollution, while C24 was close inshore adjacent to known outfalls.

Levels of coprostanol in the present study are generally lower than the 50 – 45,000 ng g^{-1} dw (Al-Omran, 1998), 108 – 45,228 ng g^{-1} dw (Saeed et al., 2012) and <LOD – 39,428 ng g^{-1} dw (Saeed et al., 2015) previously published for sediments samples collected in Kuwait. However, the extremely high concentrations of coprostanol reported by these studies were mainly observed at sites along the shoreline, close to known sewage outfalls (50 – 200m from point source). Whereas the current assessment presented here represents coastal sediments collected from sites ranging from 100m to >30km from shore. The earlier work of Al-Omran, (1998) reported high levels of coprostanol from inter-tidal sediments all around the coast of Kuwait (> 500 ng g^{-1} dw). Significantly, the highest concentrations (4080 - 45,060 ng g^{-1} dw) were detected in the region of Sulaibikhat Bay, next to the illegal Al-Ghazali storm drain (close to sites C3-C6 in the current assessment). The elevated level of sewage pollution in Sulaibikhat Bay is also supported by the recent finding of Saeed et al., 2015, who also recorded concentrations of coprostanol up to 23,803 ng g^{-1} dw at sites in the bay. This highlights the long-term, chronic nature of outfalls discharging into this area, which has been contributing significant amounts of raw sewage and pollution into the south-western corner of Kuwait Bay for several decades. The levels of contamination detected in Sulaibikhat Bay during the study of Al-Omran, (1998) actually matched or exceeded the levels of coprostanol reported in sediments collected from beaches during the 2009 -2011 Mishref sewage crisis (Saeed et al., 2012). It is also worthy to note that Saeed et al., (2012), reported the highest values of coprostanol (41,228 ng g^{-1} dw) at Al-Fintas, which is also where a review of the EPA microbial water quality data recorded extremely high episodic pulses of microbial contamination (see section 5.5.1).

A number of previous studies have developed and applied diagnostic indexes of faecal contamination, such as the ratio of coprostanol/cholesterol, where values >0.2 are considered sewage contaminated while those >1.0 are considered highly contaminated (Readman et al., 2005; Saeed et al., 2012; Tolosa et al., 2014). When applying these criteria to the present dataset we can conclude that C6 was highly contaminated, C1, C5, C9, C15-16 and C24 were moderately contaminated and C2-4, C7-14, C17-23 and C25-29 were relatively uncontaminated (Table 6.11; Figure 6.12). By comparison the earlier work of Saeed et al., (2012) documented gross sewage pollution at all sites studied around Kuwait with coprostanol/cholesterol ratios at all sites, except Failaka Island (0.07 – 0.12), ranging between 0.31 – 5.41. Interestingly, Saeed et al., (2012) documented gross sewage contamination using the coprostanol/cholesterol ratio at sites directly impacted Mishref sewage crisis (Al Bedda 0.84 – 5.41) and Al-Messala (1.27 – 4.11). These sites are close to C15 and C16 in the present study, suggesting that sewage contamination is still present, several years after the Mishref sewage discharge had stopped. Such assumptions are supported by the continued exceedance in microbial water quality parameters at these locations (section 5.5.1).

The concentration of epicoprostanol has also been used as an indicator of the level of sewage treatment of the faecal material (Mudge and Sequel 1999; Readman et al., 2005; Tolosa et al., 2014). Epicoprostanol is usually only present in trace amounts in human sewage, but increases as the effluent pass through sewage treatment processes (McCalley et al., 1981). Concentrations in the present study ranged from 5.37 - 511 ng g^{-1} dw (Table 6.11). It has been proposed that sediments containing untreated sewage display an epicoprostanol/coprostanol ratio <0.2, while values >0.8 are related to treated sewage (primary or secondary) (Mudge and Sequel 1999). The lowest epicoprostanol/coprostanol ratio were detected at C6 (0.08), C5 (0.17), C16 (0.18) and C15 (0.19), indicating that raw sewage predominated at these locations. All other samples had a ratio <0.8 indicating that the majority of sediments received untreated or partially treated sewage, which is supported by the number of S-sites continuing to fail faecal coliform, faecal streptococci and E.coli water quality assessment criteria (see section 5.6.1 and section 5.6.2).

A number of authors have applied the 5β/(5β + 5α) colestan-3β-ol index (coprostanol/(coprostanol + cholestanol)) ratio, where it has been proposed that values <0.3 represent un-contaminated areas, whereas >0.7 indicates sewage contamination (Grimalt et al., 1990; Readman et al., 2005; Reeves and Patton, 2005). However, a number of studies have suggested that a 5β/(β + 5α) cholestan-3β-ol index ratio of >0.7 for sewage contaminated sediments may be too high when applied to tropical environments, due to the faster bioconversion of cholesterol to stanols in these climatic zones (Isobe et al., 2002; Tolosa et al., 2014). It is also known that the 5β/(5β + 5α) cholestan-3β-ol ratio can be influenced by direct inputs of cholestanol from phytoplankton and zooplankton, leading to intermediate

5β/(5β + 5α) cholestan-3β-ol ratios (<0.7), being masked by the high presence of phytosterols (Carreira et al., 2004; Tolosa et al., 2012). This also appears to be a factor when reviewing the 5β/(5β + 5α) cholestan-3β-ol index ratio for the current study where only one sample (C6) has a value >0.7, thus indicating sewage contamination (

)

6.6.8.4 Conclusions

The review of water microbiological data demonstrates that sewage contamination has been a chronic problem for many years in Kuwait (see section 5.6.1). This is attributed to the failure of the sewage treatment network to keep pace with demands for capacity driven by rapid population growth that has almost tripled since 1975 (Al-Zaidan et al., 2013). This assumption is supported by the other faecal sterol contamination data available for Kuwait, which suggests wastewater discharge regimes have been chronically pulling the environment since the 1990's (Al-Omran, 1998; Saeed et al., 2012; Saeed et al,.2015). The current data presented for faecal sterol contamination of sediments indicates that there is still wide spread contamination of Kuwait's coastal zone. In particular, sites located in western Kuwait Bay (around Sulaibikhat Bay and Doha Bay are particularly impacted), with data indicating untreated sewage is being discharged in significant quantities. It is thought that the illegal connections and discharges via the Al-Ghazali storm drain may account for a considerable amount of this pollution. Therefore, the planned improvements in the wider sewage treatment system may not result in an improvement in these locations where discharges by-pass the official treatment network.

Table 6-11: Concentration of sterols analyzed in Kuwait coastline (ng g^{-1} all dry weight); cop: coprostanol (5β-cholestan-3β-ol); e-cop: epicoprostanol (5β-cholestan-3α-ol); cope: Coprostanone (5β-cholestan-3β-one); chol-e: cholesterol (Cholest-5en-3β-ol); chol-a: cholestanol (5α-cholestan-3β-ol); cop/chol-e: coprostanol/cholesterol; e-cop/cop: Epicoprostanol/Coprostanol; 5β/(5β + 5α): (Coprostanol)/(Coprostanol + Cholestanol).

Station	Cop	E-cop	Cope	Chol-e	Chol-a	Cop/Chol-e	E-cop/Cop	(5β/(5β + 5α)
C1	1880	511	663	2670	3530	0.70	0.27	0.35
C2	91.4	50.4	88.6	845	623	0.11	0.55	0.13
C3	209	81.5	179	1510	468	0.14	0.39	0.31
C4	239	68.3	127	2850	404	0.08	0.29	0.37
C5	601	102	230	1080	994	0.56	0.17	0.38
C6	2420	183	446	1530	785	1.58	0.08	0.76

Station	Cop	E-cop	Cope	Chol-e	Chol-a	Cop/Chol-e	E-cop/Cop	(5β/(5β + 5α)
C7	37.5	18.7	68.4	449	211	0.08	0.50	0.15
C8	55.9	23.9	17.8	602	641	0.09	0.43	0.08
C9	124	52.3	89.4	645	988	0.19	0.42	0.11
C10	112	42.9	101	1320	531	0.08	0.38	0.17
C11	105	44.8	140	1350	437	0.08	0.43	0.19
C12	62.4	27.3	428	1960	418	0.03	0.44	0.13
C13	45.3	18.3	195	1230	285	0.04	0.40	0.14
C14	54.4	22.7	56.9	582	446	0.09	0.42	0.11
C15	29.0	5.37	1.93	107	34.3	0.27	0.19	0.46
C16	70.3	12.4	26.8	204	36.1	0.34	0.18	0.66
C17	41.9	17.1	19.6	440	357	0.10	0.41	0.11
C18	96.8	26.6	54.8	3250	160	0.03	0.27	0.38
C19	61.2	23.8	165	993	396	0.06	0.39	0.13
C20	59.4	14.7	34.8	609	210	0.10	0.25	0.22
C21	38.3	14.2	18.5	349	252	0.11	0.37	0.13
C22	50.5	22.0	18.9	416	506	0.12	0.44	0.09
C23	79.0	30.0	51.9	889	512	0.09	0.38	0.13
C24	329	82.0	264	1540	298	0.21	0.25	0.52
C25	31.9	9.18	17.2	1370	119	0.02	0.29	0.21
C26	97.1	38.6	79.9	963	514	0.10	0.40	0.16
C27	33.2	9.00	7.97	1410	102	0.02	0.27	0.25
C28	45.0	20.7	37.4	747	410	0.06	0.46	0.10

Station	Cop	E-cop	Cope	Chol-e	Chol-a	Cop/Chol-e	E-cop/Cop	(5β/(5β + 5α)
C29	29.2	6.81	7.03	1560	69.4	0.02	0.23	0.30

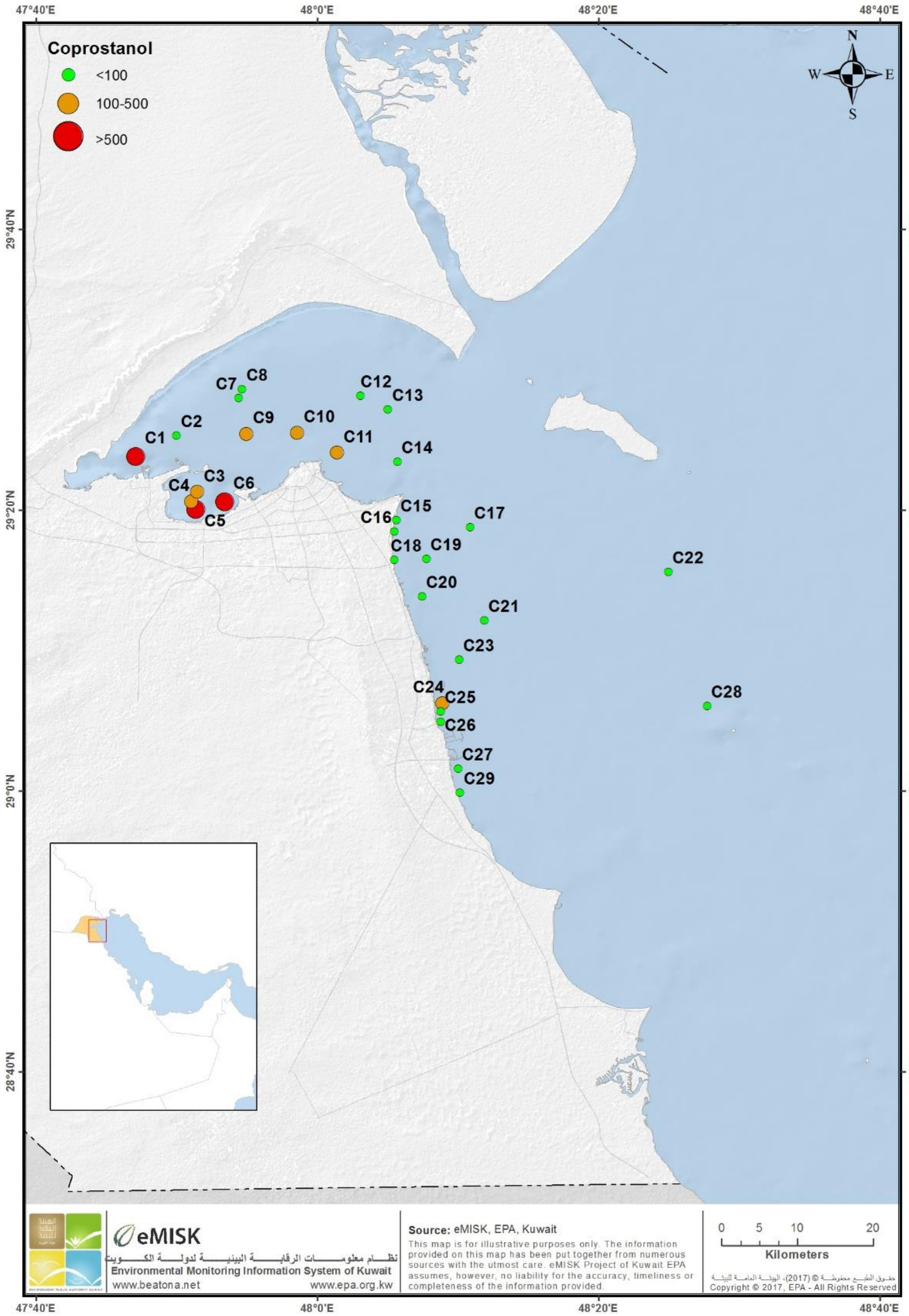


Figure 6-11 Concentrations of coprostanol in marine sediments from Kuwait. Assessed against thresholds < 100 ng g-1: uncontaminated; >100 - <500 ng g-1: sewage contaminated; >500 ng g-1: gross sewage contamination (all dry weight).

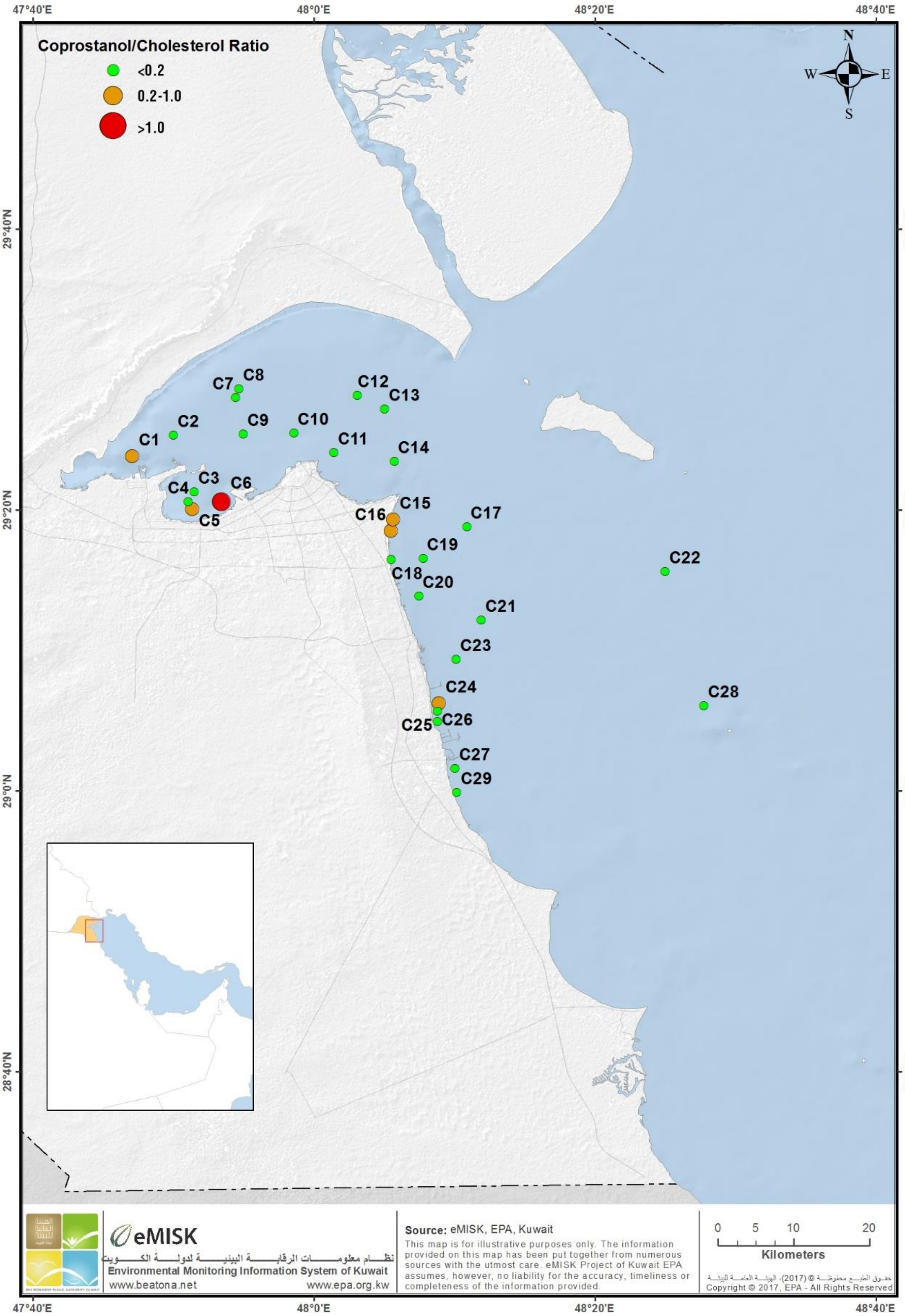


Figure 6-12: Spatial distribution of coprostanol/cholesterol index in marine sediments. Values >0.2 are considered sewage contaminated while those >1.0 are considered highly contaminated.

6.6.9 Contamination in biota: Environmental Health

6.6.9.1 Background

Chemical contamination of marine biota can be useful indicator in the assessment of overall ecosystem health. Marine species can accumulate chemical contaminants from their surroundings (water, sediment or via the food chain), which in some cases can reach levels that pose a toxicological threat. There have been a series of studies which have reported on the degree of chemical contamination present in marine biota collected from Kuwait. This section reports on those which have focused on studies which have attempted to assess the levels on contamination in relation to wider environmental health. For studies related to the safety of seafood in relation to protecting human consumers see section 5.6.2

6.6.9.2 Current state of Knowledge Kuwait

Primary producers are known to accumulate a wide range of chemical contaminants and are therefore considered important keystone species in the assessment of contaminant bioavailability and impact in marine ecosystems. A series of studies have attempted to investigate the temporal and spatial distribution of metal contamination in phytoplankton collected from sites impacted by differing levels of industrialization (Bu-Olayan et al., 2001a; Bu-Olayan et al., 2001b; Bu-Olayan and Thomas, 2004). The reported concentrations of metals differed across the sites examined, with samples collected near to the industrialised shoreline at Doha (Zn: 51 – 75, Cu: 49 – 67, Ni: 19 – 56, Pb: 33 – 62 µg g^{-1}), displaying the highest level of contamination (Bu-Olayan et al., 2001a). Interestingly, analysis of phytoplankton abundance at Doha indicated a greater richness than that seen at other sites examined, which was attributed to the local environmental conditions and increased nutrient inputs in the area (Bu-Olayan et al., 2001b). Levels of Hg have also been assessed in zooplankton, collected in a series of transects across Kuwait Bay. Concentrations were generally low with Total Hg (T-Hg) ranging from 0.004 – 0.035 µg g^{-1} dw, while methyl Hg (MeHg) accounted for <25% of T-Hg and the authors noting concentrations observed were lower than those previously reported from North America (Al-Majed and Preston, 2000).

Various invertebrate bio-monitoring species have been used to assess metal contamination in the marine environment around Kuwait. Studies conducted pre- and post the Gulf war investigated levels of metal contamination in the marine gastropod snail (*Lunella coronatus*) and pearl oyster, (*Pinctada radiate*) (Bu-Olayan and Subrahmanyam, 1997). The concentrations of Cu, Ni and Zn all significantly increased in samples collected after the war when compared to those collected before the onset of hostilities. Work conducted by Tarique et al., (2012) assessed the suitability of the bivalve clam *Amiantis umbonella* to monitor metal (Cd, Cr, Cu, Hg, Ni, Pb, V and Zn) contamination in coastal sediments collected from Kuwait Bay. An impacted site and remote reference location was sampled in parallel with the impact site located close to a desalination and power plant in the Doha region of Kuwait Bay (western end of the bay). The authors observed significant differences between sites for the majority of metals and tissues examined, with clam kidney tissue the most reliable in reflecting external (water and sediment) metal contamination at the sites investigated. Importantly, this study also highlighted the inter-site differences that occur in bivalve soft tissues, related to both environmental and biological factors. Differences were observed in the size of the organs, with gonad weight five-fold lower at the contaminated site compared to those collected from the reference site, with authors suggesting the differences could have accounted for some of inter-site observed differences in metal contamination (Tarique et al., 2012). Further studies using *A. Umbonella*, along with the analysis of sediment and porewater samples, reported a decreasing trend in metal concentration in a 5 km gradient moving away from a point source discharge associated with a power/desalination plant in Kuwait Bay (Tarique et al., 2013). The majority of the metals examined in the tissues of *A. Umbonella* were more highly correlated (r2 0.54-0.73) with those in the burrow sediment than in porewater. Elevated metal contamination was also detected in the gills of the gastropod *Cerithium scabridum* collected from around Doha with the authors attributing this to the influence of industrial effluents from the power and desalination industries in the area (Bu-Olayan and Thomas, 2001).

The effect of size and sex on the metal content of lobsters (*Thenus orientalis*) has been determined in animals caught from two locations between Fahaheel and Al-Kiran along the coastline of Kuwait (Bu-Olayan et al., 1998). Significant differences between male and female lobsters were observed for mean As, Se and Hg concentrations. Concentrations of Cu, Ni Pb V and Zn have also been reported in the marine crab, *Macrophthalmus depressus* (Bu-Olayan and Subrahmanyam, 1998) and *Portunus pelagicus* (Al-Mohanna and Subrahmanyam, 2001) with the highest concentrations associated with coastal sites close to industrialised areas of Kuwait Bay. Trace metal concentrations (Zn >Fe >Cu >Ni >Cr >Pb >Hg) have been reported in sea bream (*Acanthopagrus latus*), with higher concentrations of metals found in the sequence of liver > gills > muscles, irrespective of the season and location of sampling (Bu Olayan and Thomas 2014).

As part of the large regional study undertaken by de Mora et al., (2010) relatively low concentrations of TPH contamination have been reported for samples of Venus clam (*Circentia callipyga*) collected from Doha Bay, Al-Bida'a and Khiran, with values ranging from 15 – 40 µg g^{-1} dw (TPH equiv, ROPME oil). de Mora et al., (2010) noted differences between the sediment and clam PAH profiles collected from Doha Bay, suggesting that sediment bound contaminants were not the primary source of biota contamination. In the same study concentrations of TPH (2.3 – 2.7 µg g^{-1} dw TPH equiv, ROPME oil) and ∑PAH 2.9 - 3.5 ng g^{-1} dw reported in Hamoor (*Epinephelus coioides*) were considered unexceptional and representative of uncontaminated fish by the authors. Concentrations of PAHs have been measured across both summer and winter months in the whole body of three fish species native to Kuwaiti waters (Beg et al., 2009). Seasonal differences in concentrations were observed both within and between the species examined, with the profile of high and low molecular weight PAHs indicating they were mainly from a petrogenic origin (Beg et al., 2009). Similar to the work of Beg et al., (2009) the profile of detected PAHs indicated petrogenic sources of contamination with naphthalene (2 – 156 ng g^{-1}) and phenanthrene (5 – 89 ng g^{-1}) in particular the most abundant.

There is little information available on the bioaccumulation of other POPs in marine biota from Kuwait. The comprehensive study by de Mora et al., (2010), reported on levels of a range of chlorinated hydrocarbons, including PCBs, in the Venus clam and Hamoor. While concentrations reported were not indicative of high levels of contamination, they were still elevated compared to other samples collected from the Gulf region. Information on PBDEs, a class of chemicals commonly used as flame retardants, is limited to a handful of papers. Their accumulation in edible fillets from three commercially important fish species, yellowfin sea bream (*Acanthopagrus latus*), Klunzingers mullet (*Liza klunzingeri*) and tongue sole (*Cynoglossus arel*) has been reported in two areas, within and outside Kuwait Bay (Gevao et al., 2011). The dominant congeners detected were BDE 28, 47, 99 and 100, which accounted for >90% of the total PBDEs detected. The authors reported no significant difference between fish collected from inside or outside Kuwait Bay. Among the three species however the concentrations in mullet (∑PBDE range 11-160 ng g^{-1}) were significantly higher than sea bream (∑PBDE range 3 – 62 ng g^{-1}), although no differences were seen when compared with tongue sole (∑PBDE range 5 – 190 ng g^{-1}) (Gevao et al., 2011). Such differences between species may have reflected a combination of factors, including the ecological niche of the individual species and their average tissue lipid content (which is far higher in mullet). The authors under took a comparison exercise using lipid normalised concentrations of BDE 47. Values ranged between 1.8 – 48 ng g^{-1}, within fish collected from Kuwaiti waters, which were comparable to other international studies conducted in Greenland and the Baltic Sea. The values were however, an order of magnitude below those concentrations detected in fish close to a known production source in the UK and USA (Allchin et al., 1999; Hale et al., 2001; Gevao et al., 2011).

6.6.9.3 Assessment approach and findings

Samples of the Giant sea catfish (*Arius thalassinus*) were collected from a number of offshore locations (Figure 6-13). The concentrations of metals in the liver of *A. thalassinus* are displayed in Table 6-12. No obvious differences were noted between pooled samples of fish from the different locations sampled. There are no current environmental assessment criteria for metals (other than those to assess risks posed to human health, as covered in Section 5.6.2) Surveys of sediment metal contamination have previously highlighted elevated levels of nickel and chromium in Kuwait Bay and coastal areas close to the sites used in this present study (see Section 6.6.6). However, these metals were not accumulated to any appreciable level in either muscle or liver of *A. thalassinus* samples (Ni range: <0.012 – 0.45 mg kg-1 and Cr 0.01 – 0.88 mg kg^{-1}). The levels of all other metals in sediments at the locations sampled in the current study were considered to be below any concentration likely to cause toxicological effects. The level of metals in fish collected from the Arabian Gulf has recently been reviewed (Naser et al., 2013). de Mora et al., (2004) reported heavy metal concentrations in liver of hamoor (*Epinephelus coioides*) and spangled emperor

(*Lethrinus nebulosus*). Levels of Cd in liver from fish from the UAE (7.19 – 9.94 mg kg-*1*) and Oman (109 – 195 mg kg^{-1}) were much higher than reported in the present study. The concentrations of Zn in liver of *A. thalassinus* (range 1199 – 1816 mg kg^{-1}) appear high, but are similar to levels reported in spangled emperor caught from locations in the UAE, Oman and Bahrain (de Mora et al., 2004). Such elevated concentrations may reflect the feeding habits of the fish concerned.

The levels of PCBs detected in liver of A. thalassinus were generally low (Table 6-13). Samples were normalized for lipid weight (lw) and analysed against European Union (EU) Environmental Assessment Criteria (EACs) (OSPAR, 2004), with results demonstrating all samples were below those which as thought to pose a toxicological risk (Table 3). There is little information available on the bioaccumulation of PCBs in other marine biota from Kuwait. A comprehensive study by de Mora et al., (2010) reported levels of a range of chlorinated hydrocarbons in flesh, including PCBs, in both the Venus clam (*Circentia callipyga*) and fish Hamoor. Similar to the data in the present study the levels reported by de Mora et al., (2010) were not considered to be indicative to high levels of PCB contamination.

6.6.9.4 Conclusions

The majority of studies would indicate that while Kuwait's marine environment has been subjected to a wide array of pollution events, the actual levels of contamination remains relatively low when compared to heavily industrialised regions elsewhere in the world. From the analysis of tissue contaminant burdens for a range of environmental pollutants it can be seen that while certain priority pollutants are detectable, they are generally low when compared to other studies from polluted environments globally. Other data collected would support these findings with the general level of disease in fish low (Section 6.6.10) and significant sediment contamination restricted to a few hotpots associated with industrial facilities (Section 6.6.3).

Table 6-12: Concentrations (pooled samples) of trace elements in the muscle (mg kg–1 wet weight) of Giant sea catfish (A. thalassinus) from Kuwait. Chromium (Cr), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Cadmium (Cd), Lead (Pb), Selenium (Se), Manganese

Site	Length (cm)	Body/liver weight (g)	Cr	Ni	Cu	Zn	As	Cd	Pb	Se	Mn	Fe	Hg
1	28.4 ± 2.7	290.2 ± 82.0 3.8 ± 1.2	0.26	0.22	2.5	1199	6.2	0.11	0.06	3.8	1.7	139	0.14
2	34.7 ± 3.8	334.5 ± 158.2 4.0 ± 0.8	0.08	0.18	2.4	1347	4.2	0.4	<0.027	4	0.99	107	0.18

Site	Length (cm)	Body/liver weight (g)	Cr	Ni	Cu	Zn	As	Cd	Pb	Se	Mn	Fe	Hg
3	38.3 ± 10.1	757.5 ± 545.3 9.8 ± 6.1	0.36	0.31	2.1	1816	5.4	3.8	0.19	4.7	1.4	231	0.53
5	29.3 ± 1.4	289.5 ± 56.8 3.8 ± 1.0	2.4	1.5	2.4	1481	4.1	0.12	0.07	4.2	2	130	0.17

Table 6-13: Concentrations (ng g-1 lw) of ICES7 PCBs in liver samples of the Giant sea catfish (*A. thalassinus*)

Site	CB#28	CB#52	CB#101	CB#118	CB#153	CB#138	CB#180
1	<2.79	3.51	<2.79	6.51	29.9	12.3	8.09
2	<3.46	<3.46	3.76	8.99	63.5	25.7	21.3
3	<2.39	5.65	<2.39	4.15	29.3	11.1	7.44
5	<2.07	5.42	2.37	4.8	25.2	10.2	6.28
EAC passive	64	108	120	24	1600	316	480

6.6.10 Biological Effects: Fish disease and biomarkers of chemical contaminant exposure

6.6.10.1 Background

Monitoring the health of species inhabiting aquatic systems can act as early warning indicators of environmental quality and potential human health effects resulting from the consumption of contaminated seafood. Biomarkers being either biochemical, physiological or histological are important to interpret the toxicity of the aquatic systems and have been widely used to assess environmental health (Costa et al., 2009; Stentiford et al., 2010;

Brooks et al., 2009; Hutchinson et al., 2013; Stentiford et al., 2014). Significantly, a number of field, laboratory and mesocosm studies have also demonstrated causal links between exposure to chemical contamination and the development of toxicopathic hepatic lesions (Hinton and Lauren, 1990; Hinton et al., 1992; Myers et al., 1998; Stehr et al., 2004). Following studies of this type, it is generally accepted that certain liver lesions in marine fish can be induced by environmental contaminants and that these represent an ecologically relevant biological endpoint of exposure to pollution. Thus histological and biochemical biomarkers provide a powerful tool for detection and characterisation of the biological end points of toxicant and carcinogen exposure (Hinton and Lauren, 1990; Hinton et al., 1992; Moore and Simpson, 1992). Furthermore, the utility of histopathology as a sensitive indicator of health in wild fish populations has been demonstrated in Europe and North America (Myers et al., 1998; Costa et al., 2009; Vethaak et al., 2009; Stentiford et al., 2010).

6.6.10.2 Current state of Knowledge Kuwait

Limited data is currently available for Kuwait with only one previous study documenting fish disease its marine waters (Stentiford et al., 2014). This EPA sponsored survey documented the level of disease in two species of fish, oriental sole (*Synaptura orientalis*) and the large-toothed flounder (*Pseudorhombus arsius*), along with invertebrate species the Jinga prawn, (*Metapenaeus affinis*) and the grooved tiger prawn (*Penaeus semisulcatus*). While the study documented a range of pathologies commonly associated with both carcinogenic and endocrine disrupting chemicals the actual prevalence was low and generally indicative of an un-polluted environment (Stentiford et al., 2014). Several studies have also been conducted to assess pollution status by using biomarkers of chemical exposure. Worked conducted by KISR utilised biomarkers of metal induced oxidative stress (Beg et al., 2015a), and PAH exposure (Beg et al., 2015b) to assess the biological impacts of marine pollution. The studies utilised the fish species yellow fin seabream (*Acanthopagrus latus*) and tonguesole (*Cynoglossus arel*) as sentinel species. While the general levels biomarker response was low the studies demonstrated how such approaches can be used to provide an integrated assessment of environmental health and as such they are important baseline surveys for the region (Beg et al., 2015a; Beg et al., 2015b)

6.6.10.3 Assessment approach and findings

Fish were collected from 5 stations located within Kuwait Bay and along the cities eastern coastline during April 2014 (Figure 6-13). Sites were selected to provide representative locations of environments within and external to Kuwait Bay and at which fishing had been conducted successfully in the past (e.g. free of bottom obstructions). In addition, due to the restriction of fishing within Kuwait Bay appropriate permissions were obtain from Public Authority for Agriculture Affairs and Fish Resources (PAAFR). Fishing at each location was undertaken using the Kuwait Institute of Scientific Research (KISR) vessel Bahith-II equipped with a stern otter trawl. From the samples of fish obtained a histopathological survey to assess the health of the bottom feeding Giant sea catfish (*Arius thalassinus*) and the pelagic Fourlined terapon (*Pelates quadrilineatus*) was undertaken. In addition, concentration of PAH bile metabolites in both *A. thalassinus* and *P. quadrilineatus* was also recorded to assess exposure to this common contaminant class. Full details of the methods employed are provided in Annex 6.3: Biological Effects: Fish disease and biomarkers of chemical contaminant exposure

6.6.10.4 Bile metabolites

Many vertebrates, including fish, rapidly biotransform PAHs into less lipophilic derivatives and as a consequence the detection of parent PAHs in tissue samples may under estimate the actual level of exposure (Beyer et al., 2010). As such bile represents the major excretion route for biotransformed PAH metabolites, and the quantification of different biliary PAH metabolites has been widely used as a marker for assessing recent PAH exposure in fish samples (Ariese et al., 1993; Bayer, et al., 2010). The levels of bile metabolites (expressed as 1-OH equivalents) for both *A. thalassinus* and *P. quadrilineatus* are displayed in Table 6-14. Levels differed among sites and between species. Site 2 contained considerably higher levels of PAH metabolites in *A. thalassinus* (477.5 ± 290.7 µg kg-1 wet weight 1-OH pyrene equivalents) than sites 1, 3 and 5. While this may indicate differences in exposure history between the fish collected it is difficult to determine the biological significance of the data as the analysis of sediment at all the locations indicated very low levels of PAH contamination (∑PAH 40.7 – 97.7 µg kg^{-1} dw) (Ecotoxicology and chemical screening of water samples

6.6.10.5 Background

Waste effluents from industry and domestic sewage are thought to make up the key components of marine pollution around Kuwait (Al-Ghadban et al., 2002; Al-Abdulghani et al., 2013; Al-Sarawi et al., 2015; Devlin et al., 2015). In particular, sewage contamination, both from illegal discharges or authorised releases, has been documented as being of particular concern (Lyons, et al., 2015; Saeed et al., 2012). Other effluents from power stations, desalination plants and industrial or commercial processes also reach the marine environment from various outfall around the coastline of Kuwait. Due to these various inputs, the waters of Kuwait Bay and the Gulf coast are subject to a constant stream of complex effluents varying in volume, constituents and flow. The problems associated with understanding the overall effect of these mixed effluents were recognised by the early 1990s (Matthiessen et al., 1993) as research showed that effluents from sewage treatment plants may also, through various chemical pollutants, demonstrate endocrine disruption effects (Desbrow et al., 1998; Harries et al., 1996; Jobling et al, 1998). These effects can be caused by natural steroids and also by industrial chemicals acting as endocrine disruptors (Aerni et al, 2004; Thomas et al, 2004). Interest in what is in these complex effluents has widened and a wide range of pharmaceutical and personal care product compounds have now been identified in the receiving waters (Prasse et al., 2010). The presence of pharmaceuticals is of particular concern, as they are designed to have specific biological effects and low concentrations, and so are thought to pose high risk to organisms in receiving waters (Gaw et al., 2014). Such effluents contain a complex mix of potential hazardous substances and current chemical monitoring programmes are only capable of measuring a relatively small proportion of the total contaminants present. Predicting the risk such complex mixtures pose to both environmental and human health has been one of the key issues facing environmental managers in the 21st century (Backhaus and Karlsson, 2014; Backhaus et al, 2011). Effective biological assays can provide data on the overall effects of a complex mixture, and help to target impacted sites without any pre-knowledge of what chemicals might be present. Finding the right combination of suitable biological and chemical analysis can give the capability to monitor for both specific and unknown pollutants. One effective screening assay for effluent based contamination is the yeast estrogen screen (YES) (Routledge and Sumpter, 1996). This is a tool for investigating the potential for steroid and steroid mimicking chemicals to be present in environmental samples, and gives a measure of the overall effect of active steroid-like chemicals. It is a widely accepted bioassay and has been used in many countries to look at contamination in effluents, rivers, estuaries and marine areas (Balaam et al, 2010; Galluba and Oehlmann, 2012; Thomas et al., 2004). In addition, the general toxicity of effluent samples can be effectively assessed using various invertebrate bioassay tests. One such test commonly employed in environmental surveys is the 48hr oyster embryo bioassay, which has shown to be a sensitive indicator of both seawater and effluent toxicity (Thain, 1991; Lyons et al., 2013).

6.6.10.6 Current state of Knowledge Kuwait

It is known that Kuwait's marine environment is subject to pressures arising from both industrial and sewage effluents. However, to date little work has been conducted to assess the toxicological risk these may pose to both environmental and human health. The only published work to date used a microbial based toxicity test (MicroTox™) to identify areas of Kuwait Bay and the Northern Gulf where extracts obtained from sediment samples elicited a toxic response (Beg and Al-Ghadban, 2003).

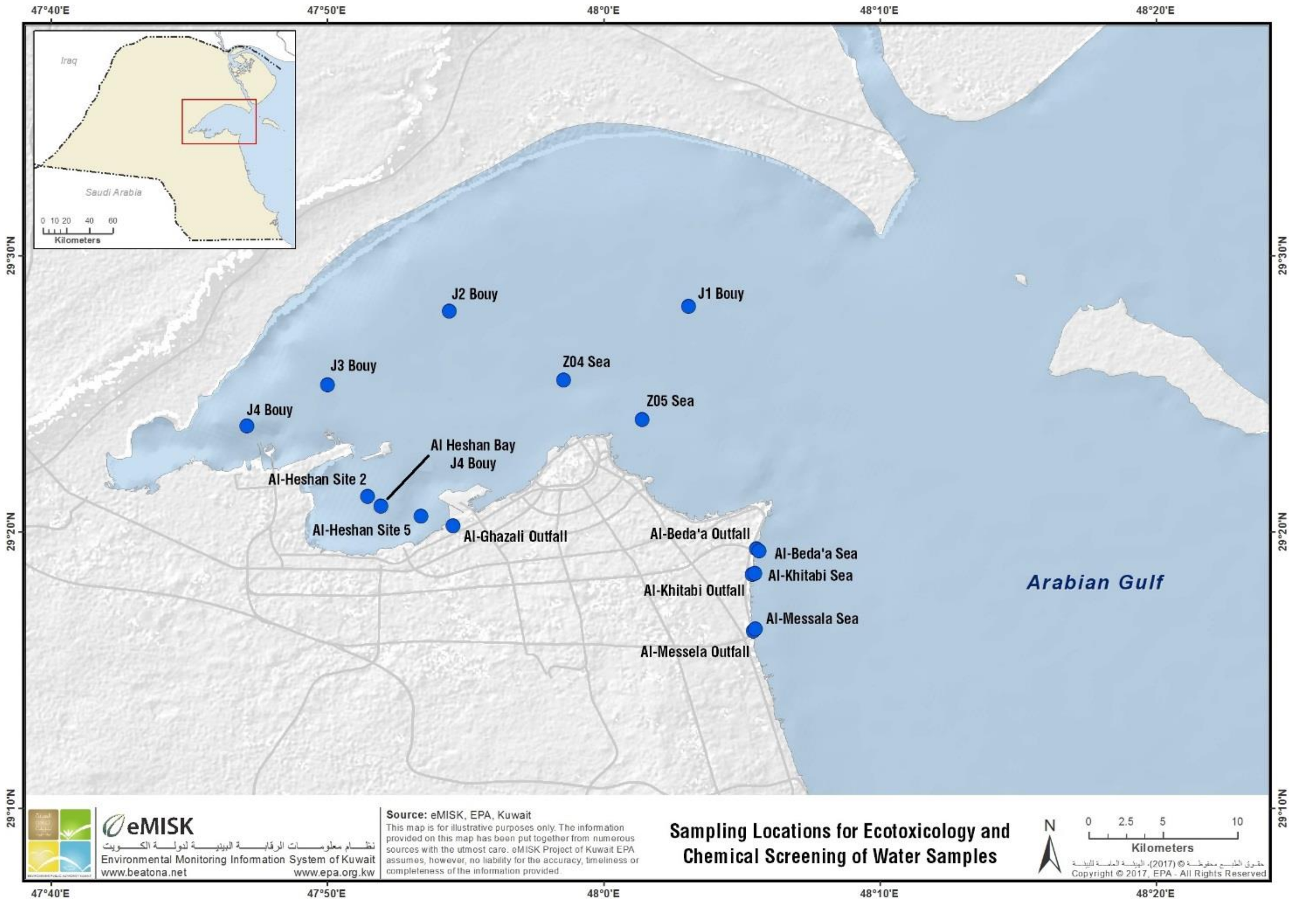


Figure 6-4: Sampling locations for ecotoxicology and chemical screening of water samples

6.6.10.7 Assessment approach and findings

Samples were collected to assess the potential toxicological and endocrine disrupting risks posed by effluents currently discharging into Kuwait's marine environment. A series of water and effluent samples were collected from a number of sites known to be impacted by effluent discharges to establish if such a threat exists. Water samples were screened using a GC–MS target based screening approach, to identify the main pollutants present and assessed for both toxic and endocrine disruption potential using bioassays. During April 2014 a total of sixteen water samples were collected from four known point-sources of effluent input, Al Ghazali, Salmiya, Al Bedaa and Al Messela, and from twelve other sites located offshore in Kuwait Bay and along the Gulf coastline adjacent to the city (Figure 6-4). Approximately 2.5 litres of water or effluent were collected at each site using either a stainless steel bucket or Winchester bottles to collect samples from immediately beneath the water surface. All samples were stored in 2.5 litre amber Winchester bottles prior to extraction and analysis. The Winchesters were transported back to the EPA laboratory, where they were immediately prepared for vacuum extraction. Full details of the analytical and toxicological protocols are provided in Annex 6.2 Ecotoxicology and chemical screening of water samples

Oyster embryo bioassay

The Oyster embryo screen was run on a subset of the samples, selected to represent the breadth of expected site characteristics (Figure 6-5). These included outfalls associated with Al Bedaa, Salmiya and the Al Messela districts. In addition historic EPA smart buoy locations in Kuwait Bay (known as J-buoy sites) were also examined. In particular the J5 buoy was selected as it is located in the entrance Sulaibikhat Bay close to the Al Ghazali outfall, so would be expected to be impacted by this known point source discharge. Under normal (unpolluted) conditions normal oyster development should be greater than 80%. The two control samples run as part of this study achieved this value, demonstrating that the bioassay was meeting internationally specified quality criteria (Thain, 1991). Sites sampled in the middle of Kuwait Bay (J1 Buoy and J2 Buoy), displayed mild toxicity with normal development falling to just over 60%. Higher toxicity was seen at the outfall locations and the J5 Buoy and Salmiya, where in some instances no normal oyster development was observed. This clearly demonstrates that effluents entering the sea at these points pose a direct toxic treat to the marine environment. Of particular concern were the elevated level of toxicity at both the J5 Buoy and Salmiya, which are several hundred meters removed from point sources of pollution and indicate that the influence extended from the source of impact at these locations.

Endocrine disruption bioassays

Data from the YES bioassay are shown in Figure 6-6. The YES data displayed a positive response in a number of the samples. This indicates that chemicals present in these samples have endocrine disrupting activity. The clearest evidence of endocrine disrupting activity was observed at the Al Ghazali and Al Messela outfalls. Responses indicating higher concentrations of endocrine disrupting chemicals were also observed at sites on in Kuwait Bay (J-Buoy sites), Sulaibikhat Bay (Al Hesah Sites 2, 5) and those along the Gulf coast (Al Bedaa sea). It is uncommon to find these sort of effects in open water marine samples because the amount of dilution available is usually enough to drive all responses below the limits of detection.

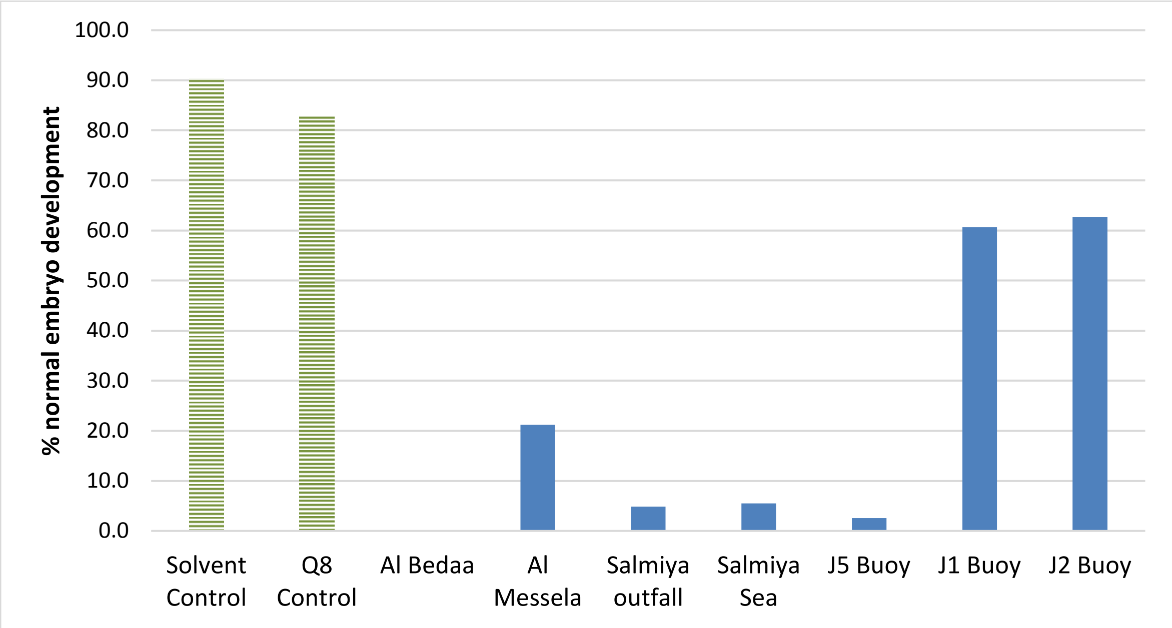


Figure 6-5: Oyster embryo development screen. Y-axis represents percentage of embryos **developing normally. Solid bars represent results from sites of interest. Striped bars indicate control sample** results (>80% normal development indicating a valid test)

Chemical contaminant screening

The samples were also run through a chemical screening procedure (Table 6-6). The approach compares samples against a library of over 1000 different chemical pollutants. Sites have been grouped together as the offshore J-Buoy sites, the Mishref outfalls, the enclosed Sulaibikhat Bay sites and the unlicensed Al Gahazali outfall on its own. The J-buoy sites and Sulaibikhat Bay registered 19 chemicals of interest. Al Ghazali on its own had a list of 78 detectable chemicals. The tables describe the potential uses for the chemicals, which allow a certain amount of speculation as to how the chemicals arrived in the effluent. Various chemicals were observed at the different sites including caffeine, parabens, bromoform, PAHs and flame retardants. As a marker of sewage contamination cholesterol was the largest contaminant by concentration, which was picked up at high concentrations at the Al Ghazali outfall. Amongst the known endocrine disrupting chemicals found, Al Ghazali sites showed Bisphenol A, and several phthalates at microgram (µg) per litre concentrations. The outfalls at Al Bedaa, Salmiya and Al Messela had similar levels of two phthalates, whilst some of the J Buoy sites had varying levels of phthalates, or Bisphenol A. 17-a-Ethinyl estradiol, found in most sewage effluents due to use of the contraceptive pill, did not appear on the list of chemicals detected, but is highly potent even at ng/l levels which would not be picked up by the rapid screening tool deployed here. Other common human steroids such as 17-β estradiol, estrone and estriol are also likely to be present in the effluents in low concentrations, adding to the levels of effect detected by the YES bioassay.

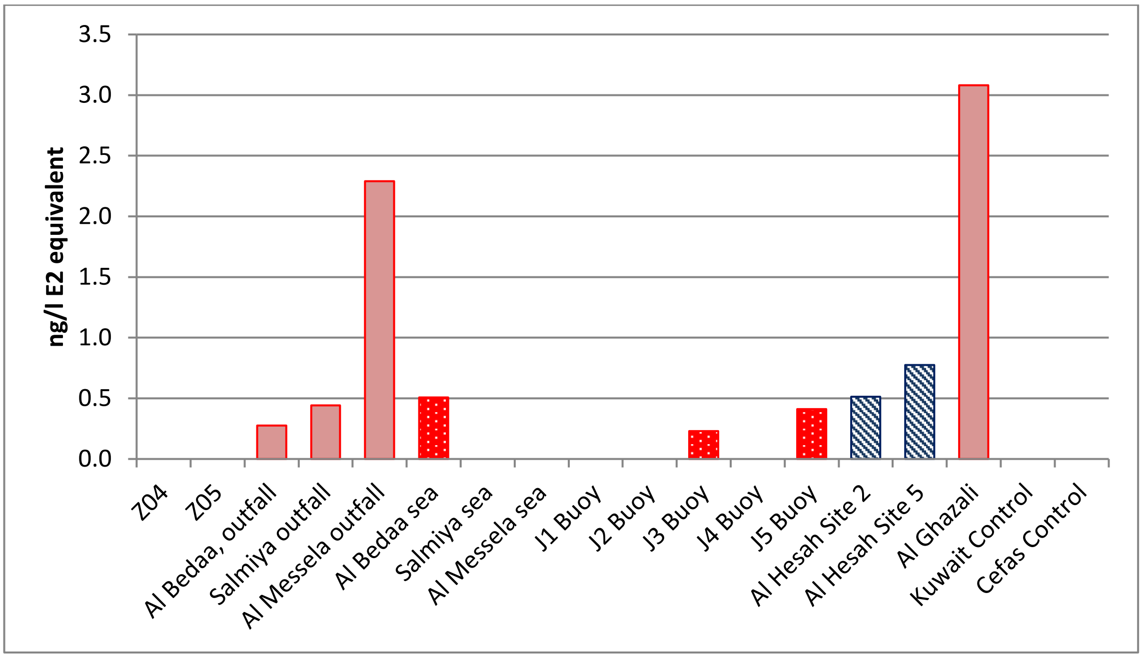


Figure 6-6: Response for samples tested using the Yeast Estrogen Screen. The vertical scale represents the amount of E2 in ng/l required to produce a response similar to that cause by the sample. Solid orange data bars represent the concentration in outfalls. Blue diagonally striped bars represent near shore samples. Red spotted bars indicate open water samples. No bar = no response detected.

CAS number	Name	Approximate concentration µg/l	Possible use
75252	Bromoform	0.04–0.48	Volatile solvent
74953	Dibromomethane	0.01–0.05	Volatile solvent
99763	Methylparaben	0.1–2.3	Antifungal preservative in cosmetics
120478	Ethylparaben	0.8	Antifungal preservative in cosmetics
88755	2-Nitrophenol	0.01–0.02	Manuf dyes, paint coatings, rubber coatings and fungicides
119619	Benzophenone	0.05	Fixative for heavy perfumes
142916	Isopropyl palmitate	7.5	Widely used in cosmetics and personal care products
5466773	Octyl-methoxycinnamate	0.02	Personal care products, sun blocker
118605	2-Ethylhexyl salicylate	0.1–9.7	Used in cosmetics and sunscreens to absorb UVB
6197304	Octocrylene	0.13–9.9	UV-filter
88040	Chloroxylenol	0.06	Biocide/antiseptic
131113	Dimethyl phthalate	0.06	Additives for plastics known as phthalates
3622842	Benzenesulfonamide, *N*-butyl-	0.14–0.3	Intermediate for the synthesis of dyes, photochemicals and disinfectants
80057	Bisphenol A	0.03	In the manufacture of epoxy resins and polycarbonates for food packaging
77907	Tributyl acetylcitrate	0.05	Plasticizer or carrier solvent permitted in the field of food additive, food contact material as well as for polymers especially for cellulosics
10323	1 Bis(2-ethylhexyl) adipate	0.06–0.13	Plasticizer
10544500	Sulphur (S8)	0.03	Acaricide/insecticide
58082	Caffeine	0.04–0.37	Psychoactive stimulant drug
57885	Cholesterol	7.3	Waxy steroid of fat that is manufactured in the liver or intestines

Table 6-6: Open water J-buoy sites 1–4. Chemicals identified by GC–MS residue scans. Listed chemicals are toxic, carcinogenic, indicators of other pollutants, indicators of industrial process wastes, pharmaceuticals or personal care products.

6.6.10.8 Conclusions

These two bioassay tests employed show definite differences between the sites and between control samples and contaminated sites. The oyster embryo test results represent the effects of chemicals which have both toxic and developmental impacts on this very sensitive life stage. This could include any number of the chemicals identified as being present by the chemical screen, as pharmaceuticals, agricultural chemicals, plasticisers and petrochemicals all contain chemicals implicated in developmental abnormality. With the YES screen, it has been well established since the 1990s that domestic and industrial sewage effluents potentially contain a number of chemicals which can bind to and activate parts of the endocrine system, such as the estrogen receptors used in this test. Several of the sites are at or very close to sewage effluent outfalls, so the source of these chemicals and the route they take to get into the environment are clear and would be expected to affect both the oyster and YES screens. Of more concern are the estrogenic and developmental/toxic responses seen in samples, such as those taken from the J Buoy sites in open water section of Kuwait Bay. The dilution factor of any effluent stream would be expected to be very high at this point, making detection of any but the most highly contaminated effluents very unlikely. The concentrations found were low ng/l, but this high when compared to other studies reporting on open water marine locations (Atkinson et al, 2003; Beck et al, 2006).

Sediment contamination: Polycyclic aromatic hydrocarbons (PAHs)); Lyons et al., 2015). Such levels, were below any internationally recognized sediment quality guidelines and therefore thought to pose little or no toxicological threat to resident species. Indeed the levels of bile metabolites detected in both species are very low compared to other studies that have also applied this method in biomonitoring studies (for review see Ariese et al., 1993; Bayer, et al., 2010). For examples Lyons et al., (1999) reported levels of biliary PAH metabolites between 14,572 to 22,247 µg kg^{-1} wet weight 1-OH pyrene equivalents in flatfish caught from contaminated estuaries in the UK. Recently, attempts have been made to develop assessment criteria for bile metabolites (Davies and Vethaak, 2012). While it is acknowledged these are species specific, it is clear from reviewing those available for both flatfish and pelagic fish species, that the levels detected in this current study are an order of magnitude below those concentrations thought to pose a toxicological threat.

6.6.10.9 Fish disease

Histological analysis using light microscopy revealed several lesion types in *A. thalassinus* and *P. quadrilineatus*, (Table 6-15; Figure 6-14), although the prevalence was generally considered low, with no discernible differences observed among sampling locations. A total of sixty *A. thalassinus* were sampled from four sites (S1, S2, S3 and S5) and a total of fifty *P. quadrilineatus* were sampled from three sites (S1, S3 and S4). A relatively high degree of inflammation (lymphocytic and monocytic infiltration) was often observed in *A. thalassinus* liver cells (hepatocytes) in fish at all sites and was occasionally seen forming discrete foci (Figure 6-14). Inflammation (lymphocytic and monocytic infiltration) and hepatocellular necrosis were observed in four and seven individuals of *P. quadrilineatus* respectively across all sampling locations and appeared less pronounced than those observations in *A. thalassinus*. Similarly, melanomacrophage aggregates (MAs) were noted at relatively high prevalence at all sampling locations. These pathologies were often observed associated with either individual hepatocellular necrosis exhibiting nuclear changes or relatively large areas of significant necrosis and accompanying architectural disorganisation (Figure 6-14b).

Regenerative hepatocytes were also observed on occasion. Interestingly, two *A. thalassinus* demonstrated putative hepatic cholestasis, shown by the presence of a brown-like pigment (bilirubin) within the cytoplasm of affected hepatocytes (Figure 6-14c). Large adipocytes were occasionally seen in close association with the pancreas and dorsal surface of the liver. No neoplastic lesions (associated with exposure to carcinogenic chemicals) were observed in *A. thalassinus* at any of the sampling sites although, pre-neoplastic (tumorous) foci of cellular alteration (FCA) were observed in six fish from S1, S2 and S5 (Table 6-15). No pre-neoplastic FCA or neoplastic lesions were observed in *P. quadrilineatus*. Hepatocellular FCA are suggested to be an early stage in the stepwise formation of hepatic tumours and as such, are considered to be a histopathological biomarker for contaminant exposure (Hinton et al., 1992). Despite their observation in flounder (*Platichthys flesus*) and dab (*Limanda limanda*) from contaminated sites in Europe and in other benthic species from around the world (Myers et al., 1998; Stehr et al., 2004; Costa et al., 2009; Stentiford et al., 2010; Oliva et al., 2013), FCA was rarely observed in this present study. Stentiford et al., (2014) also reported low levels of pre-neoplastic and neoplastic lesions in oriental sole (*S. orientalis*) and the large-toothed flounder (*P. arsius*) sampled from Kuwait Bay. Other pathologies observed in the current studies included apoptosis (characterised by hepatocellular shrinkage, karyorrhexis and formation of apoptotic bodies,(Table 6-15); hepatocellular and nuclear polymorphism; and macrovesicular steatosis. Putative hepatic cholestasis was observed in five specimens of *P. quadrilineatus*. Similar to *A. thalassinus*, adipocytes were occasionally seen associated with the pancreas.

Site	Giant sea catfish	Fourlined terapon
1	185.3 ± 51.8	312.8 ± 108.1
2	477.5 ± 290.7	NS
3	129.0 ± 50.7	417.2 ±167.8
4	NS	NS
5	163.2 ± 77.4	NS

Table 6-14: Mean ± Standard Deviation concentrations (µg kg^{-1} wet weight 1-OH pyrene equivalents) of biliary PAH metabolites as a biomarker of exposure in the Giant sea catfish (*A. thalassinus*) and Fourlined terapon (*P. quadrilineatus*). NS, no sample.

6.6.10.10 Conclusions

Histological assessment indicated that the prevalence and severity of lesions observed in this study were not considered to be at a significant level to highlight cause for concern. Taking the histology and biomarker data in combination it would appear fish sampled in this study were relatively healthy, representative of living in an environment not heavily impacted by chemical pollution. However, this investigation did reveal that *A. thalassinus* and *P. quadrilineatus* appear to exhibit a low prevalence of lesion types previously seen in studies investigating the effects of environmental contaminants i.e. pre-neoplastic FCA, hepatocellular necrosis and regeneration (Myers et al., 1998; Stehr et al., 2004; Costa et al., 2009; Stentiford et al., 2010; Oliva et al., 2013). Overall the data (albeit limited to a small dataset) show that *A. thalassinus* and *P. quadrilineatus* appear to be susceptible to pathologies associated with environmental contaminants and are therefore suitable for further investigation as sentinel species for biological effects monitoring. A more extensive monitoring effort using larger numbers of fish is required to further validate the use of these species for biological effects monitoring.

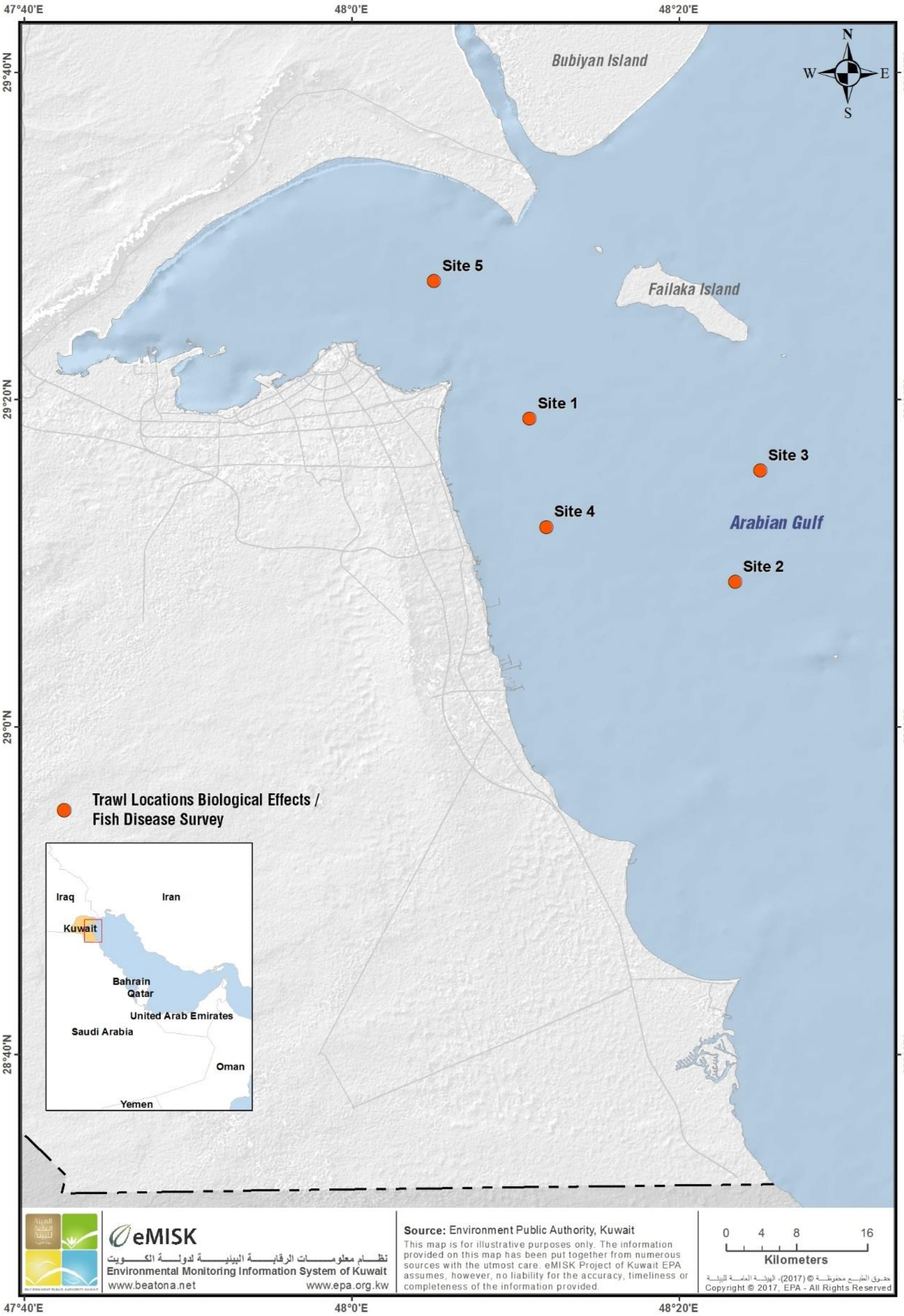


Figure 6-13: Trawl locations for the biological effects/fish disease survey

Table 6-15: Prevalence of liver histopathology observed in *A. thalassinus* (Giant sea catfish, GSC) and *P. quadrilineatus* (Fourlined terapon, FT), sampled from sites around the coastline of Kuwait. Figures in parenthesis indicate percentage prevalence observed.

Site	S1		S2	S3		S4	S5
Species	GSC	FT	GSC	GSC	FT	FT	GSC
n=	18	20	15	12	15	15	15
NAD (no abnormalities detected)	2 (11.1)	1 (5.0)	0 (0)	0 (0)	0 (0)	2 (13.3)	0 (0)
Early non-neoplastic toxicopathic lesions							
Phospholipoidosis	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Fibrillar Inclusions	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
H&N pleomorphism	0 (0)	2 (10.0)	1 (6.7)	0 (0)	1 (6.7)	0 (0)	0 (0)
Hydropic degeneration	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Spongiosis hepatis	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Foci of Cellular Alteration (FCA)							
Clear-cell FCA	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Vacuolated FCA	1 (5.6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Site	S1		S2	S3		S4	S5
Species	GSC	FT	GSC	GSC	FT	FT	GSC
n=	18	20	15	12	15	15	15
Eosinophillic FCA	1 (5.6)	0 (0)	0 (0)	1 (8.3)	0 (0)	0 (0)	1 (6.7)
Basophillic FCA	1 (5.6)	0 (0)	0 (0)	1 (8.3)	0 (0)	0 (0)	0 (0)
Mixed-cell FCA	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Benign Neoplasms							
Hepatocellular adenoma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cholangioma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hemangioma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pancreatic acinar cell adenoma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Malignant Neoplasms							
Hepatocellular carcinoma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cholangiocarcincoma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pancreatic acinar cell carcinoma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Site	S1		S2	S3		S4	S5
Species	GSC	FT	GSC	GSC	FT	FT	GSC
n=	18	20	15	12	15	15	15
Mixed hepatobiliary carcinoma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hemangiosarcoma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hemangiopericytic sarcoma	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Non-specific and inflammatory lesions							
Coagulative necrosis	4 (22.2)	7 (35.0)	0 (0)	0 (0)	2 (13.3)	2 (13.3)	0 (0)
Apoptosis	0 (0)	3 (15.0)	0 (0)	0 (0)	0 (0)	2 (13.3)	0 (0)
Microvesicular steatosis	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Macrovesicular steatosis	0 (0)	1 (5.0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hemosiderosis	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Variable glycogen content	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
MMC	16 (88.9)	17 (85.0)	12 (80.0)	12 (100)	15 (100.0)	13 (86.7)	15 (100.0)
Lymphocytic/monocytic infiltration	12 (66.7)	1 (5.0)	14 (93.3)	9 (75.0)	1 (6.7)	2 (13.3)	13 (86.7)

188

Site	S1		S2	S3		S4	S5
Species	GSC	FT	GSC	GSC	FT	FT	GSC
n=	18	20	15	12	15	15	15
Granuloma	0 (0)	0 (0)	2 (13.3)	0 (0)	0 (0)	0 (0)	0 (0)
Fibrosis	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Regeneration	2 (11.1)	5 (25.0)	0 (0)	1 (8.3)	5 (33.3)	5 (33.3)	0 (0)
Cholastasis (putative)	0 (0)	0 (0)	1 (6.7)	1 (8.3)	4 (26.7)	1 (6.7)	0 (0)

189

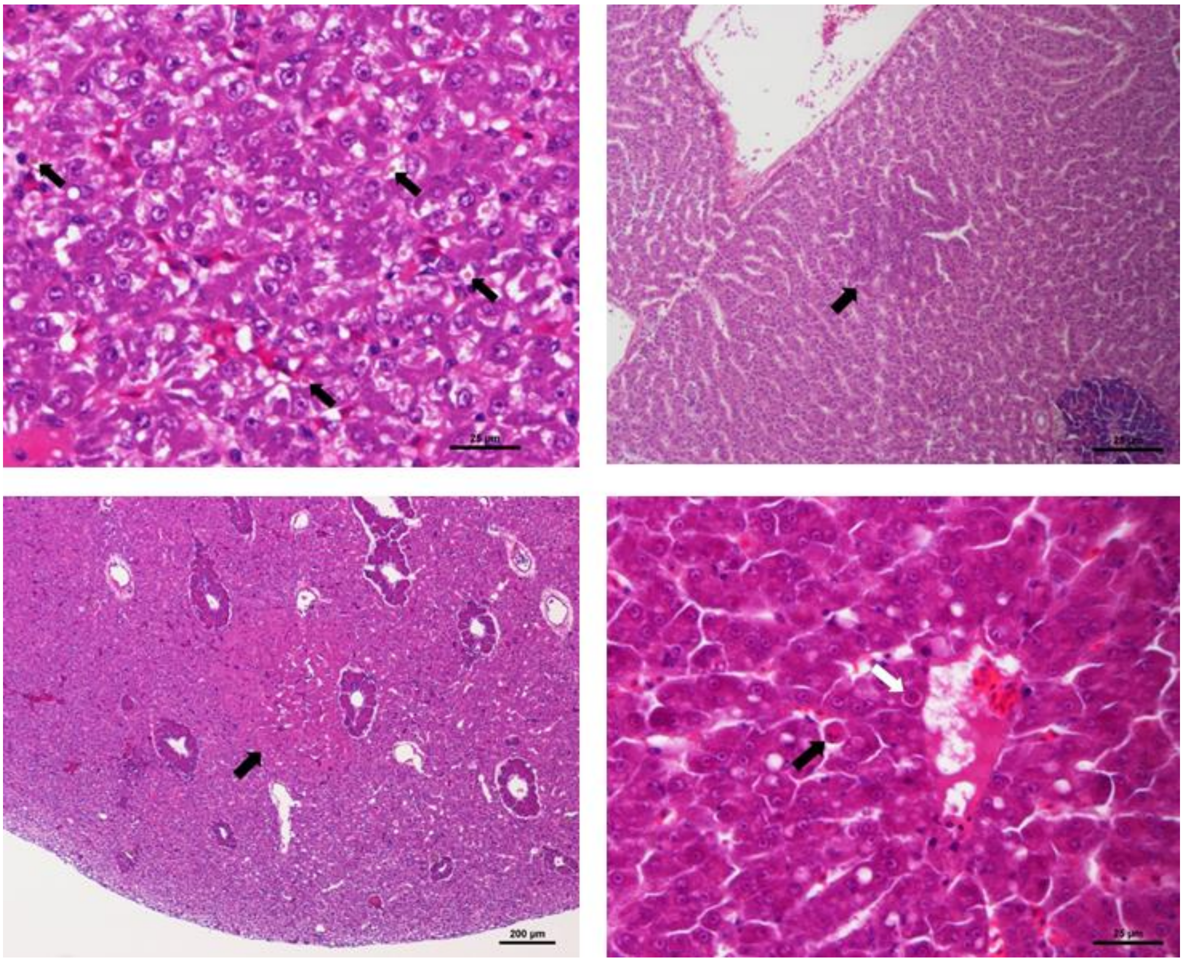


Figure 6-14: Liver histopathology micrographs- (a) A. thalassinus - discrete area of focal necrosis (*) enveloped by lymphocytic/monocytic inflammatory response (arrow). (b) A. thalassinus - extensive area of necrosis exhibiting loss of normal architectural structure (*) and marked lymphocytic/monocytic infiltration (arrow). (c) A. thalassinus - brown-like pigment within the cytoplasm of hepatocytes (arrows) suggested putative hepatic cholastasis, although this was unconfirmed. (d) P. quadrilineatus- relatively small basophilic foci of cellular alteration (FCA) (arrow). (e) A. thalassinus - eosinophilic FCA (arrow). (f) P. quadrilineatus- hepatocellular apoptosis (arrows) adjacent to large blood vessel. Note the presence of cellular shrinkage and DNA fragmentation (karyorrhexis) (black arrow).

7 Commercial Fisheries

7.1 Introduction

Kuwait, once a community of fisherman and pearl divers, has developed into a country with diverse industrial and economic outputs. However, fishing is still considered a valuable resource and fisheries provide 16% of the global populations animal protein intake according to the Food and Agriculture Organisation of the United Nations. Fishing in Kuwait was once restricted to artisanal fishing, however with the introduction of new fishing methods in the 1970's and 1980's fish stocks came under increasing pressure. The fishing industry is comprised of three distinct fleets employing a variety of gears. Artisanal fleets include speed-boats and dhow boats, and these vessels are licensed to use only one type of gear, which can be gargoor, drift nets, or fixed gill nets of various mesh sizes.

7.2 Data sources

Abundance and distribution data for commercially important fish species in Kuwaiti waters is available, however these data are collected sporadically, particularly since 1992. Data from before the Iraqi invasion of Kuwait in 1990/1991 is no longer available having been removed by the invading forces and never returned (Matthews, 1994). The Kuwait Institute of Scientific Research (KISR) have carried out periodic surveys collecting data on fish abundance as part of a GCC wide survey plan, however this data is not yet available to reference. KISR have carried out numerous research projects looking at specific species, in particular the shrimp fisheries (for both *Penaeus semisulcatus* and *Metapenaeus affinis*). PAAAFR are responsible for fisheries resource management in Kuwait and data on landings is collected at the two main fish markets for registered fishing vessels.

In 1972 the Kuwait Institute of Scientific Research (KISR) published the book Fishes of Kuwait (Kuronuma and Abe, 1972). This book was deemed the definitive description of fish species found in Kuwaiti waters. In 1997 the Food and Agriculture Organisation of the United Nations commissioned a field guide for Fishery purposes on the living marine resources of Kuwait, Eastern Saudi Arabia, Bahrain Qatar, and the United Arab Emirates (Carpenter, 1997). This guide built on the work of Kuronuma and Abe, and was the first time data from numerous sources was brought together to attempt to produce a definitive guide for the whole region. In 2003, KISR produced the most current list of fish species in Kuwait (Bishop, 2003), containing 345 species and 95 families. This is the most recent and considered complete list of ichthyofauna species in Kuwait.

7.3 Summary of outcomes

Currently there are no set indicators for monitoring the health of fisheries in Kuwait. Given paucity of data, indicators being used in Europe like state of commercial fish stock (stocks fished within safe limits, proportion of fish stocks which are within safe biological limits), mean size of fish or proportion of large fish are not suitable. The indicators that have been used to measure success across this objective, such as fishing pressure or long term trends were not available to make a full assessment (Table 7-1).

Table 7-1:Overview of commercial fishing assessment.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
						Commercial Fisheries
Status assessment is MODERATE. The assessment of status is moderate with landings data showing a significant decline over last 15 years. The future trajectory for commercial fishing is predicted to continue to decline without additional management action. Recreational fishing has a significant impact on fish resources in Kuwait. There has been a reduction in total fishing vessels, which may be related to the reduced national catch. In contrast, the imported fish numbers have increased over time. An additional issue is discarding, particularly in the shrimp fishery where up to 98% of the bycatch is discarded. Habitat loss and habitat damage may also be reducing fisheries production. Catches of prawns have significantly reduced throughout the region through overexploitation of the shrimp fisheries and the reduction in flow from the Shatt-Al-Arab river. Cuttlefish, squid and octopus are opportunistically harvested within Kuwait waters. Improved data collection and reporting is required to enable robust assessment of fisheries status. In conclusion, from available catch information and extrapolation from studies across the wider Gulf region, overfishing of many stocks is thought to be occurring. Many Gulf fisheries have deteriorated or collapsed and concerns are held for the trajectories of Kuwait commercial fisheries.						
COMMERCIAL FISHERIES	Commercial fish stocks	Fishing activity	●	⬇	■	Status assessment is MODERATE. Catch estimates, show declines in all major species. Recreational fishing has a significant impact on fish resources in Kuwait with recent data suggesting that there are many more recreational fishing boats than commercial fishing boats. There has been a reduction in the total number of commercial fishing vessels. However there are no formal measures of the level of fishing activity so confidence in the assessment is low.
	Prawns	Annual catch estimates	●	?	■	Status assessment is MODERATE. Prawns are Kuwait's second most valuable export after oil. Catches are believed to have fallen in recent years. An additional issue for Kuwait is the amount of discarding, particularly in the shrimp fishery where up to 98% of the bycatch is discarded. Catches of prawns have significantly reduced throughout the region in recent years through overexploitation of the shrimp fisheries and the reduction in flow from the Shatt-Al-Arab river.
	Cephalopods	Annual catch estimates	?	?	■	Status assessment is UNKNOWN. Trajectory is also unknown due to limited data and no systematic monitoring data is collected. Cuttlefish, squid and octopus are opportunistically harvested within Kuwait waters. Cuttlefish are the primary commercial species however, insufficient information on taxonomy, abundance and distribution in Kuwait waters prohibits an accurate assessment. Cuttlefish populations are believed to be influenced by seasonal rises in sea temperature and the availability of muddy seafloor substrates.

Given the lack of fisheries data and that there have been some criticisms of the indicators mentioned in section **Error! Reference source not found.**, it may be more appropriate to attempt to define indicators at a biodiversity level. One such indicator could be species richness and species diversity. Data from published articles could be used to as a baseline

(Bishop, 2003). It could be argued that fishing pressure could be used as an indicator (see section **Error! Reference source not found.**), however once again without reliable data on landings this alone cannot be deemed fully appropriate as a reliable indicator of fishing pressure without data on the fishing gears deployed as well.

The overarching management objective for fishing (F-SG1) is “overfishing is prevented and all stocks of commercially exploited species are harvested within levels that enable high long-term sustainable yield consistent with the concept of maximum sustainable yield”. The data that has been presented in this assessment points to reduction in fisheries catch and suggests that this objective is not met under current fishing pressures and management (Table 7-1).

7.4 Assessment of fishing indicators.

7.4.1 Commercial Fishing

7.4.1.1 Background

There are few reliable sources of data on fishing pressure in Kuwait. The only long term time series is from the data collected by PAAAFR and given to the Kuwait Central Statistics Bureau (CSB) (www.csb.gov.kw). This data on fishing pressure is in the form of the registration of licenced fishing vessels (Table 7-2)

Table 7-2: Official numbers of licenced vessels fishing in Kuwait 2000-2015

	Wooden Ships	Iron Ships	Fibre Ships	total
2000	89	37	753	879
2001	118	37	747	902
2002	119	36	748	903
2003	120	35	733	888
2004	124	35	729	888
2005	121	35	699	855
2006	Data not accessible	Data not accessible	Data not accessible	
2007	128	28	726	882
2008	126	30	718	874
2009	126	30	718	874
2010	140	22	723	885
2011	150	13	711	874
2012	151	13	698	862
2013	158	8	690	856
2014	156	8	657	821
2015	158	8	673	839

There has also been a small but gradual decline in the number of licenced fishing vessels in Kuwait during this period (7%).

There is almost no official data on recreational fishing in Kuwait, however it is suggested that since the rapid increase in population from 1992, that recreational fishing has a significant impact on fish resources in Kuwait (Carpenter, 1997). Recent data collected by Public Authority of Agriculture Affairs and Fisheries Resources (PAAFR), suggests that there are 30 times more recreational fishing boats than commercial in Kuwait (taken from presentation by Husain Al Sayegh, PAAFR). However, no data on the amount of effort this translates to is available.

7.4.1.2 Kuwait: Current state of knowledge

There is now no data before 1990 that can be accessed to allow long term data analysis. However, work carried out by KISR in 1988 titled ‘Catch Rates and Sustainable Yield of Kuwait’s Trawl Fishery’ (Samual, 1988) could be used as a proxy for historic landings data. Monthly summary data is provided to the CSB on 23 imported and locally caught commercial fish species, along with a combined figure containing other unspecified fish and shellfish species. The trends of these combined total weights per annum since 2000 is shown in Figure 7-1, which shows a significant reduction in the catch of locally caught fish. There is also a reduction in total fishing vessels, which may be related to the reduced national catch. However, in contrast, the imported fish numbers have increased over time. The figure also contains the trend line of the total number of licenced fishing vessels over this period (no data was obtainable for 2006 for licenced fishing vessels at the time of the production of this report).

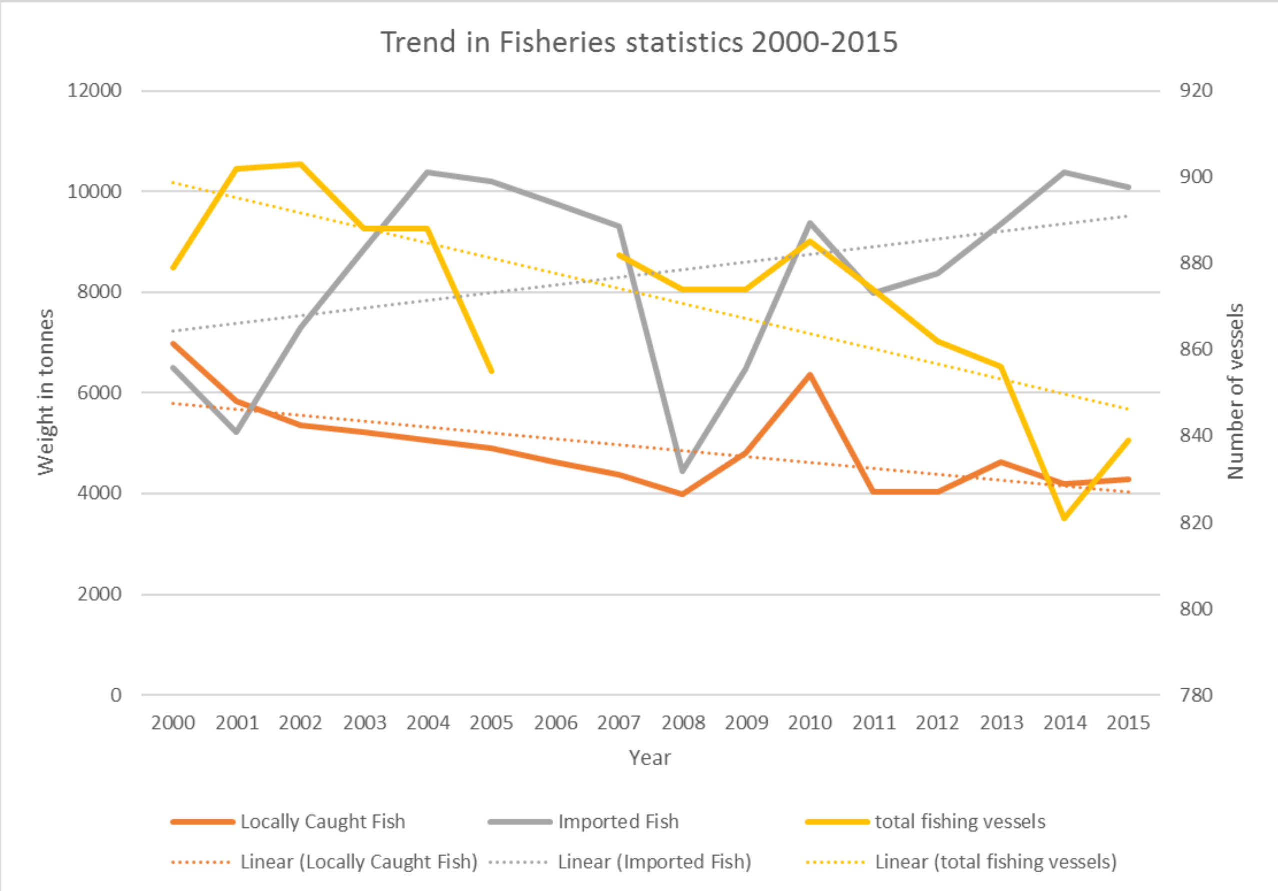


Figure 7-1: Official fisheries statistics 2000-2015

As is evident from the data, landings of locally caught fish have decreased (38%) whilst imports have increased (55%). There has also been a small but gradual decline in the number of licenced fishing vessels in Kuwait during the same period (7%).

7.4.1.3 Assessment approach and findings

Overall, investigations have suggested that catches in the Gulf as a whole are potentially underestimated by a factor of two between 1950 to 2010 (Dalal Al-Abdulrazzak, 2015). An additional issue for Kuwait is the amount of discarding, particularly in the shrimp fishery where according to work by De Young (Young, 2006), 98% of the bycatch is discarded without being recorded in any way. This gives massive uncertainty around stock sizes in the majority of finfish species.

In recent years two main reviews of fisheries in the Northern Gulf have been carried out by Amani Al-Zaidan, (Amani S.Y. Al-Zaidan, 2013) and Dalal Al-Abdulrazzak (Dalal Al-Abdulrazzak, 2015). Both highlight the relatively poor fisheries dependant and independent data collection programs in Kuwait and the need for more robust data collection and monitoring processes.

Work carried out by KISR estimated total production in the mid-nineties ranged between 8 and 9 thousand tonnes in Kuwaiti waters while it reached only three thousand tonnes in 2013. This decline was attributed to many environmental (increase in salinity in the Northern Gulf and changes in productivity at the base of the food chain) as well as non-environmental factors (excessive fishing effort both regulated and illegal). These pressures are not unique to Kuwait of course, but once again, lack of long term data sets hamper attempts to provide robust management responses.

7.4.1.4 Conclusions

Although landings data shows a decline in locally caught fish, this is not enough to confirm anecdotal information about falling stock sizes for the majority of Kuwait's fish stocks and certainly not with any confidence, with the possible exception of shrimp assessments. Without good quality long term data sets of fisheries independent data, there is no evidence to support indicator development at this time.

Whilst it is difficult to present a Kuwait wide assessment of fishing, we can refer to the literature on the Arabian gulf. Sheppard et al., 2016 reports that overfishing is a major problem across the Gulf (). Most fisheries have deteriorated to some degree, or have collapsed (Grandcourt, 2012, Sheppard et al. (2010) Approximately half to two thirds of fish caught are reef associated species (Grandcourt, 2012) so that, in addition to issues of overfishing, reef destruction has added additional consequences of habitat loss for fish. The overall consequences may already be being shown: Grandcourt (2012) shows that, over the last 30 years, overall fishing intensity has risen resulting in a rise in total fish catch, but not of reef-associated species for about the last 25 years (Fig. 5). Of the most commercially important reef fish species, 65.5% were considered to be over exploited with a further 5.3% fully exploited (Grandcourt, 2012). To add to the problem, the region suffers from gross underreporting and inaccurate data: reconstructions by Al-Abdulrazzak and Pauly (2013) using remote sensing show that unreported catches of coastal fisheries exceed by as much as six-fold the reported catch.

7.4.2 Crustaceans

7.4.2.1 Background

Although 14 species of prawn/shrimp have been identified in Kuwait's catches, only three are important commercially. In descending order of importance, they are the green tiger prawn (*Penaeus semisulcatus*), the kiddi shrimp (*Metapenaeus affinis*), and the jinga shrimp (*Parapenaeopsis stylifera*). Their percentage contribution to shrimp landings varies from year to year, but generally *P. semisulcatus*, *M. affinis*, and *P. stylifera* account for about 60%, 30%, and 10% of the landings, respectively (Al-Husaini et al., 2015; Chen et al., 2013).

7.4.2.2 Current state of knowledge

The most up to date information on seasonal prawn density within Kuwait waters comes from Chen et al (2013) who measured catch rates between September 2010-January 2011. A double rigged trawl (51 mm body mesh, 45 mm codend mesh, 21.3 m head rope, 23.2 m foot rope, approximate opening 16 m x 2.5 m) was used and averaged harvest of 7 kg/h (±3.1) for *P. semisulcatus* and 3.3 kg/h (±0.2) for *M. affinis* derived. The seasonal catch rates for both species have been found to be highest in September (19.6 kg/h combined) and dramatically decline through to January (1.1 kg/h combined) when the season ends. This is likely a function of seasonal migration to warmer waters for the winter period.

Slipper lobsters (*Thenus orientalis*) and crab (*Portunus pelagicus*), are also commercially harvested in Kuwait as a component of coastal trawl fisheries targeting penaeid shrimp species (Chen et al., 2013; Jones et al., 1993). The distribution and abundance of *T. orientalis* within Kuwait waters is unknown at present although work by Jones (1993) suggests the species likely favours areas characterised by coarse sandy sediment habitat between 30-60 metres deep.

The crab, *P. pelagicus* is believed to be ubiquitous in habitats favoured by prawns and has been found to represent ~12% of retained by-catch on prawn trawlers (see Chen et al., 2013). No further information on its abundance or distribution within Kuwait is known at the time.

7.4.2.3 Assessment approach and findings

Prawns, slipper lobsters and crabs are all fished commercially within Kuwait waters. Prawns support the most important fishery in Kuwait as it accounts for more than 35% of the total fisheries landings volume annually and has historically constituted Kuwait's main export after oil (Pauly and Palomares, 1987). Over the past decade, annual shrimp landings have averaged around 2000 metric tons (t) (Chen et al., 2013). It is widely believed that catches of prawns have significantly reduced throughout the region in recent years, although an absence of historic 'effort data' makes this hard to confirm. For context, regional *M. affinis* abundance at the two main fish markets in Basrah (Iraq) averaged 1000 kg/day between September-November 1985 (Salman and Al-Adhub, 1990).

Though the distribution of *P. semisulcatus* in the Arabian Gulf is not uniform, the species is far more widespread than either *M. affinis* or *P. stylifera* which occur only in the extreme northern Gulf (Farmer and Ukawa, 1986; Al-Husaini et al., 2015). Kuwait's stock of *P. semisulcatus* appears to be discrete from that just south of the border with Saudi Arabia (Bishop et al., 2001). Juvenile distributions of *P. semisulcatus* occur during spring in shallow waters of sandy or reef bottoms, with attached vegetation such as sargassum, whereas juveniles of *M. affinis* occupy shallow muddy bottoms during summer (Bishop, 1988, 1989, 1994; Al-Husaini et al., 2015). Kuwait Bay and its adjacent areas as well as coastal areas south of Kuwait Bay have been found to be the major nursery areas for *P. semisulcatus*

(Mohamed et al., 1981; Jones and Al-Attar, 1982; Al-Attar, 1984a). Analysis of catches from Iraq suggest small-sized shrimp favour shallow waters while large shrimp are more abundant within the marshes (Salman and Al-Adhub, 1990). Although maximum recruitment (of *M. affinis*) in Iraq has been found to occur when temperatures reach 23-25 °C, the discharge of the Shatt Al-Arab may also be an important factor regulating recruitment (Salman and Al-Adhub, 1990). Nonetheless potential for climate change to influence recruitment of commercial prawn species found within Kuwait is highlighted by such findings.

7.4.2.4 Conclusion

Prawns are Kuwait's second most valuable export after oil. Their domestic harvest, as well as that of other crustaceans provides additional socioeconomic value as 'food security' for a nation that is a net importer of food. It is not known if stocks are overfished and no maximum sustainable yield has yet been calculated for respective species. Although catches are believed to have fallen in recent years the absence of a dedicated fisheries monitoring scheme means declines cannot be categorically proven at the present. In developing future management plans for prawn stocks their spatio-temporal abundance is a key consideration. Such measures must take account of the limited fishing season (September-January), transboundary migrations and juvenile dependence upon discrete habitats (e.g. reef) and predicted sea temperature rise if they are to prove effective.

7.4.3 Cephalopods

7.4.3.1 Background

Although Indian squid (*Loligo duvauceli*) and big blue octopus (*Octopus cyaneus*) are caught in Kuwaiti trawls the only commercially harvested cephalopod is the Pharaoh cuttlefish (*Sepia pharaonis*) (Chen et al., 2013) for which there is an important fishery throughout its geographic range (Reid et al. 2005).

7.4.3.2 Current state of knowledge: Kuwait

7.4.3.3 Assessment approach and findings

S. pharaonis is believed to be a species complex (Anderson et al. 2011; Norman 2003, Reid et al. 2005) although the sub-species inhabiting the Arabian Gulf has yet to be taxonomically described. The abundance of *S. pharaonis* has been assessed by the as IUCN as 'Data Deficient as although it has a very wide geographic distribution it consists of a species complex. Until taxonomic clarity is provided this species cannot be accurately assessed (Barrat and Allcock, 2012).

S. pharaonis is a demersal species which occurs in shallow depths, associated with mud substrata. It is caught as bycatch as well as in artisanal and commercial fisheries via traps baited with eggs (Chen et al., 2013; Reid et al. 2005). The species appears to favour warmer waters and is commonly found furthest north during August, and further south in May

(Chembian et al., 2011). Such findings suggest the species is likely a summer migrant to Kuwaiti waters although further information is required to confirm this.

As with all cuttlefish, ocean acidification caused by increased levels of carbon dioxide in the atmosphere represents a potential threat to *S. pharaonis*. Studies have shown that under high pCO2 concentrations, cuttlefishes lay down a denser cuttlebone which is likely to negatively affect buoyancy regulation (Gutowska et al. 2010).

7.4.3.4 Conclusion

Cuttlefish, squid and octopus are both targeted, and opportunistically harvested within Kuwait waters. Cuttlefish are the primary commercial species however, insufficient information on the exact taxonomy, abundance and fine scale distribution of *S. pharaonis* in Kuwait waters prohibits an accurate assessment of the fishery at the present time. Kuwait populations of *S. pharaonis* are believed to be influenced by seasonal rises in sea temperature and the availability of muddy seafloor substrates.

8 Eutrophication and HABS

8.1 Description of Eutrophication and HABS

The primary biological response to nutrient enrichment in marine systems, given suitable environmental conditions (such as light availability and water temperatures), is the growth of phytoplankton and higher plants, (Devlin et al., 2011). Known consequences of nutrient enrichment include increased primary production, increased biomass of primary producers such as phytoplankton (indicated by concentrations of chlorophyll-*a*) and depletion of dissolved oxygen (hereafter DO) due to decomposition of accumulated biomass, resulting in local hypoxic or anoxic conditions. Other consequences can include shifts in species composition, blooms of nuisance and toxic algae and macroalgae, increased growth of epiphytic algae, red tides, water discolouration and foaming, loss of submerged vegetation (hereafter SAV) due to shading, and changes in benthic community structure due to oxygen deficiency or the presence of toxic phytoplankton species (Tett 1987; Gillbricht 1988; Lancelot et al. 1987; Boynton et al. 1996; Bricker et al. 1999, 2003, 2007; Smayda and Reynolds 2001).

In its simplest form, eutrophication is caused by excess nutrients, which lead in turn to excess primary productivity and accelerated growth of phytoplankton and macroalgae. Issues with increased phytoplankton can also lead to the proliferation of nuisance and toxic species. Increased productivity from alternate species can impact on biodiversity including the inhibition of larval settling and the removal of oxygen from the system as the bloom decays which can lead to anoxic conditions as well as oxygen deficiencies, fish kills and large populations of opportunistic benthos (de Jonge and Elliott, 2002). The complex relationship between increased nutrients and biological impact is non-linear, and the extent of impact dependent on a range of other factors such as the turbidity of the water system (Cloern 1999, 2001).

The range of impacts from nutrient enrichment can span from single cell production to major trophic shifts. It is not possible, nor feasible, to monitor or assess all parts of a marine system to identify all impacts, so a selection of indicators is required that wiII adequately describe the eutrophic status of the environment. The development of classification systems and ecological assessment tools is an important and technically challenging aspect of assessing the consequences of eutrophication. Assessments typically combine a selection of key indicators that enable reasonable evaluation of the overall status of eutrophication in coastal and marine waters, which enables managers and policy makers to make decisions about the mediation of problems linked to nutrient enrichment.

Susceptibility is driven by the interactions between nutrients, sediments (measured as either suspended sediment, turbidity or light climate) and the physico-chemical conditions of the environment. The development of classification systems and ecological assessment tools is an important and technically challenging aspect of assessing the consequences of nutrient enrichment. Assessments typically combine a selection of key indicators that enable reasonable evaluation of the overall status of eutrophication in coastal and marine waters, which enables managers and policy makers to make decisions about the mediation of problems linked to nutrient enrichment (Devlin et al., 2011).

8.2 Drivers of eutrophication and HABS in Kuwait

The Arabian Gulf is a marginal sea with tides, winds, waves and evaporation affecting mixing of the water column (Al-Rashidi et al., 2009; Robinson and Brink, 2006) with well mixed water in the north and stratified waters in the south of the Gulf. Waters of Kuwait Bay are also well mixed by macro-tidal, semi-diurnal tides (Al-Rashidi et al., 2009). Seasonality patterns of Kuwait environmental parameters are important drives of the natural variability associated with water quality conditions across Kuwait marine waters.

Anthropogenic activities which impact on Kuwait Bay's marine environment include diffuse loads associated with the Shatt al-Arab River and the connection of water between Kuwait marine waters and the northern Arabian Gulf. More acute pressures include urban development with increases in population, sewage discharges and industrialization

The main river draining into the northern Arabian Gulf is the Shatt al-Arab River, formed by the confluence of the Euphrates and the Tigris in southern Iraq (Al-Ghadban et al., 2002; Al-Ghadban and El-Sammak, 2005). It is the primary fresh-water source to the Gulf and historically, discharges an annual average of 5 x 10^9 m^3 nutrient rich water into the Arabian Gulf, a discharge which varied seasonally, corresponding to the input from the many tributaries (Abaychi et al., 1988). Seasonal changes in river influx are influenced by winter rainfall causing increases in flow through January to March. In April, the melting snow of the Armenian mountains can cause increases in discharge rates that reaches peak flow in May and June (Al-Hassan, 1999). Minimum discharge rates occur in the hot summer season (July-September) as well as fall (October-November).

The Shatt al-Arab river is important in the input of freshwater, nutrients and sediments into the North Western Arabian Gulf. Prior to the industrialisation of the Kuwait coastline, the main source of dissolved inorganic nitrogen, measured as nitrate, was from land drainage via the Shatt al-Arab River. High inputs of dissolved phosphate into the North Western Gulf were also attributed to the Shatt al-Arab river with export of suspended matter and the transport of fine particles being the conduit for the input of phosphorus (Abaychi et al., 1988). Water removal and diversion, as well as natural seasonal and multi-annual variations affect the total volume of freshwater discharge into the Gulf. Previous estimates of the annual-mean discharge varied from 35 km^3/year (Saad, 1978), being equivalent to 0.15 m/year when evenly distributed over the surface of the Gulf, to 45 km^3/year (0.19 m/year). However, Al-Yamani (2008) raises concerns that these values are likely to be overestimates of current river discharge rates, which have been reduced to an unknown extent by dams that were built on the upstream rivers, reducing the productivity of the North Western Gulf (Al-Yamani et al., 2007), and substantially reducing the river loads into the Northern Arabian Gulf and Kuwait Bay. The water resource developments in the watersheds of the upstream rivers now capture a large proportion of the flow and significantly reduce the river flow into the Arabian Gulf. These developments, from the late 1970s, relate to water mining, marsh drainage, active damming policies and little to no action on bilateral water management causing the drastic reductions in water flow for Shatt al-Arab and a rise of salinity levels in the river and receiving waters (Abaychi et al., 1988; Al-Yamani, 2008; Saad, 1978).

Kuwait has seen rapid expansion over the past 40 years with the last official census in 2005 reporting over 2.2 million people. This represents a population density of 200.2 people per square kilometre (518.4 people per square mile) and is a 17-fold increase from a population of 152,000 recorded in 1950. The 2014 population of Kuwait is now estimated at nearly 3.65 million people supporting a 98% urbanized population, with approximately 83% of the total population residing in the area of Kuwait City.

It is estimated that the majority of this urban population live within the 810 km^2 that covers the Kuwait Metropolitan Area. This major population center is currently served by five main Sewage Treatment Plants (STP) and three smaller facilities (Lyons et al., 2015). Until as recently as 2011, it was estimated the network was receiving up to 100,000 m3 day-1 of raw sewage above its design capacity, representing sources from both domestic and industrial waste waters, This has led to frequent discharges of raw or partially treated effluent into the marine environment (Lyons et al., 2015). In recent years, environmental disasters, such as the Mishref pumping station breakdown in August 2009 have also contributed to the degradation of Kuwait’s marine environment (Saeed et al., 2012). Sustained exceedances of microbiological guidelines over many years, particularly at sites closest to the malfunctioning pump station and the industrial area around Doha located at the western end of Kuwait Bay show a pattern of long term point source discharges into Kuwait marine waters (see section 5.6.1).

Effluent discharges into Kuwait’s marine environment come from a number of industrial and domestic sources over most of the county’s 195 km of coastline (Al-Sarawi et al., 2015). The highest density of these point sources of contamination is associated with populated areas around the city or with industrial centres such as Doha and Shuaiba (Al-Ghadban et al., 2002). However, the extensive review of industrial pollution by Al-Sarawi et al. (2015) reports that elevated levels of contamination associated with industrial discharge have tended to be localised and associated with specific point sources of contamination, such as the major industrial facilities based at Doha, Sulaibikhat Bay and the Shuaiba industrial area (SIA) (Al-Ghadban et al., 2002; Al-Ghadban et al., 2001; Al-Sarawi, 2001; Gevao et al., 2006).

8.3 Sources of data

This assessment utilises a long-term, 30-year data set to report on trends in the status of water quality in the Kuwaiti marine environment. It also utilises information from a series of recent studies and reviews considering anthropogenic inputs and their effects on biological ecosystems in the marine waters of Kuwait (Al-Husaini et al., 2015; Al-Sarawi et al., 2015; Al-Zaidan et al., 2015; Lyons et al., 2013; Moore et al., 2015; Smith et al., 2015; Stentiford et al., 2014).

The Kuwait Environmental Protection Authority (KEPA) has been collecting water and sediment quality parameters from thirteen marine sites within Kuwaiti marine waters over the past 30 years (Figure 8-1). These 13 marine sites are monitored monthly as part of KEPA's long-term water quality monitoring programme (http://www.emisk.org/emisk/). Environmental water quality parameters including water temperature, salinity, dissolved oxygen (DO), total suspended solids (TSS), chlorophyll-a, dissolved inorganic nitrogen (DIN = NO2+NO3+NH4), dissolved inorganic phosphate (DIP = PO−34) and silica (Si04) have been measured over the 13 sites from 1983 to 2013. Sampling is generally monthly but can be impacted by weather.

Sampling sites include six sites within Kuwait Bay (Z01–Z06), and the remaining seven coastal sites distributed along the Kuwait coastline (Z00, Z07–Z012). The western part of the Kuwait Bay is characterised by shallow and turbid waters as well as slow dilution (Al-Ghadban and El-Sammak, 2005b) with direct impacts from the industrial activity, desalination and power plants, ports, recreational, emergency, and water storm outlets around Al-Doha, Sulaibikhat Bay and Shuwaikh Port. The water in the eastern portion of Kuwait bay is regularly exchanged with fresh seawater from the Arabian Gulf at a much higher rate (Al-Yamani et al., 2004) and less influenced by the high industrial activity on the western side of the Bay.

The monitoring information provides valuable information on the spatial and temporal trends in physio-chemical data, dissolved nutrients and phytoplankton biomass (reported as chlorophyll-a) and details the significant changes over time in response to shifts in diffuse and point source drivers.

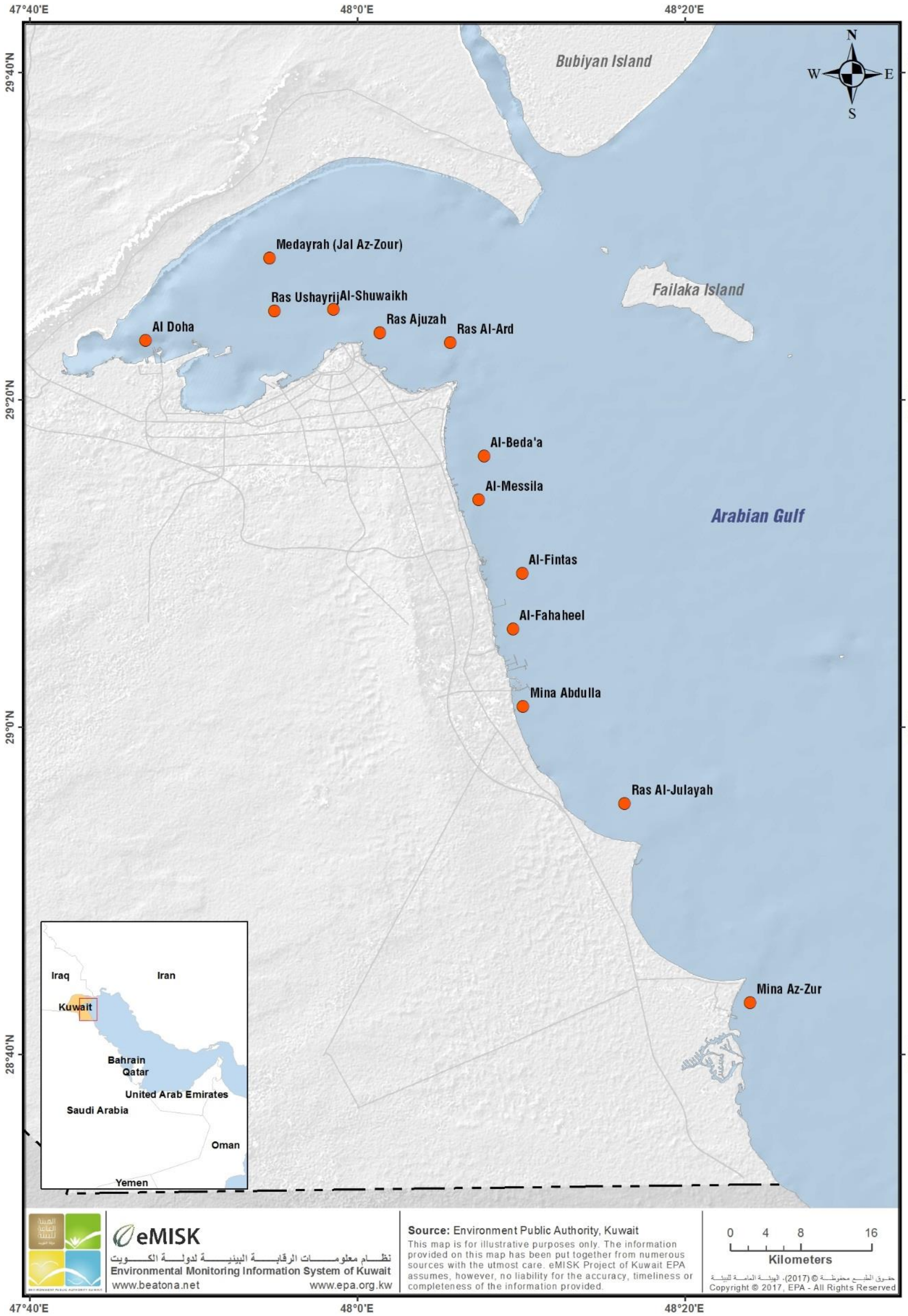


Figure 8-1: Site locations of the thirteen monitoring sites under current EPA Water Quality program.

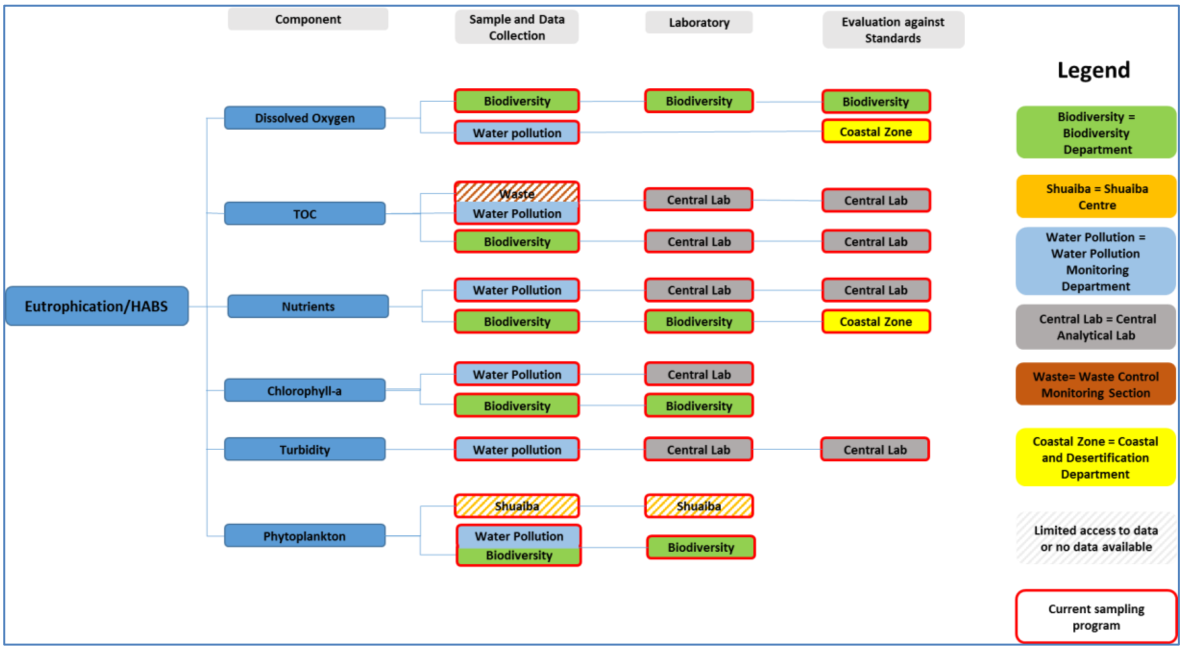


Figure 8-2: Data availabe for eutrophication assessment from current EPA monitoring programs

8.4 Assessment process

Indicators for eutrophication and harmful algal blooms are typically focused around measures of dissolved nutrients, phytoplankton biomass and community composition, suspended sediment and dissolved oxygen (Table 8-1).

Table 8-1: Objectives for eutrophication and HABS assessment.

Management indictor	Indicator	Data
EH-SG1: Human-induced eutrophication, and its adverse or undesirable effects, are minimised	No evidence of increase or impact for dissolved nutrients, phytoplankton biomass, dissolved oxygen Multimetric approach. – No undesirable disturbance	Kuwait EPA has been collecting water and sediment quality parameters from thirteen marine sites within Kuwaiti marine waters over the past 30 years (Figure 8.1).

Management indictor	Indicator	Data
	from eutrophication measured in Kuwait marine waters (need definition of undesirable disturbance).	These 13 marine sites are monitored monthly as part of KEPA's long-term water quality monitoring programme (http://www.emisk.org/emisk/). Environmental water quality parameters including water temperature, salinity, dissolved oxygen (DO), total suspended solids (TSS), chlorophyll-*a*, dissolved inorganic nitrogen (DIN = NO2 + NO3 + NH4), dissolved inorganic phosphate (DIP = $PO^{-3}{}_4$) and silica ($Si0_4$) have been measured over the 13 sites from 1983 to 2013. Sampling is generally monthly but can be impacted by weather.
EH-SG2: Human-induced causes of HABs are minimised to reduce the frequency of HABs, and where possible the adverse consequences of HABs are minimised.	Presence of HABS	HABS are not monitored regularly, and there have been no <u>major</u> HABS outbreaks since 2001. All required conditions for previous HABS outbreaks continue to occur.

If we use the OSPAR criteria for Eutrophication - Eutrophication is the result of excessive enrichment of water with nutrients which may cause an increase in the <u>accelerated growth of algae</u> in the water column and higher forms of plants living on the bottom of the sea. This may result in a <u>range of undesirable disturbances in the marine ecosystem</u>, including a shift in the composition of the flora and fauna which affects habitats and biodiversity, and the depletion of oxygen, causing death of fish and other species.

This, and many other eutrophication strategies does not just depend on a single set of objectives, such as demonstrating an increase in nutrients, but needs secondary steps where it is possible to link the measurement of an “undesirable” disturbance to the increase in nutrients. The work required for Kuwait is the identification of that undesirable disturbance and environmental standards that identify when the disturbance has been breached.

The negative effects of excessive phytoplankton growth are 1) changes in species composition and functioning of the pelagic food web, 2) increased sedimentation of organic material, and 3) increase in oxygen consumption that may lead to oxygen depletion and the consequent changes in community structure or death of the benthic fauna. The excessive settling of plankton algae may be enhanced by changes in species composition and functioning of the pelagic food web. Eutrophication can also promote harmful algal blooms that may cause discoloration of the water (and thus negative aesthetical impacts), foam formation, death of benthic fauna and fish, or shellfish poisoning of humans.

To test the many components of a eutrophication assessment, it is useful to present the data as part of a multi-metric assessment where we weight the independent operational indicators as part of a single operational assessment. This evaluates the components of each category to determine whether there is evidence of anthropogenic nutrient enrichment and any measured anthropogenic response. Evaluations of indicators are used to determine evidence of increased nutrient loads, increased nutrient concentrations, changes in nutrient ratios, and accelerated growth of primary producers (i.e. phytoplankton, SAV, macroalgae, microphytobenthos. Dissolved Oxygen is also used as an indicator of Indirect Effects that are caused by, for example, excessive phytoplankton or macroalgal biomass, and algal toxins are used as an indicator of Other Possible Effects. The final classification is, in European waters given as a Problem Area, Non Problem Area or Potential Problem Area, however for this first iteration of the SOMER process, we will provide a qualitative assessment (good, moderate, poor or bad) based on the tiers of information provided around each category (Figure 8-3).

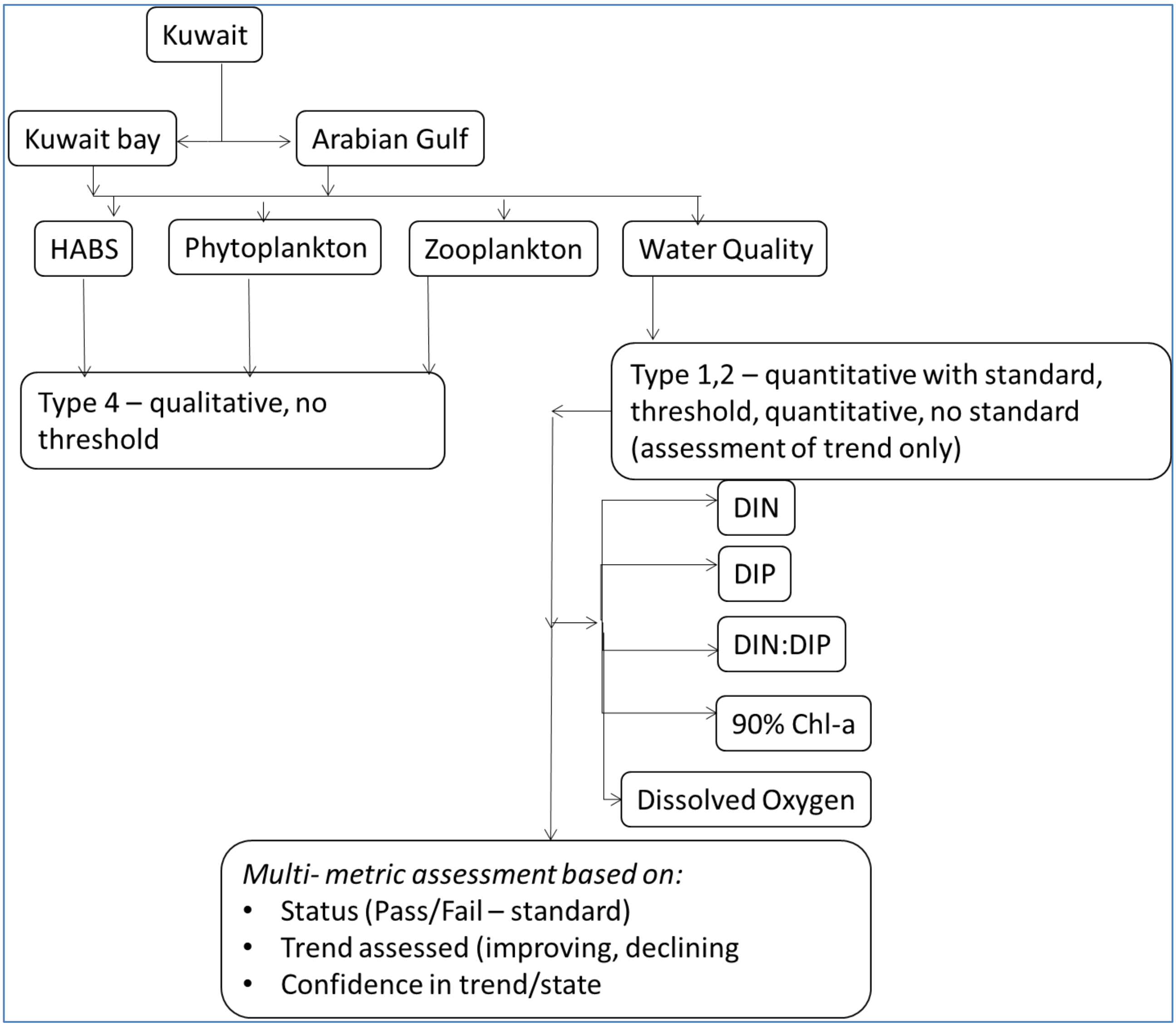


Figure 8-3: Conceptual figure of the assessment at a single environmental standard and at a multi metric level

8.5 Summary of outcomes

These outcomes show significant long-term anthropogenic changes of Kuwaiti marine waters associated with the expansion of the city and industrial activity and the changing river flow of the Shatt Al-Arab. In addition, it also provides information on the impact of large volumes of sewage discharge on an already impacted environment.

The assessment of eutrophication in Kuwait marine waters is summarise in Table 8-2.

Table 8-2:Overview of assessment of eutrophication and HABS for Kuwait marine waters.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
Water Quality (Eutrophication and Harmful Algal Blooms)						
Status assessment is MODERATE. The status assessment is due to long term increases in nutrients, changes in phytoplankton and reduced dissolved oxygen. One of the most serious concerns facing Kuwait coastal and marine waters is the continued discharges of raw and partially treated sewage into the marine environment. This is also the main driver in the assessment of POOR status for Water Quality for human health and is responsible for elevated nutrient loads into the coastal environment. A combination of chronic and diffuse nutrient loads has had a major impact on the status of the water quality indicators, particularly the concentrations of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) which have increased significantly over the last 30 years. The marine system is being affected by the increasing nutrient inputs in to Kuwait Bay and along the Gulf coast, coupled with a decreasing river discharge and changing salinity in Northern Kuwait waters. These pressures can result in changes in plankton species composition, diversity and biomass, which have had knock-on effects for higher trophic levels. Further investigation of the coupled impacts from the cumulative pressures is required. Harmful algal bloom (HAB) outbreaks have been recorded in recent times but at small scales. The conditions which were responsible for the previous recorded HABs outbreaks continue to occur and thus the estimates of future trajectory must consider that the re-occurrence of HABs outbreaks is highly likely. In conclusion, the marine system is being affected by the increasing nutrient inputs in Kuwait Bay and the Southern Gulf region, coupled with a decreasing river discharge and changing salinity in Northern Kuwait waters. These pressures can result in changes in plankton species composition, diversity and biomass, which have had knock-on effects for higher trophic levels. Further investigation of the coupled impacts from the cumulative pressures is required. HABs have not occurred in high numbers in recent years, however conditions that are linked to HABs outbreaks are present.						
WATER QUALITY (EUTROPHICATION AND HARMFUL ALGAL BLOOMS)	Eutrophication	Dissolved Inorganic Nitrogen (DIN)				Status assessment is POOR. Predicted trajectory is a continued declining state. Dissolved inorganic Nitrogen has increased across Kuwait marine waters, especially around Kuwait city and developed areas. Nitrate has been increasing from the early 2000's associated with industrialisation and inputs from Shatt Al-Arab. However chronic sewage discharges since 2007 have caused an increase in ammonium. Levels of DIN are reducing over the last two years due to some reduction in sewage discharges, however concentrations are still high in contrast to EPA thresholds and baseline concentrations.
		Dissolved Inorganic Phosphorus (DIP)				Status assessment is POOR. Predicted trajectory is a continued declining state. Dissolved inorganic Phosphorus has also increased rapidly since the late 1990's, associated with the increased urbanisation and coastal discharges. DIP is also linked to the river flow, and exhibits long term variability.
		Phytoplankton—Chlorophyll-a				Status assessment is MODERATE. The long-term chlorophyll-a data shows a reduction in the phytoplankton biomass associated with seasonal blooms particularly around the period of the extended contamination associated with sewage discharges from 2007. This may relate to a shift in the species composition of the phytoplankton community in response to the elevated ammonium concentrations. However confidence in this assessment is low due to limited understanding of the phytoplankton community.
		Phytoplankton—Community composition				Status assessment is unknown. Phytoplankton data was not available for analysis in this assessment. Recommendation for further work as a key measurement in eutrophication assessment.
		Dissolved oxygen				Status assessment is MODERATE. Whilst the dissolved oxygen concentrations are generally stable, there have been low dissolved oxygen events occurring more frequently in areas around Kuwait City and Kuwait Bay. On occasions the oxygen concentrations drop below ecological thresholds. Historic fish kills were associated with DO sags, and thus issues with low DO may be a possibility in coastal waters. The newly established EPA buoy network will provide fuller data for future assessment.
		Water quality index				Status assessment is MODERATE. The water quality index combines the nutrient, phytoplankton and oxygen data to obtain an overall index of water quality in relation to eutrophication. The overall eutrophication assessment of MODERATE is based on evidence of increased nutrient concentrations and nutrient ratios, changes in the phytoplankton and reduced dissolved oxygen.
	HABs	Harmful Algal Blooms				Status assessment is MODERATE. There has been evidence of HABs outbreaks across the wider Arabian Gulf having had severe consequences. HABs identified associated with fish kills in 1999 and 2001. However, there have been no large systemic HABs outbreaks in Kuwait in recent years. However, the conditions thought to promote HABs are still occurring and could potentially lead to additional outbreaks.

8.6 Eutrophication and HABS indicator assessments.

8.6.1 Water Quality parameters.

8.6.1.1 Background

Kuwait, as with all major cities in the Arabian Gulf, has experienced high increased in population growth, corresponding to a rapid coastal expansion and the increasing pressures associated with a high coastal population, including water quality pollution from urban and industrial inputs. Anthropogenic activities which impact on Kuwait Bay's marine environment include diffuse loads associated with the Shatt al-Arab River and the connection of water between Kuwait marine waters and the northern Arabian Gulf. More acute pressures include urban development with increases in population, sewage discharges and industrialization.

Shatt Al-Arab river is relevant when considering impacts on water quality. This is not only for the northern gulf hydrodynamics (due to the fresh water plume development and variability), but also for the primary production, which is higher than in the southern part of the bay (Al-Yamani, 2008) and an important part of the ecological functioning in northern Arabian Gulf. The discharge of Shatt Al-Arab river (which is formed by the confluence of Tigris and Euphrates rivers) into the Arabian Gulf influences both hydrodynamics and water quality. Previous estimates of the annual mean discharge are in the range of 1500 m^3/s (35 km3/year≈1110m3/s (Sadd, 1978), 45 km3/year ≈1500m3/s (Wright, 1974; Reynolds, 1993)), although it seems that these values have been significantly reduced as a consequence of water extraction upstream rivers (dam building, irrigation, etc. See, for instance, (Al-Yamani, 2008; Isave and Mikhailova, 2009 and Abdullah, A. D. et al., 2015)). Abdullah, A. D. et al. (2015) provides some data on the monthly averaged discharges of rivers Tigris (at Missan station) and Euphrates (at The-Qar station) in the pre-dam and post-dam periods, showing a 4-fold reduction of the maximum discharge for the Tigris and an approximate 3-fold reduction for the Euphrates.

8.6.1.2 Current state of knowledge

Main source of dissolved nutrients into the Kuwait Marine waters is from the Shatt Al-Arab River and through sewage discharges. The increase in Dissolved Inorganic Nitrogen (DIN_ is evident from the 1990s, in line with increasing urbanisation. The DIN signal is strongly dominated by Nitrate (NO3) which is likely to be influenced by the diffuse sources such as the input from Shatt Al-Arab river. However, from 2012, DIN increases 2 to 3 fold, driven by a rapid increase of NH4 inputs, corresponding to the illegal sewage discharges through the Mishref incidence, which saw 30 months of raw sewage discharge into Arabian Gulf.

The Mishref crisis was alleviated in August 2014, however, the DIN values recorded through the Kuwait EPA monitoring program remain high, indicating that sewage issue continues to be a problem, and maybe more widespread than assumed, with multiple sources of illegal discharges continuing to be a serious problem for long term enrichment of Kuwait coastal areas (Lyons et al., 2015; Devlin et al., 2015).

Thresholds for annual mean value of the nutrient species are not available for nitrate, nitrite or DIP, however a EPA threshold of 31ug/L for NH4 has been exceeded annually since 2009 (Figure 8-4). All nutrient concentrations have increased including DIN (Figure 8-4a), Ammonium (Figure 8-4b) and for DIP (Figure 8-4c).

The DIN:DIP ratios have increased over time with nutrient ratios moving towards a nitrogen limited system (Figure 8-5) as the ratio approaches a value of 14. If we used the OSPAR guidelines of a 50% elevation from a baseline condition (DIN:DIP = 2, based on 1988 to 1992 data), then the environmental standards would be substantively exceeded.

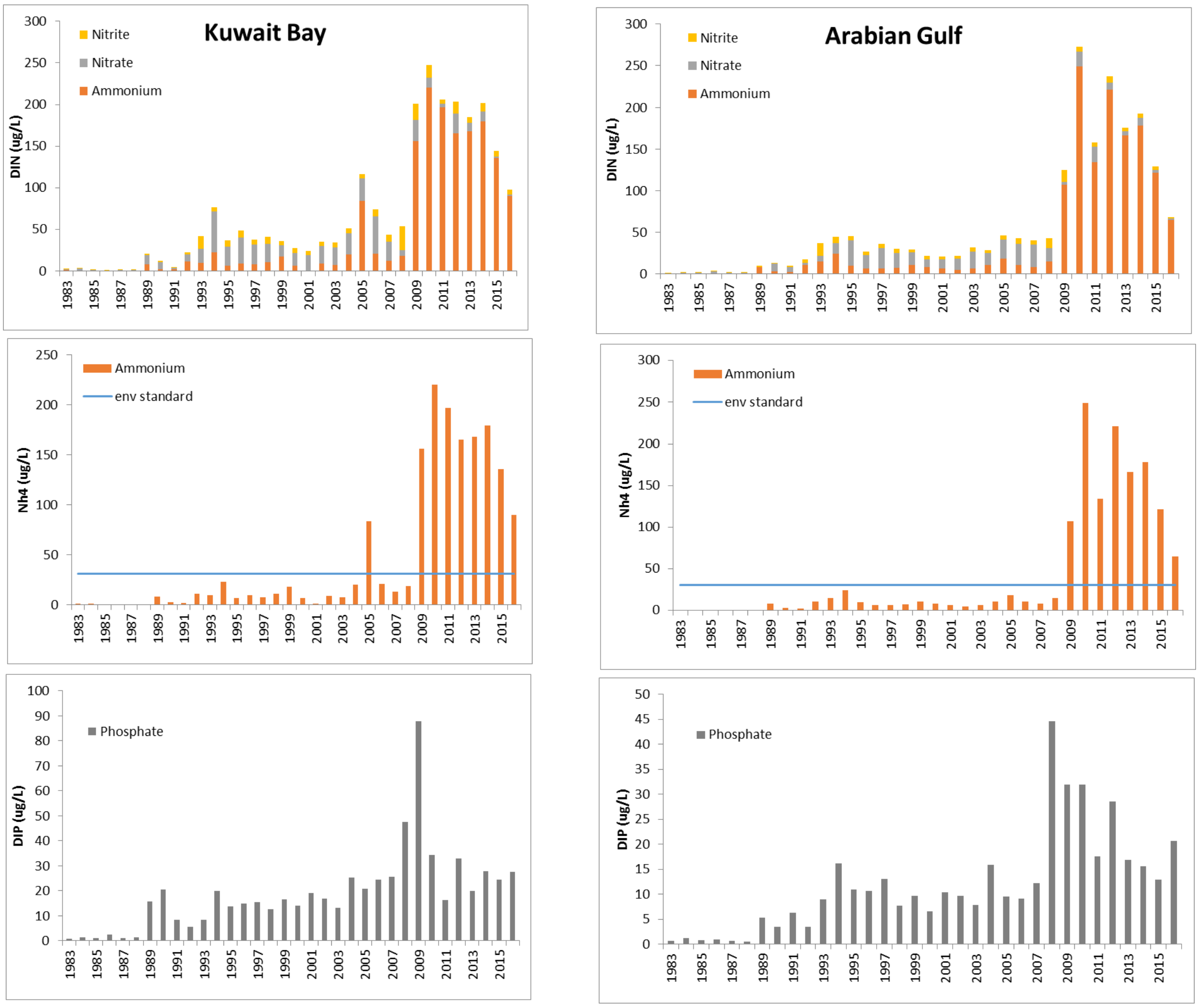


Figure 8-4: Long term annual mean value for (a) dissolved inorganic nitrogen, calculate as the sum of nitrite, nitrate and ammonium, (b) Nh4 compared against a EPA threshold of 31ug/L) and DIP.

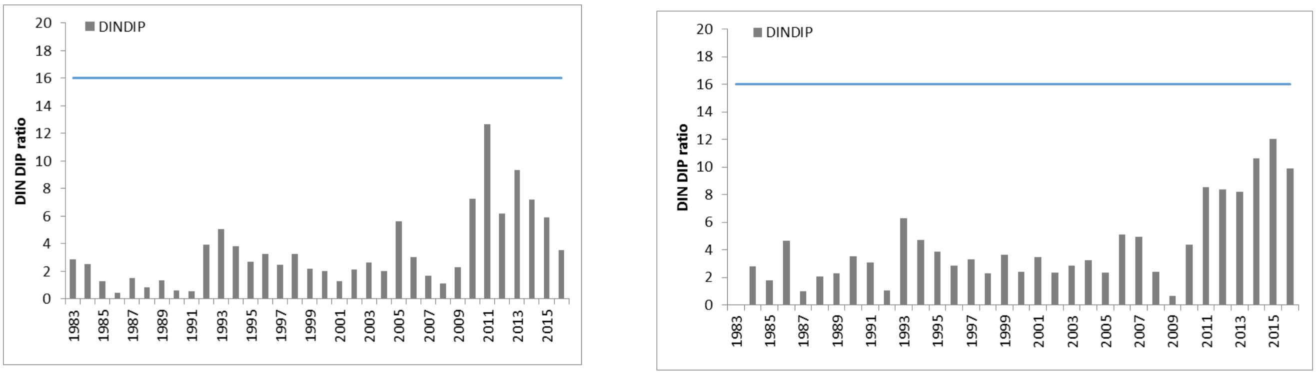


Figure 8-5: Long term annual mean value of the DIN:DIP ratios for Kuwait Bay and the Arabian Gulf sites.

Measurement of chlorophyll concentrations derived from phytoplankton biomass can be indicative of enhanced nutrient inputs in many circumstances (Furnas et al. 2005) and can provide a simple, reliable indicator of water column nutrient status in the absence of high frequency water column nutrient concentration measurements (Yunev et al., 2002; Harding and Perry, 1997). Chlorophyll concentrations represent a very simple and integrative measure of the phytoplankton community response to nutrient enrichment. Increase in the phytoplankton biomass can be measured by an increase in the chlorophyll-a concentrations.

Environmental data such as phytoplankton chlorophyll exhibits periodicity and episodic change and as a result tends to be asymmetrically distributed with few high values (outliers or spikes) and many low values. A recognised statistical approach is to derive 90th percentile values as a bulk measurement of the data (Atchinson, 1986; Clarke, 1994). The 90th percentiles represented a statistical method encompassing the spread of data for chlorophyll biomass omitting highly skewed values, which can be present during bloom periods. Phytoplankton biomass index is measured as chlorophyll concentration and is calculated as a 90th percentile of all chlorophyll data collected over the annual period (Figure 8-6). The 90th percentile value is compared with the threshold value derived from appropriate reference conditions.

The EPA water quality data provides an excellent tool for the reporting of environmental status in response to the increase in sewage and industrial discharges. In addition, it also provides information on the impact of large volumes of sewage discharge on an already impacted environment. It clearly demonstrates that sewage and industrial discharges to Kuwait marine waters have caused nutrient enrichment due to the increased supply of dissolved inorganic nitrogen and phosphorus (DIN, DIP). Whilst the nitrate (NO_3) increase is evident from the early 1990's and representative of Kuwait wide changes to the quality of water quality, the rapid increase in NH_4 over the last 6 years, and in particular from 2009, represents a direct water quality impact from the Mishref discharges. Impacts from the Mishref discharge increase are not clear, but analysis of the chlorophyll-a data suggests that the phytoplankton community has shifted, with decreases in the 90th percentile value, particularly in response to the increasing NH_4 signal through Mishref. This suggests that the community responding to changing light and nutrient conditions has shifted and may now providing less energy in the food web. From the middle of 2012, when Mishref discharges had ceased, the chlorophyll a values have started to decrease, representing a small recovery to baseline conditions for the phytoplankton. Further work and analysis of phytoplankton and zooplankton data is required for a more holistic assessment of changing phytoplankton community dynamics. This is particularly important when considering the impacts of turbidity and a potential increase in sedimentation in Kuwait Bay (Figure 8-7).

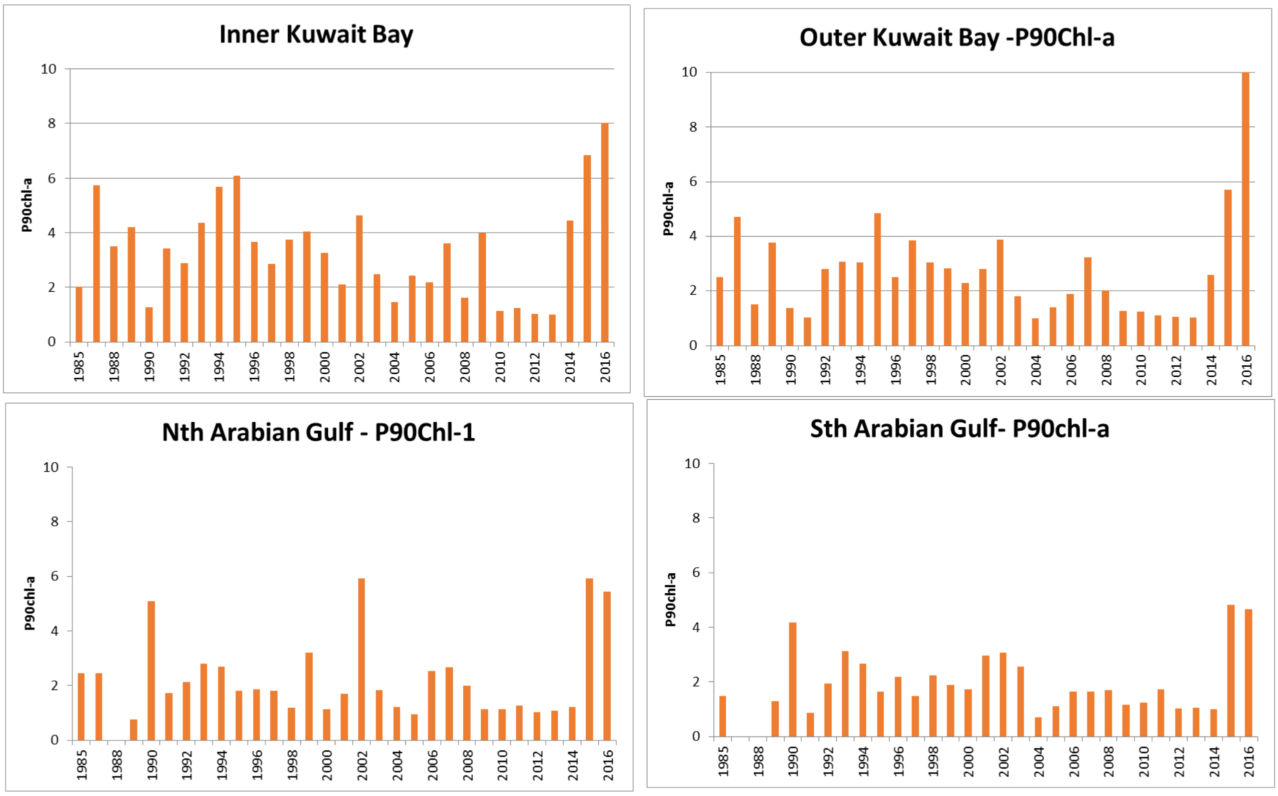


Figure 8-6: Annual measurements of the 90th percentile chlorophyll-a (P90Chl-a) for four areas in Kuwait marine waters.

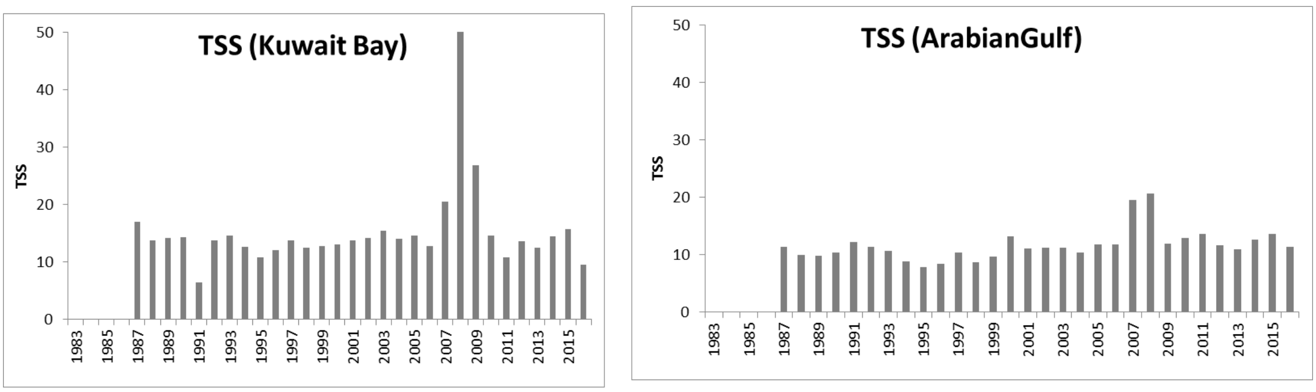


Figure 8-7: Annual measurements of the turbidity for sites aggregated into Kuwait bay and Arabian Gulf.

The fate and behaviour of dissolved oxygen is of critical importance to marine organisms in determining the severity of adverse impacts. Also important are the factors affecting the degree of fluctuations in dissolved oxygen level (Best et al., 2007). Oxygen deficiency is widely used to assess the impact due to nutrient enrichment pressure (Devlin et al, 2007). The revised common procedure for the identification of the eutrophication status of the OSPAR maritime area (OSPAR 2005), identifies oxygen deficiency as an indirect effect of nutrient enrichment. Oxygen deficiency can be induced by decaying algal blooms, long term nutrients and associated organic matter enrichment, especially in sedimentation areas, areas with long residence times and also in shallow areas with attached nuisance algae. Consequently, oxygen deficiency “during the growing season” is measured indicator under OSPAR, with 2-6 mg l^{-1} oxygen defined as a “deficiency” and less than 2mg l^{-1} as “acute toxicity”. Oxygen concentrations above 6 mg l^{-1} are considered to cause few or no problems under OSPAR. Mean annual values for DO are presented in Figure 8-8 (a) with the lower annual 5th percentile presented for Figure 8-8 (b).

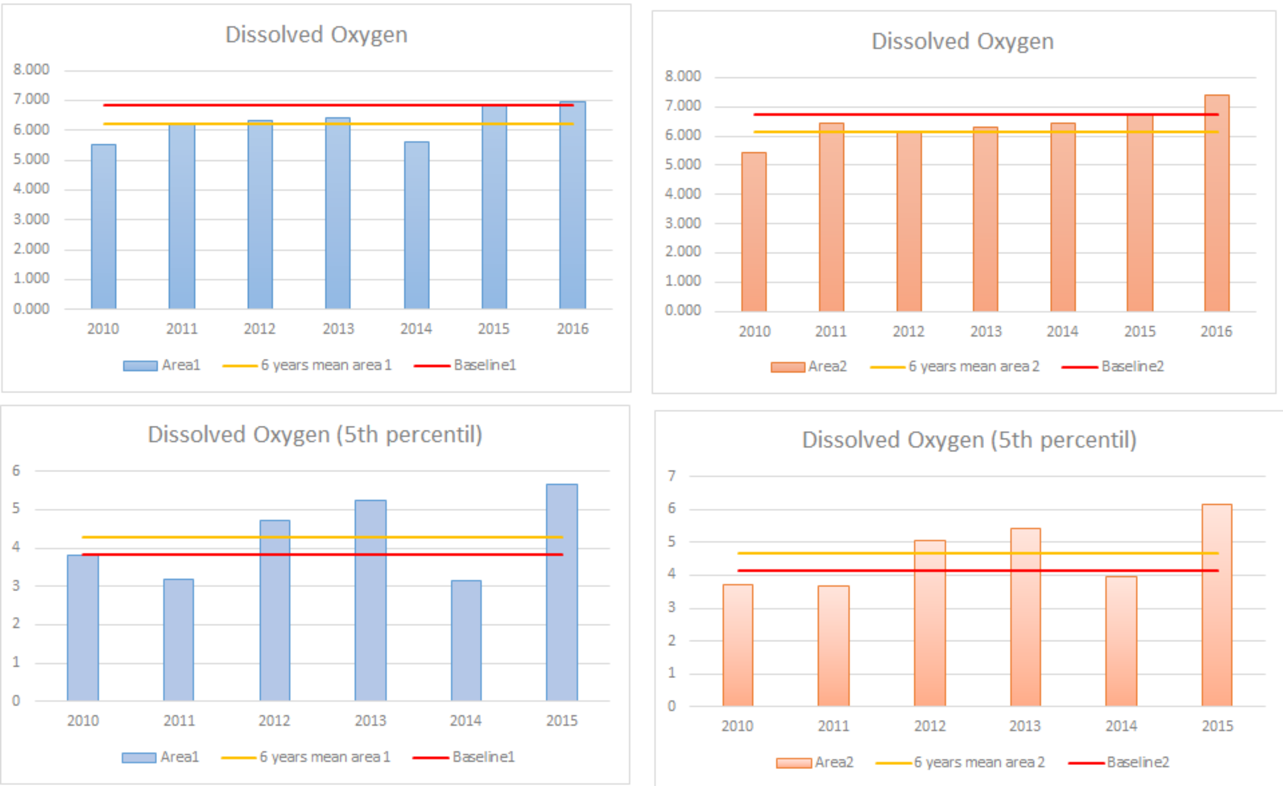


Figure 8-8: Annual measurements of the (a) mean DO and (b) lower 5th percentile DO from 2010 to 2015. Area 1 = Kuwait Bay, Area 2 = Arabian Gulf sites.

Whilst it is not practical to use the recommended thresholds without more appropriate testing of the regional significance of those thresholds, they can be used as a guideline. We also present European Water Framework Directives standards for dissolved oxygen which are reported as 5%-ile against 4mg/L, i.e. the threshold should be exceeded for 95% of the time. Whilst the annual measurements of dissolved oxygen are typically exceeding the 6mg/L thresholds with the exception of 2010 for both Kuwait Bay and the Arabian Gulf. In addition, the comparison of the 5th percentile value against the lower environmental standard of 4mg/L shows that the European thresholds are being exceeded, with less than 95% of data being above 4mg/L for 3 of the last 6 years for both Kuwait Bay and Arabian Gulf.

8.6.1.3 Assessment approach and findings

Long term analysis shows a shifting baseline, with nutrient enrichment from both dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) evident from the early 1990s. The increase in DIN is dominated by the increase in nitrate (NO_3) in the early to late 90s but shifting to an increase in ammonia (NH_4) in the later 2000's through to the current period.

It is postulated that the increase in NH_4 has supported a shift in the phytoplankton community, though this hypothesis needs testing by assessment of long term phytoplankton data. However, while the mean chlorophyll values have not fluctuated, the 90th percentile values of chlorophyll-a have decreased in the Arabian Gulf waters, indicating a change in phytoplankton community. This change is not evident in Kuwait Bay waters, as its shallow and turbid waters may be the factors limiting growth of phytoplankton in this area.

The NH_4 is associated with the rapid expansion of sewage and industrial outfalls from 1993 to the present day. The increase in nutrients, particularly NH_4, is shown across all sites, indicating a Kuwait marine wide impact from the sewage discharges.

Long-term analysis shows a shifting baseline, with nutrient enrichment from both DIN and DIP evident from the late 1990s. The increase in DIN is dominated by the increase in NO_3 in the early 90s but shifting to an increase in NH_4 in the later 90s through to the current period. The NH_4 is associated with the rapid expansion of sewage and industrial outfalls from 1993 to the present day. The increase in nutrients, particularly NH_4, is shown across all sites, indicating a bay wide impact from the sewage discharges. The increase across Kuwait Bay sites also suggests that sewage discharges are impacting across the entire Kuwaiti marine environment, and requires a management response to all illegal sewage outfalls. On a positive note, the repair of the Mishref pumping station and subsequent reduction in raw sewage being discharged in 2012 corresponds with a small decrease in NH_4 across the Arabian Gulf sites closest to the main effluent outfalls.

Whilst the environmental standards set for dissolved oxygen need to be tested for relevance in a tropical system, the exceedances of the 4mg/L thresholds is worrying, and indicates some issues of dissolved oxygen sags that seem to be persistent across the coastal waters. Further focused monitoring is recommended.

8.6.1.4 Conclusion

The increase in nutrients across all monitoring sites suggests that sewage discharges are influencing areas across the entire Kuwaiti marine environment and not limited to the areas of highest nutrient discharge. It requires a management response to all illegal sewage outfalls or times when overcapacity in the sewage treatment network results in raw effluent being discharged directly to sea. It also requires a greater understanding of the impacts of the changing nutrient regime on the phytoplankton community, and the possible impacts on higher trophic levels. There is also an urgent need to understand the role of the Shatt Al-Arab River on water quality for Kuwait and the Northern Arabian Gulf, and what the future consequences of reducing river flow may be for the region and the shifting of influence from diffuse nutrient loads to chronic nutrient loads and increased pollutant stress.

The repair of the Mishref pumping station and subsequent reduction in raw sewage being discharged in 2012 corresponds with a small decrease in NH_4 across the Arabian Gulf sites closest to the main effluent outfalls. The analysis of microbiological data and the assessment of poor state for this indicator (section 5.8.1) indicates the input of raw sewage still a major issue and continues to be a main source of dissolved nitrogen into Kuwait waters.

In the face of population growth and increasing demand for water, rapid growth of agriculture, increasing environmental degradation and socioeconomic impacts, regular reporting of the current status of Kuwait marine waters, including both Kuwait Bay and the Arabian Gulf, with respect to nutrient enrichment will be important sources of information in the on-going investigations into the impact of anthropogenic discharges into Kuwait marine waters and to provide advice for protection, rehabilitation and restoration.

Management responses to incidences such as the Mishref incident has been varied but predominately focused on the improvement in the carrying capacity of existing and new sewage plants. It is important to have the ability to monitor and provide an assessment of changing water quality conditions, to be able to report continued deterioration but also to have the ability to highlight positive changes to water quality conditions based on improved infrastructure around sewage runoff. Data needs to be collated and integrated and reported simply on a month to month basis through a traffic lighting system. This short term reporting also needs to be part of a fully supported annual and multi-annual reporting process which provides information on the status of water quality to the public and water managers. This can be done through simple to understand traffic lights (red, amber, green related to a gradient of improvement to deterioration) or a more detailed assessment provided through a report card system.

8.6.2 Water Quality Index

8.6.2.1 Background

Kuwait, as with all major cities in the Arabian Gulf, has experienced high increased in population growth, corresponding to a rapid coastal expansion and the increasing pressures associated with a high coastal population, including water quality pollution from urban and industrial inputs. Anthropogenic activities which impact on Kuwait Bay's marine environment include diffuse loads associated with the Shatt al-Arab River and the connection of water between Kuwait marine waters and the northern Arabian Gulf. More acute pressures include urban development with increases in population, sewage discharges and industrialization.

8.6.2.2 Current state of knowledge

8.6.2.3 Assessment approach and findings

The assessment of eutrophication is typically done as a multi metric assessment, linking the nutrients and phytoplankton measures together in a single metric. The overall water quality index suggests that the combination of increased nutrients, have led to changes in phytoplankton biomass. There are also suggestions of localised dissolved oxygen sags, which, whilst localised, indicate a more persistent and ongoing problems associated with extended nutrient enrichment of the coastal environment.

Kuwait Bay	Temperature	Salinity	Slicate	TSS	Chlorophyll	DO	Ammonium	Nitrite	Nitrate	Nox	DIN	Phosphate
Trend	↓ -1	↓ -1	↓ -1	↓ -1	↑ 1	↑ 1	↓ -1	↓ -1	↓ -1	↓ -1	↓ -1	↑ 1
Compliance	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1

Arabian Gulf	Temperature	Salinity	Slicate	TSS	Chlorophyll	DO	Ammonium	Nitrite	Nitrate	Nox	DIN	Phosphate
Trend	↓ -1	↓ -1	↓ -1	↓ -1	↑ 1	↑ 1	↓ -1	↓ -1	↓ -1	↓ -1	↓ -1	↓ -1
Compliance	1	1	1	-1	-1	-1	-1	-1	1	1	-1	1

Figure 8-9: trend and compliance of water quality indicators based on comparison of annual value over last 6 years against a baseline thresholds (1988 – 1992) and a rolling 6 year mean. Trend is based on an increasing or decreasing signal and not indication of deterioration.

The trend and compliance of water quality indicators based on comparison of annual value over last 6 years against a baseline threshold (1988 – 1992) and a rolling 6-year mean is presented for each water quality indicator (Figure 8-9). Trend is based on an increasing or decreasing signal and not indication of deterioration.

8.6.2.4 Conclusion

A integrated assessment has been applied in Table 8-3 where we have used the structure of the OSPAR approach, to report over three criteria, including (i) degree of nutrient enrichment (causative factors), (ii) direct effects of nutrient enrichment and, (iii) indirect effects of nutrient enrichment. All three criteria have data for assessment in Kuwait marine waters, despite data not being available for indirect effects such as phytoplankton community and zooplankton community.

Trend and compliance values have been reported for each index over the last 6 years. Baseline is reported as the average annual value measured prior to 1992 for KB (Baseline 1) and AG (Baseline 2). Trend is reported as an increase from a previous 6 year rolling mean for KB (trend 1) and AG (trend 2). The annual measure is reported as a problem when the annual measured value exceeds the baseline for the appropriate areas.

High nutrient concentrations, increasing trends, changes in river loads, evidence of changes in chlorohyll-a concentraions and occasional reductions in DO contribute to a high degree of confidence that nutrient enrichment has and continues to be a major issue for the Kuwait Marine Environment.

Table 8-3: Summary of outcomes for Eutrophication multi-metric

Assessment Parameters	Description
Category I. Degree of nutrient enrichment (causative factors);	
1. Riverine inputs and direct discharges (area specific)	Limited information on Al Shatt River. Flow has significantly decreased over the past 50 years, thus potentially affecting the productivity of the northern Gulf region. However, as data on flow conditions is limited, and little work has been done on the potential impacts of reduced flow, this sub-metric was not included in the quantitative analysis but is recognised as a main driver of diffuse inputs into the marine waters. Turbidity has been linked to the changes in Shatt Al-Arab River. Baseline is reported as the average annual value measured prior to 1992 for KB (Baseline 1) and AG (Baseline 2). Trend is reported as an increase from a previous 6 year rolling mean for KB (trend 1) and AG (trend 2). The annual measure is reported as a problem when the annual measured value exceeds the baseline for the appropriate areas

Average of TSS	Last 6 years data									
Years	KB	AG	6 years mean Line1	6 years mean Line2	Baseline1	Baseline2	Trend1	Trend2	1 problem	2 problem
2010	14.634	12.904	13.431	12.404	13.766	10.402	↑ 1	↑ 1	● -1	● -1
2011	10.852	13.656	13.431	12.404	13.766	10.402	↓ -1	↑ 1	● 1	● -1
2012	13.609	11.596	13.431	12.404	13.766	10.402	↑ 1	↓ -1	● 1	● -1
2013	12.556	10.950	13.431	12.404	13.766	10.402	↓ -1	↓ -1	● 1	● -1
2014	14.440	12.610	13.431	12.404	13.766	10.402	↑ 1	↑ 1	● -1	● -1
2015	15.680	13.643	13.431	12.404	13.766	10.402	↑ 1	↑ 1	● -1	● -1
2016	9.582	11.311	13.431	12.404	13.766	10.402	↓ -1	↓ -1	● 1	● -1
Overall average	**13.431**	**12.404**	13.431	12.404	13.766	10.402				

Assessment Parameters	Description
2. Nutrient concentrations (area specific) Elevated level(s) of winter DIN and/or DIP	The period of assessment is taken as an arithmetic mean across the whole year. Thresholds for nutrients were taken from the Kuwait EPA monitoring program which has set thresholds for NH4. For example, Winter DIN thresholds – relative to salinity/area. Kuwait Bay/Arabian Gulf – salinity 35 - 40. Threshold for NH4 = 31µg/L

Average of Nitrate	Last 6 years data									
Years	KB	AG	6 years mean Line1	6 years mean Line2	Baseline1	Baseline2	Trend1	Trend2	1 problems?	2 problems?
2010	15.270	5.765	9.712	5.151	1.538	1.475	↑ 1	↑ 1	-1	-1
2011	5.087	5.055	9.712	5.151	1.538	1.475	↓ -1	↓ -1	-1	-1
2012	14.640	7.380	9.712	5.151	1.538	1.475	↑ 1	↑ 1	-1	-1
2013	6.307	4.099	9.712	5.151	1.538	1.475	↓ -1	↓ -1	-1	-1
2014	9.720	5.232	9.712	5.151	1.538	1.475	↑ 1	↑ 1	-1	-1
2015	6.240	4.458	9.712	5.151	1.538	1.475	↓ -1	↓ -1	-1	-1
2016	6.111	1.615	9.712	5.151	1.538	1.475	↓ -1	↓ -1	-1	-1
Overall average	9.712	5.151								0
										1

Average of NH4	Last 6 years data									
Years	KB	AG	6 years mean Line1	6 years mean Line2	Baseline1	Baseline2	Trend1	Trend2	1 problem	2 problems?
2010	220.283	252.291	174.546	190.503	5.518	5.027	↑ 1	↑ 1	-1.000	-1.000
2011	196.891	154.459	174.546	190.503	5.518	5.027	↑	↓	-1.000	-1.000
2012	165.051	207.795	174.546	190.503	5.518	5.027	↓ -1	↑ 1	-1.000	-1.000
2013	168.329	166.326	174.546	190.503	5.518	5.027	↓	↓	-1.000	-1.000
2014	179.484	174.275	174.546	190.503	5.518	5.027	↑ 1	↓ -1	-1.000	-1.000
2015	135.585	125.878	174.546	190.503	5.518	5.027	↓	↓	-1.000	-1.000
2016	90.143	69.358	174.546	190.503	5.518	5.027	↓ -1	↓ -1	-1.000	-1.000
Overall average	174.546	190.503							1.000	1.000

<table>
<tr><th>Assessment Parameters</th><th>Description</th></tr>
<tr><td></td><td>
<table>
<tr><td>Average of DIN</td><td>Last 6 years data</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th>Years</th><th>Area1_DIN</th><th>Area2_DIN</th><th>6 years mean Line1</th><th>6 years mean Line2</th><th>Baseline1</th><th>Baseline2</th><th>Trend1</th><th>Trend2</th><th>1 problems?</th><th>2 problems?</th></tr>
<tr><td>2010</td><td>247.4296697</td><td>276.2360478</td><td>183.6302604</td><td>176.1991517</td><td>12.212</td><td>11.604</td><td>1</td><td>1</td><td>-1</td><td>-1</td></tr>
<tr><td>2011</td><td>206.191619</td><td>168.0074703</td><td>183.6302604</td><td>176.1991517</td><td>12.212</td><td>11.604</td><td>1</td><td>-1</td><td>-1</td><td>-1</td></tr>
<tr><td>2012</td><td>203.6175399</td><td>219.7973529</td><td>183.6302604</td><td>176.1991517</td><td>12.212</td><td>11.604</td><td>1</td><td>1</td><td>-1</td><td>-1</td></tr>
<tr><td>2013</td><td>184.598</td><td>179.0852041</td><td>183.6302604</td><td>176.1991517</td><td>12.212</td><td>11.604</td><td>1</td><td>1</td><td>-1</td><td>-1</td></tr>
<tr><td>2014</td><td>201.5833482</td><td>182.858</td><td>183.6302604</td><td>176.1991517</td><td>12.212</td><td>11.604</td><td>1</td><td>1</td><td>-1</td><td>-1</td></tr>
<tr><td>2015</td><td>144.119875</td><td>131.8829233</td><td>183.6302604</td><td>176.1991517</td><td>12.212</td><td>11.604</td><td>-1</td><td>-1</td><td>-1</td><td>-1</td></tr>
<tr><td>2016</td><td>97.87177083</td><td>75.52706349</td><td>183.6302604</td><td>176.1991517</td><td>12.212</td><td>11.604</td><td>-1</td><td>-1</td><td>-1</td><td>-1</td></tr>
<tr><td>Overall average</td><td>183.6302604</td><td>176.1991517</td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td><td>0</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1</td><td>1</td></tr>
</table>
P was assessed as part of the N/P ratio (see assessment parameter 3, below).
</td></tr>
<tr><td>3. N/P ratio (area specific)

Elevated winter N/P ratio (Redfield N/P = 16)</td><td>Significant deviation (>50%) from Redfield ratio based on the ratio between annual average nutrient concentrations.</td></tr>
<tr><td colspan="2">Category II. Direct effects of nutrient enrichment;</td></tr>
<tr><td>1. Chlorophyll concentration (area specific)

Elevated percentile</td><td>90th percentile calculated for each year

Suggested Thresholds:

No agreed environmental standards for chlorophyll-a</td></tr>
</table>

Assessment Parameters	Description
	(spreadsheet below)

Last 6 years

Year	Area1	Area2	6 years mean Line1	6 years mean Line2	Baseline	Baseline2	Trend1	Trend2	1 problems	2 problems
2009	1.97	1.20	2.78	1.96	4.69	2.9474	↓ -1	↓ -1	1	1
2010	1.20	1.30	2.78	1.96	4.69	2.9474	↓ -1	↓ -1	1	1
2011	1.30	1.60	2.78	1.96	4.69	2.9474	↓ -1	↓ -1	1	1
2012	1.10	1.10	2.78	1.96	4.69	2.9474	↓ -1	↓ -1	1	1
2013	1.10	1.20	2.78	1.96	4.69	2.9474	↓ -1	↓ -1	1	1
2014	6.03	1.20	2.78	1.96	4.69	2.9474	↑ 1	↓ -1	-1	1
2015	6.79	6.11	2.78	1.96	4.69	2.9474	↑ 1	↑ 1	-1	-1
P90Chl-a	2.78	1.96								

Assessment Parameters	Description
2. Phytoplankton indicators (area specific) Elevated levels of phytoplankton species (and increased duration of blooms)	Phytoplankton assessment elevated counts of phytoplankton taxa. Limited data available at this point so not included in quantitative assessment, However, information provided as secondary information
3. Macrophytes including	Not included in assessment

Assessment Parameters	Description
macroalgae (area specific)	
Category III. Indirect effects of nutrient enrichment.	
1.Oxygen deficiency Decreased levels (< 4-6 mg l^{-1}) and lowered % oxygen saturation	The assessment levels that are used are concentrations measured below **4 – 6 mg l^{-1}** (**50 -75 % oxygen saturation**) to judge whether oxygen is scored as an undesired oxygen deficiency level for each area • Assessed as an annual measurement of the 5^{th} percentile value • Mean of the lowest quartile (lowest 25%) of the data
2. Zoobenthos and fish	Not assessed
3. Organic Carbon/Organic Matter	Not assessed

8.6.3 Occurrence of HABS

8.6.3.1 Background

Factors that lead to new invasions of HAB species are prevalent in the ecology and the oceanography of the Gulf—considerable global ballast discharge into warm stable waters with elevated nutrients. Reviews of Gulf issues have identified that the increases in anthropogenic discharge, combined with projected, episodic warming events (Sheppard et al. 2010; Sale et al., 2011) and the construction of further protected lagoons may continue to create suitable conditions leading to the expansion of HAB events throughout the Gulf.

Tropical harmful algal blooms (HABs) are increasing in frequency and intensity and are substantially affecting marine communities. In October/November 2008 a large-scale HAB event (> 500 km^2, dinoflagellate Cochlodinium polykrikoides) in the Gulf of Oman caused the complete loss of the branching corals, Pocillopora and Acropora spp., and substantial reductions in the abundance, richness and trophic diversity of the associated coral reef fish communities. Although the causative agents of this C. polykrikoides bloom are unknown, increased coastal enrichment, natural oceanographic mechanisms, and the recent expansion of this species within ballast water discharge are expected to be the main agents. With rapid changes in oceanic climate, enhanced coastal eutrophication and increased global distribution of HAB species within ballast water, large-scale HAB events are predicted to increase dramatically in both intensity and distribution and can be expected to have increasingly negative effects on coral reef communities globally.

Nearly three-quarters of benthic community change in Dibba was due to reductions in the cover of Pocillopora damicornis (55.7% contribution) and Acropora arabensis (17.6% of contribution). P. damicornis comprised 49.4% +/- 15.6% cover at Dibba before the HAB event, but was completely eliminated during the HAB event; A. arabensis was less abundant (0.5 +/- 0.2% cover), but also experienced 100% mortality during the HAB. Such changes in coral cover at both locations may have been due to the substantial reductions in O2 and PAR during the HAB event (Valiela, 1995). Low dissolved oxygen levels during algal blooms have been identified as one of the primary causes of benthic mortality (Smith 1975; Guzman et al., 1990), and the combination of reduced surface light penetration and anoxia are likely to have rapidly decreased coral photosynthetic efficiency and increasing respiratory rates (Jokiel and Coles, 1990).

8.6.3.2 Current state of knowledge: Kuwait

Seasonal non-harmful blooms are normal phenomena in Kuwait’s waters and in the Gulf region (Al-Hassan et al., 1990; Al-Yamani et al., 2000; Subba Rao et al., 1999, 2003). In general, microalgal blooms can cause discoloration of the water (generally known as red tides), some of which can have harmful effects such as mass mortalities in fish, invertebrates, birds, and mammals. There are serious impacts of red tide incidences and occurrences of the harmful algal blooms (HABs) on human health, fishery resources, and marine ecosystems throughout the world. When toxic species are in bloom conditions, the toxins can be quickly transferred through the food chain and indirectly passed onto humans via fish and shellfish consumption, sometimes resulting in gastrointestinal disorders, permanent neurological damage, or even death (Faust and Gulledge, 2002).

8.6.3.3 Assessment approach and findings

Potentially harmful species that were reported elsewhere in the world as toxin producers or causing blooms with associated harmful effect have been identified in Kuwait (Al-Yamani et al., 2010). A total of 62 identified taxa can be categorized as potentially harmful species in the samples from Kuwait waters and intertidal flats. A total of 43 taxa can be related to potentially toxic to humans and marine biota, and 10 taxa have been previously described elsewhere as potentially harmful to fish and invertebrates. Moreover, 15 species have been already observed as bloom-forming.

8.6.3.4 Conclusion

The understanding of HAB events in the Gulf region is progressing however it is surprising that additional HAB events have not been documented (Sale et al., 2011) given that the ongoing conditions that have led to the documented outbreaks are continuing. Kuwait has been the source of two major HABS outbreaks, resulting in fish kills in 2001 and 2003 and those conditions that led to the HABS outbreaks are still possible given that nutrient enrichment has stayed high and the long term predictions for warming conditions in Kuwait marine waters.

The sudden emergence of *C. polykrikoides* across the larger Gulf region coincides with an apparent global expansion of this taxon, as well as a recent increase in HAB impacts observed in this region. The mechanisms underlying this expansion require further investigation, and may include increased nutrient enrichment of coastal waters in the Arabian Gulf from domestic and industrial inputs, natural meteorological and oceanographic forcings, and the recent introduction of this species through ballast water discharge. A pattern of subsequent recurrence of *C. polykrikoides* blooms following an initial outbreak has been observed in other parts of the world, suggesting that this species may become a persistent HAB problem in this region. As Arabian Gulf countries rely on desalination plants as the primary source of freshwater, the disruption of plant operations by recurring *Cochlodinium* blooms poses a serious threat to the drinking water supply in the region, and represents an unprecedented HAB impact.

In the face of population growth and increasing demand for water, rapid growth of agriculture, increasing environmental degradation and socioeconomic impacts, regular reporting of the current status of Kuwait marine waters, including both Kuwait Bay and the Arabian Gulf, with respect to nutrient enrichment will be important sources of information in the on-going investigations into the impact of anthropogenic discharges into Kuwait marine waters and to provide advice for protection, rehabilitation and restoration.

9 Coastal processes and oceanography

9.1 Introduction

The Arabian Gulf is a semi-enclosed marginal sea, exposed to an arid, sub-tropical climate. The Gulf is approximately 990 km long with a maximum width of 370 km, and occupies a surface area of approximately 239,000 km^2 and has an average depth of 36m.

From the context of structural geology, the Gulf of Arabia forms a typical foreland basin bordered on one side by the Arabian Shield and on the other side by the Iranian (Zagros) fold belt (Evans, 2011). The geological and geomorphological evolution of the Kuwait marine area is characterised by the tectonic movements and geomorphic processes occurred in the Gulf during the late Pliocene-Pleistocene age (Kassler, 1975; in Al-Bakri et al., 1984).

Main sediment supply into the Gulf are terrigenous sediments from the Iranian flank and the deposits of the Tigris, Euphrates and Karun rivers which form the deltaic plains of Mesopotamia (Evans, 2011). The Gulf has a high productivity area but it is colonised by a depleted Indian Ocean flora and fauna due to its extremes of salinity and temperatures much greater than those in the Indian Ocean: according to Evans (2011) planktonic foraminifera are only present as far north as something like the latitude of the Qatar peninsula.

A secondary and important supply of sediment to the Gulf region are aeolian sediments from dust storms. These phenomena bring large quantities of terrigenous material to the Kuwait offshore region and in general to the Gulf of Arabia (Khalaf et al., 1984). Based on a year monitoring along the coastal areas of Kuwait, Khalaf and Al-Hashash (1983) estimated the annual fallout to be 1 mm yr-1 (1 m every 1000 years); such a rate is much higher than the average rate of aolian deposition in the oceans, i.e. 10-3-10-4 mm yr-1 (Foda et al., 1985). Several attempts have been made to identify the sources of aeolian sediment. Al-Dousari and Al-Awadhi (2012) have identified five major sources:

- south-western desert of Iraq,
- the Mesopotamian Flood Plain in Iraq,
- north-eastern desert of Saudi Arabia,
- drained marshes areas in southern Iraq,
- sabkhas, dry marshes and abandoned farms in Iran at northern coastal areas of the Arabian Gulf.

Other sources were identified in the Bubiyan and Warba (sabkhas) islands in Kuwait, the drainage system in the border area between Kuwait, Saudi Arabia and Iraq, the playas and drainage basins in the south-western desert of Iraq close to Kuwait and the coastal sabkha in Saudi Arabia, near the southern border with Kuwait (Figure 9-1).

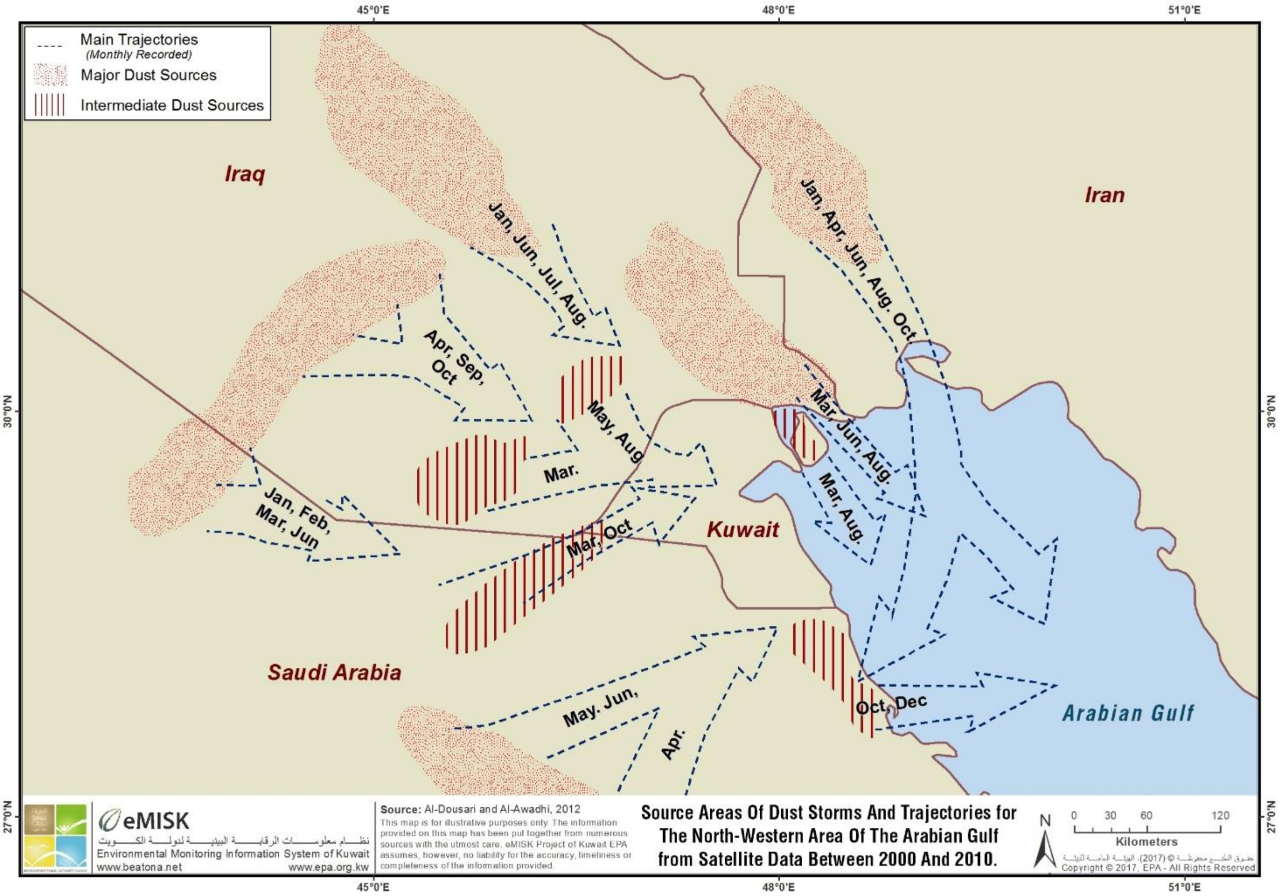


Figure 9-1: Source areas of dust storms and trajectories for the north-western area of the Arabian Gulf from satellite data between 2000 and 2010 (from Al-Dousari and Al-Awadhi, 2012).

Kuwait has approximately 235 km of coastline, 500 km when including its nine islands, with an estimated 5000 km^2 of territorial waters in the north-western area of the Gulf of Arabia (Al-Ghadban et al, 2002, Neelamani et al., 2007). The bathymetry of Kuwait's marine areas is generally shallow with depths within 20 m increasing in a southeasterly direction to a maximum of 30 m (Al-Bakri et al., 1984). Depths increase gradually offshore but more rapidly along the southern coastline (Al-Ghadban et al., 2002). Based on coastal landforms, sediments and processes Al-Bakri (1996) divides the coast of Kuwait in two main geomorphic provinces. The northern province is characterised by extensive muddy intertidal flats and a depositional and low-energy environment. The southern province has relatively steeper beach profiles, rocky and sandy tidal flats and is dominated by a moderate to high-energy environment.

The northern boundary of Kuwait is marked by the delta of Shatt-Al-Arab, the river formed by the convergence of the Tigris and Euphrates rivers, as well as the Karun River from the Zagros mountains of Iran. The Shatt Al Arab is considered to be the main provider of freshwater to the northern region of the Gulf, including the Bay (Reynolds, 1993; Sheppard et al., 2010). The Shatt-Al-Arab has a seasonally variable discharge with an annual mean of 1,400 m3/s (Pous et al., 2015) and a net annual suspended sediment discharge into the Gulf of Arabia of 0.93 million tonnes (Karim and Salman, 1987)

Due to the strong north-westerly wind, the Shamal, the delta receives, in addition to its fluvial load a large supply of aeolian sediment (up to 43% of the total supply Gunatilaka pers.comm., 2006 to Evans, 2011) derived mainly from its hinterland. Therefore, the delta is building with mostly polygenic, siliciclastic deposits into a sea dominated by carbonate sediment and bordered by a desert with carbonate sediment-dominated coastal plain (Gunatilaka, 1986; Evans, 1989; quoted in Evans, 2011).

Below the delta is the embayment of Kuwait Bay, a semi-enclosed, shallow body of water extending about 35 km inland, with an average depth of 5 m (Al-Ghadban et al., 2002; Al-Banaa and Rakha, 2009) and a maximum depth of 20 m. Its northern shorelines are dominated by the escarpment of Jal-az-Zoar and broad intertidal flats, formed by the abundance of sediment supply and a tidal range of 3.5m. The southern shoreline of Kuwait Bay is densely developed and consists of a series of perched beaches and low headlands formed in intertidal coral rocks (Kana and Al-Sarawi, 1988). With a tidal amplitude of almost 2 m, two-thirds of Kuwait Bay are exposed during very low tide (Warren, 2016). Due to low wave energy and the proximity of muddy sediments from Shatt-Al-Arab, the central part of the Bay is very muddy and almost impossible to walk through according to Warren (2016).

Kuwait Bay includes smaller units, notably Unna Island and Sulaibikhat Bay. This shallow bay has an average water depth of less than 8.0 m and is situated in the southwest corner of Kuwait Bay. Sulaibikhat Bay is known for hosting some of the most extensive intertidal mudflats in the Gulf. The bay is a sub-system of Kuwait Bay and forms one of the most biologically active areas in the Gulf region, a unique ecosystem where tidal processes dominate and intertidal and subtidal mudflats host a rich variety of marine species, including two new crab species according to Jones and Clayton (1983; in Al-Banaa and Rakha, 2009).

The Ras-al-Aardh headland separates Kuwait Bay from the open Arabian Gulf. South of this headland, the shoreline is formed by a series of shallow embayments with sandy beaches between cuspate forelands and it is generally deeper with higher water energy (Kana and Al-Sarawi, 1988; Al-Ghadban et al, 2002). There are three coral islands, Kubbar, Qaru and Umm Al-Maradem, and several submerged coral reefs in Kuwait waters (Al-Ghadban et al. 2002). Umm Al-Namil Island is one of the small northern islands located within Kuwait Bay. Subtidal flats within the island consist of soft muddy sand with high productivity. The island mainland is carbonate and dominated by oolitic limestone and loose oolitic sand (Al-Zamel et al., 2007).

9.2 Drivers and pressures on coastal processes

Studies of marine sediments in Kuwait waters (Pilkey and Nobel, 1966, Kukal and Saadallah, 1973, Al-Bakri et al., 1984, Khalaf et al, 1984) confirm that marine sediments are mostly of detrital origin, derived from dust fallout (estimated to be up to a third of all Gulf marine sediment by Sugden, 1963) and recent surface deposit in Kuwait. Given that the greater part of the Tigris-Euphrates suspended material is deposited in the marshes of Iraq and the studies on marine sediments, Al-Bakri et al. (1984) suggest that the dust and dust storms derived from the Shamal winds passing over southern Iraq and Kuwait are more important contribution than the Shatt-Al-Arab River system as a source of detrital sediments in the Kuwait waters. Therefore, they concluded that recent marine sediment in Kuwait are mostly of detrital origin and polygenetic. In order of importance of source contribution, they are made up of dust fallout originated by southern Iraq and the surface deposits of Kuwait, abraded material from local coastal sediments, direct biochemical precipitation from Gulf waters, sediment transported by the Shatt-Al-Arab and submerged ancient sediments on the offshore seabed.

Khalaf et al (1984) found the offshore surface sediment mainly consisting of several mixtures of sand, silt and mud, mainly mud, sandy mud and sandy silt. These prevailing fine-grained mixtures were found to occupy the deeper areas and the sheltered shallow offshore sites. Relatively coarse-grained sediments (sand, muddy sand, and silty sand) are of very limited distribution: they are associated with shallow rocky bottoms, subjected to strong waves and currents, in tidal flat and nearshore areas extending from Ras Ajuzah in Kuwait Bay to Al-Khiran in the south, in tidal flat and nearshore areas of Failaka Island and the small islands of southern Kuwait and the rocky seabed at the bathymetric highs in the north-eastern area of Kuwait waters. The biogenic component (mainly carbonates from shells, shell fragments and pellets) is mainly included in coarse-grained sediments and represents the 35-80% of sand fraction. Although not of biogenic formation, ooids were found in few samples and counted with the biogenic components. The highest carbonate content (> 60%) is found in nearshore sediments of the Gulf, around the islands in the south and around the bathymetric highs. Khalef et al (1984) attribute the high content of carbonates in nearshore sediments to the nearby rocky tidal flats largely composed of ooids and cemented shells and shell-fragments. Biogenic component and rock fragments in the sand fraction are both produced by the in situ breakdown of rocky seabed and coastal material by wave and current action as well as organic activity. Molluscs, foraminifera and echinoids represented together more than 90% of the faunal content of the sand fraction. Large shells and shell fragments are abraded by waves and currents from the nearby raised beaches and submerged reefs. Khalaf and co-authors concluded that Kuwait offshore area is a low-energy environment mainly depositional with little net sediment movement inside the area. Conversely, sediment movement occurs in relatively high-energy areas due to tidal currents, waves and wind-generated longshore currents: those include the southern offshore area of Kuwait Bay and in the nearshore area along the southern coast of Kuwait (Khalaf et al., 1984).

The northern part of the Arabian Gulf is considered one of the hottest regions of the planet and summer air temperatures can reach over 50.0°C (Kim and Jeong, 2013). Last summer on 21 July 2016, a weather station in Mitribah, a remote area of north-west Kuwait, registered a record temperature of 54°C (Guardian Newspaper, UK, 23 July 2016). Humidity in the Gulf coastal areas averages 50% to 60%, but may reach over 90% in summer and autumn. The historical maximum sea water temperature in the Gulf is reported as 36.2°C at the eastern coast of Saudi Arabia (Kim and Jeong, 2013). The mean annual sea water temperature of Kuwait Bay is about 24°C. The lowest value was recorded in January, 11.9°C, the highest in August, 36°C (; Al-Yamani et al. 2004; cited in Al-Rashidi et al., 2009). Anderlini et al. 1982 found that the water temperature in the north of Kuwait Bay is lower than the south of the bay, probably due to the effect of the north-westerly wind (shamal) but also the result of the high industrial and urban development on the southern part of the bay (Al-Rashidi et al., 2009). Sea water temperature is one of the important physical parameters for sustainability of marine species.

Recent studies (Al-Rashidi et al., 2009; Al-Banaa & Rakha, 2009) have shown that the seawater temperature in the northern Gulf is increasing with a rate higher than currently accepted global values. Al-Rashidi et al. (2009) found that AVHRR (NOAA) satellite data of Kuwait Bay, collected between 1985 and 2002, show that sea surface temperature (SST) has increased at a rate of 0.6 (±0.3)°C/decade. This trend is three times the values of increase in global average reported by the Intergovernmental Panel on Climate Change. The greatest rate of change was found in May and June and the least change during winter months. The trends defined by satellite data were validated by routine in situ monthly measurements of SST and were also comparable to air temperature trends recorded at Kuwait airport. The monthly measurements of SST also show a peak in summer temperature occurring simultaneously with an El Niño event in 1998. A lower summertime peak during 1991 is considered to be the result of atmospheric dimming caused by dense smoke that persisted in the region during that year in the aftermath of Iraqi invasion of Kuwait (Al-Rashidi et al., 2009).

According to Reynolds, 2002, the northern Arabian Gulf is considered a well-mixed water body due to high semi-diurnal tidal variation, wave activity, winds and high rates of evaporation.

Due to high evaporation and the relative shallowness of the Gulf waters, values of salinity over most of the Gulf reach a maximum value of 40 – 40.5 leading to the formation of a very salty and and dense water body (quoted by Bower et al., 2000). The formation of dense water masses drives an inverse estuarine type water exchange through the Strait of Hormuz (Fengchao and Johns, 2010), where fresher water inflow from the Indian Ocean enter the Arabian Gulf at the surface and more saline, denser waters leave the Gulf at nearer to the bed of the strait (Bower et al., 2000).

9.3 Data sources

Evidence for change has been provided by academic and governmental bodies, Kuwait University and Kuwait Research Institute. In some areas of Marine Research, evidence from international bodies is available, particularly in the field of geomorphological and geological change, or where issues are driven by international interests, sea water temperature change as part of climate change or climate forcing of ocean circulation in the Artabian Gulf region. Kuwait's coastal and marine environment has e received less scrutiny than neighbouring countries of the southern Gulf coastline, United Arab Emirates, Bahrain and Qatar.

A limited number of studies are available in the field of coastal dynamics, holding data on local tidal and wave forcing and sediment transport/dynamics. The Kuwaiti coastline is generally low energy coastal environment, where extreme events are rarely experienced and coastal erosion or flooding tend to be localised and/or negligible and do not threaten (at present) local communities or the economy in general.

Evidence is mostly qualitative, with some localised procedural analysis to quantify processes, usually for engineering design purposes (coastal sediment budgets) than as part of environmental monitoring to assess coastal risk for example.

9.4 Assessment process for coastal processes

The lack of quantitative data and absence of agreed objectives for coastal processes makes it difficult to apply type 1 or type 2 assessments to the coastal data. As a preliminary first assessment, the information has been presented across all coastal processes and drivers and a narrative is provided on the current assessment. A further narrative is provided on the possible future trajectory of coastal processes, particularly in line with the rapid expansion in northern Kuwait.

9.5 Summary of outcomes

Since the discovery of vast oil reserves in 1938, Kuwait has developed at pace unbound by constraints of resource. The desire for modernisation resulted in expansion rivalled only by other Gulf states. In contrast to many other countries where the coastal zone is easily accessible the great majority of pressures exerted upon Kuwait's Coastal zone and coastal sea are derived from anthropogenic sources. The effects of waves or tidal surges at the coast are rarely experienced, although erosion hotspots do provide a risk of localised flooding during only modestly rough conditions.

The climate of the region is extreme by any standards and acts to exert pressure on coastal conditions by degradation of water quality rather than generating forcing at the ocean surface (waves and tides). Extreme rates of evaporation, reduced freshwater input (due to river extraction), high rates of aeolian sedimentation, hyper-saline plumes and pollutants from industrial emissions act to severely impair water quality. Low flushing rates in embayments and ports and marinas exacerbate the degradation with high turbidity and nutrient concentrations resulting in reduced levels of dissolved oxygen.

The water quality issues are well documented and significant pressures on the coast and marine domain in the past have been driven by:

- Residential – new developments – marinas, housing
- Industrial – ports and shipping, oil refining, commercial and leisure
- Services and facilities – power and desalination.
- Pollution and emissions from industry

Managing these highly active areas of Kuwait's economy to reduce harm to the environment and ecosystem is of paramount importance if damage is to rectified or reduced to a minimum. The problems of priorities between industry, growth and maintaining quality of the environment is a delicate balance to achieve.

In addition to the rapid growth, the future will add further pressure from:

- Sea level rise attributed to climate change
- Major urbanisation - north coast and Bubyan Island
- Population growth – yielding sustainable food and water supplies.

The assessment plus additional information presented in Annex 9 describes how each part of the Kuwait landscape, seascape and its richly, biodiverse environment are inter-dependent, finely balanced, and how their present state in many areas needs careful management.

The stability of the coastline has shown resilience through decades of intense development albeit in some areas the generally low energy, coastal zone environment exhibits stress at specific hotspots where human interference in the natural processes are prevalent, risk of occasional flooding is evident particularly in the south of the country. The full assessment is presented in Figure 9-2.

The opportunity to coordinate and improve management of coastal development in the north of the country through future decades, where presently undeveloped coastline provides a rich suite of habitats will be possible. Consistent and reliable monitoring procedures will empower coastal managers to gauge where impacts occur

Numerical modelling of parameterised physical and biogeochemical marine processes forms a reliable method to simulate these conditions over wide spatial and temporal scales. This report highlights many interesting and valuable recent studies but Kuwait lacks a marine modelling system which can provide a consistent and routine advice service, warning environmental managers of potential problems. The report shows how such a system could be implemented to provide regular information of how the effects of thermal/saline plumes and industrial discharges degrade water quality and their associated marine habitats.

THEME	Attribute	Component	OUTCOMES			Narrative — Per Component
			Status	Future trajectory	Confidence of assessment	
Coastal Processes and Drivers						
Status assessment is GOOD. Despite rapid coastal development over the past 30 years, Kuwait coastal stability has been markedly resilience, with only localised impacts of measured stress. However, some local hot spots next to major developments have resulted in sediment starvation as a result of modifications to sediment transport processes. This assessment is made with low confidence due to a lack of regular monitoring and uncertainty over the potential impact of the upcoming developments. The future trajectory of coastal stability status may decline, given the continued modifications of the coastal zone by the expansion of the northern residential area and major developments such as the Sheikh Jaber Al-Ahmad Al- Sabah Causeway.						
COASTAL PROCESSES AND DRIVERS	Coastline stability	Coastal change		*		Status assessment is GOOD. Despite coastal development, Kuwait's coastal stability has been markedly resilient, with only localised impacts of measured stress. However, some local hot spots next to major developments with sediment starvation as a result of impacts on sediment transport processes. Low confidence in the prediction of future status due to a lack of information on the impact of the upcoming developments.
		Changes in sedimentology.				Status assessment is MODERATE. As with coastal change, there has been little documented evidence of any major movement of sediment, or increasing turbidity in the Arabian gulf. Some evidence of increasing turbidity in Kuwait Bay, potentially related to discharges into the Bay. Coastal sediments usually coarse, so only limited localised impact on turbidity.
	Coastal currents	River flow				Status assessment is POOR. Poor status due to a change in river flow impacting on sedimentology, and a major driver in changing turbidity. Further impacts on primary productivity, but wider impacts on Kuwait marine waters unknown.

Figure 9-2: Outcomes of the coastal assessment for Kuwait marine waters

The modelling system demonstrated is applicable to a wide range of marine problems experienced in Kuwait, simulating waves, ocean circulation and many phenomena which routinely confront environmental managers. The system can provide the basis to establish status of physical conditions at the sea bed, in bed and suspended sediments, water composition and all elements of ocean circulation and biogeochemical processes. From these starting points, future scenarios can be created and management and strategic actions designed to halt degradation and improve the marine environment.

9.6 Coastal process indicator assessments

9.6.1 Coastal morphology

9.6.1.1 Introduction

Marine physical processes are the driving forcing of any marine environment and define the energy under which coastal and marine ecosystems develop. It is essential to have a strong knowledge base of natural conditions in terms of sedimentology, geology and oceanography, of the coastal environment. These parameters form the basis of the characterization of coastal and marine environmental environments.

The exponential and explosive increase in of urban and industrial development along Kuwait's biodiverse coastlines makes imperative to deepen the knowledge of coastal processes and how human activities have affected them and the resilience capacity of the system to recover.

9.6.1.2 Current state: Kuwait

Coastal and marine environments in the Arabian Gulf are where most of the major housing, recreational, and economic developments have occurred in recent decades (Naser et al., 2008). Coastal development has led to the reduction (and destruction) of coastal habitats through dredging and land reclamation. It is estimated that more than 40% of the coastline of the Arabian Gulf have been developed (Hamza and Munawar, 2009; quoted by Naser, 2014) and it is estimated that land reclamation will accelerate in the future to secure new land as the population continues to grow (Naser, 2014).

In the Arabian Gulf, reclamation is undertaken by deposition of sand and mud either excavated from designated marine borrow areas or, alternatively, extracted from land based quarries (Naser, 2014). Dredging and reclamation result in removal or smothering of benthic communities and alteration of the physical environment, in terms of seabed topography and sediment distribution. Deposition of dredged material leads to the deoxygenation of the underlining sediments (Allan et al., 2008). Reclaimed land also interferes with water circulation to the point of modifying water salinity (Al-Jamal et al., 2008; Naser, 2014). Dredging and land reclamation therefore lead to short and long term biological, physical and also biochemical impacts (Naser, 2014).

Several areas along the Kuwait coastline have undergone profound alteration to accommodate both large and small scale coastal development projects.

North Kuwait

Amongst the undeveloped coastal areas of Kuwait are those on the northern shoreline of Kuwait Bay, along the Ras Al-Subiyah and the Boubyan Island on the Shatt-Al-Arab delta. Naturally the coastlines of Sabiya and Boubyan island are dynamic as a result of sediment discharged through the estuary and conveyed by the anticlockwise tidal currents. Tidal range is between 4.0 to 4.5 m during spring tides with current velocities up to 1m/s (Neelamani and Uddin, 2010). The flow rates of the Shatt-Al-Arab have changed significantly due to implementation of drainage management by the several countries transgressed by the Tigris and Euphrates. The introduction of tens of dams have reduced fresh water and sediment output from the rivers. During 2000, Iraq completed the diversion of the Euphrates River to a man-made canal named the Third River, which flows to the north-western part of the Gulf through Shatt Al-Basra Canal. The drainage of more than 85% of the marshes in southern Iraq were completed by 2000. Particularly, the creation of the Third River and the drainage of Iraqi marshes are believed to have resulted in changes to hydrodynamic and sediment dynamics of Khor Al-Zubair estuary and the delta as well as affecting their salinity and temperature (Al-Mussawi and Basi, 1993; Neelamani and Uddin, 2010).

Kuwait is developing a “mega” coastal town in this area and a major port on Bubiyan Island. The Subiya town is being built although the Madinat Al-Hareen (City of Silk) on Bubiyan Island is currently on hold. The new residential area is needed to accommodate people working in the northern region oil industry as well as to decrease the pressure of population growth in Kuwait City. A 36-km long Shiekh Jaber Al Ahmed Al Sabah Causeway is being built to connect the main road network of Kuwait City from the Shuwaikh Port in Sulaibikhat Bay with the new Subiya town. Sedimentological and geomorphologic characteristics of Ras Al-Subiyah have been investigated by Al-Hurban et al (2008) to provide baseline studies to inform environmental impact assessments of future developments in the area. There is a major master plan for tourism expansion in Failaka Island.

South of Kuwait Bay and Kuwait City

Kuwait Bay has been the historical centre of development (Kana and Al-Sarawi, 1988). Kuwait used to be an established trading and shipbuilding centre in the Arabian Peninsula, before the discovery of the its vast oil reserves in the 1930s. Building of coastal structures started during 1800s, when a walled city was developed along the shorelines of the Bay and harbours for trading dhows were built at several sites. These harbour structures consisted of rubble mound breakwaters with double entrances and become dry at low water due to the high tidal range (Kana and Al-Sarawi, 1988). The oil industry transformed the economy of Kuwait during the late 1940s and prompted rapid development along the coast with the construction of port facilities for oil transhipment at Mena Al-Ahmadi and later a Mina Abdulla and Mina Saud, south of Ahmadi. A cargo port was built at Shuwaikh, on the west of Kuwait City, which included a 3 km landfill dyke at the west end of the port, one of the largest alteration to the coast that cut off the natural channel into Sulaibikhat Bay (Kana and Al-Sarawi, 1988).

In the 1950s and 1960s with economic development, the population grew following immigration of oil workers and consequently also demand for housing and infrastructures (Kana, 2002). The old walled cities were largely demolished to allow expansion and to accommodate new private developments and commercial buildings. Rubble from the historical sites was used for land reclamation along the 25-km waterfront of Kuwait City, west of Ras Al Ardh. Most of the beach and natural dunes were replaced by an armoured backshore fronted by the rocky low-tide terrace. A common and now discontinued early practice consisted of mining limestone from the intertidal zone for shoreline armouring. Blocks of between one and two tonnes were extracted and placed at the edge of the landfill to protect new structures, including the shoreline highway that ringed the city (Kana and Al-Sarawi, 1988, Kana, 2002). The reclamation extended the land into deep water, creating the conditions for chronic erosion and wave overtopping with consequent flooding (Kana, 2002).

Since the late 1960s, several yacht harbours have been built to provide navigable channels at all stages of the tide. A typical configuration consists of breakwaters, built with rubble mounds, rip-rap and armouring blocks, which extend from the shore behind the low-tide terrace into deep water acting as littoral barriers. Several concrete outfalls, built along the developed shoreline to control surface runoff, also extend behind the low-tide terrace and act as barriers to natural sediment transport. The shoreline at some sites, such as the suburb of Salmiyah, has been compartmentalised with short high-tide beaches, separated by groynes, outfalls, or boat ramps, and armoured with concrete walls and/or rock revetments (Kana and Al-Sarawi, 1988).

During the late 1970s and 1980s, Kuwait municipality embarked upon a project to improve 20 km of waterfront in Kuwait City and attract people back to the waterfront, where several beaches had been lost to land filling operations. The project included the reclamation of a 400-m diameter artificial island, The Green Island, the creation of eight artificial beaches between groynes and in front of a heavily armoured sector otherwise unusable for beach recreation. The coastal landmark named the ‘hook’ at the Kuwait Towers was created during the project. The extensive armouring comprises dolos breakwaters and large quarry-stone revetments (Kana et al., 1986) (Figure 9-3).

The design of the coastal plan took into account the predicted morphological response to the project. The artificial beaches were designed to align with the principal wave approach direction to reduce sand loss and did not require sand re-nourishment for after more than 15 years from completion (Kana, 2002). The original plan to create an island was modified to include beaches modelled into a tombolo, after it was demonstrated that littoral sands would have naturally accumulated in the lee of the island (Kana, 2002). The Kuwait waterfront, built on land reclaimed in the previous decades, alleviated erosion and overtopping issues created by earlier less efficient designs, by providing wave absorbion revetments in places where steep shoreface precluded the creation of beaches. These were installed over filter media to prevent leaching of fine sediments from the foundations of the structures (Kana, 2002).

The project has provided other environmental benefits to water quality. The many hundreds of individual drain outfalls were replaced by a network of outfalls placed strategically with extended discharges out to sea; this combined with improvement in the sewer collection and treatment systems helped to reduce pollution from urban runoff. Unlike earlier marinas dating from the 1960s, which were designed with single narrow entrances, the new yacht basins and fishing harbours either have two entrances, or include a second flushing channel to promote water circulation and reduce problems of water stagnation (Kana,2002).

According to Kana (2002), the waterfront projects have established successful examples of redevelopment that continue to be followed around the Gulf. These projects have successfully integrated multiple uses of the waterfront urban areas, from scientific and commercial services to a wide range of recreation amenities and facilities and ultimately brought people back to use the coastal space.

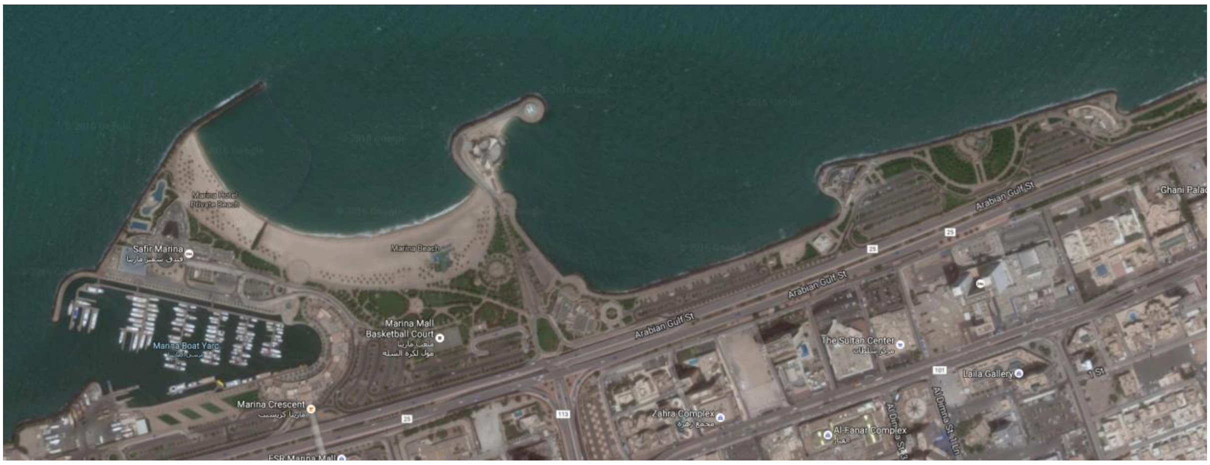


Figure 9-3 A section of the Kuwait City waterfront with heavy armouring, yacht basin, artificial beach and other recreation amenities (from Google maps, October 2016).

Southern Kuwait

Unlike the north-eastern part of the country, where natural processes still dominate the evolution of the coast, in the southern part of Kuwait Bay and the south-eastern part of Kuwait, the coastal evolution is heavily constrained by anthropogenic activities, like the construction of marinas, ports, jetties, seawalls, slipways for boats, seawater intakes (Neelamani et al., 2011).

During the period 1989 – 2007, Neelamani and co-authors found that a sand spit developed and blocked the mouth of Khor Iskandar in southern Kuwait to the point that beach house owners are only able to take their boats out at sea only during high tide conditions. Another accreting coastal area was identified around the Az-Zour power plant intake location, where the coastal zone was stabilised by rip raps. A sand spit has also developed at Ras Az-Zour (Neelamani et al., 2011).

Al-Zour hosts a large industrial area with power plant. Kuwait National Petroleum Company (KNPC) is constructing one of the largest oil refining plants in the world in the same area. The refinery will be built on land reclaimed by contractor Van Oord in a ‘sabkha’ area, a salt plain near the coast some 30 kilometers north of the Saudi border. The project involves dredging and reclaiming 65 million cubic meters of sand followed by extensive ground improvement. The project also includes construction of various channels, a basin for a future jetty, a barge dock and interconnecting roads. The dredging company has found a solution to pump the material from trailing suction hopper dredgers over distances of 10 km to the onshore reclamation area (from dredgingtoday.com, 2015, 2016).

The Al-Khiran Pearl City is an ambitious residential project intended to respond to the local demand for sea chalets. Rather than building into the sea, the idea is to convert desert land to lagoons. The operation is less costly because excavation is performed by land-based equipment and, besides, the excavated material can be re-used. The ongoing project will create 1,500 hectares of canals and 15,000 residential units over about seven km^2 in the unique environment of Al-Khiran estuary, close to the Saudi border. Al-Khiran consists of two small tidal estuaries, Khor Al-Ama and Khor Al-Mufatteh, from hypersaline tributaries bounded by fringing salt marsh and sabkha. The area hosts Pleistocene and Holocene oolitic sediments in parallel ridges, ancient and recent barrier beaches and coastal dunes (Picha, 1978). Picha related the large accumulation of oolites in the area, especially at the mouth of the two tidal channels (khors), to their waters over-saturated of calcium carbonate discharging over broad tidal flats in analogy with the growth of oolites in Bahamas. It is not clear whether oolites were still forming. The excavations of the lagoons in place of the tidal channels have certainly resulted in a profound modification of the coastal zone, not only in terms of coastal morphology but also in terms of loss of natural sedimentary environments.

9.6.2 Impacts on hydrodynamics and sediment dynamics

9.6.2.1 Introduction

Dredging, land reclamation, and coastal structures activity (sea walls, jetty, concrete outfalls, etc) associated to urban and industrial development in coastal areas lead to changes to local current and waves, that consequently result in changes to sediment composition (habitat risks) and sediment transport. Changes to sediment transport has consequences to the pattern of erosion/accretion along the coastline, e.g. jetty/land reclamation and outfalls prevent natural longshore currents and distribution of sediment and function as groynes and trap sand on the updrift side. It is essential to identify erosional and accretional trends in the coastal zone to propose effective coastal management in Kuwait as in other coastal areas (Neelamani et al., 2011). Neelamani et al. (2011) undertook a study with remote sensing techniques and field investigations to quantify coastal morphology changes in the south-eastern part of Kuwait and around the Sabiya power plant area between 1989 and 2007. Neelamani and co-authors found that there was significant accretion during the 18 years of study in some parts of the southern Kuwait coast, and in a few spots inside the Kuwait Bay and in parts of Khor Sabiya areas to the northern Kuwait. These areas were interested by the widening of the beach up to 1,400 m and the accretion process included the formation of sand spits with a length in the order of 1,500 m.

9.6.2.2 Current State:Kuwait

Sabiya power plant is located in the Ras Al-Subiyah area, about 65 km from the Shatt-Al-Arab estuary. The plant is at the entrance of Khor Al-Sabiya in the drainage system of Shatt-Al-Basra. The morphology and sediment dynamics of the surrounding areas are affected by the presence of the plant. Field investigations by Neelamani et al (2011) found that the coastal zone in the Sabiya site has widened by 1,400 m since construction of the power plant intake in 1989 and up to 2007. The structures of the intake projected into the sea for about 1,400 m act as groynes and favour deposition on both sides of the intake (Figure 9-4). The area between the intake wall has acted as a settling basin for the suspended sediments and on average about 1 m sediment deposits and about 400,000 m^3/yr of sediments are dredged from inside the intake structure and the intake channel basin area, respectively, and dumped on the land area south of the power plant (Neelamani and Uddin, 2010). Cooling waters are discharged at the outfall on the southern side of the plant. The accretion of the area is believed to be the result of the dumping of material dredged from the intake with the contribution of both suspended sediment discharged at the outfall with cooling waters and the additional suspended sediment load reaching the Khor due to the drainage of the Iraqi marshes (Neelamani and Uddin, 2010)

A major dredging and reclamation project involves the construction of a channel of 7,7 km and 163 m wide as part of the deepening of a seawater outlet canal to serve the Subiya power and desalination plant, to the north of Kuwait Bay (from dredgingtoday.com, 2013). Based on their findings, Neelamani et al (2011) suggested that any planned increase of seawater intake at the same structure for a new power plant would result in further siltation of the area. According to a study from 1980s, due to low wave energy and lack of tropical storms and associated storm surges, beach erosion is limited to periods of highest tides and infrequent ‘shamal’ winds from northern sectors. Erosion rates seem to be low in Kuwait City (Khana and Al-Sarawi, 1988).

Figure 9-4 Left: Subiyah power plant with intake structure projecting into the Khor Al-Subiya and resulting coastal morphological change on the lee of intake walls, and outfall discharge to Kuwait Bay (From Google maps, November 2016). Right: view of the sediment deposits downdrift.

Unlike the north-eastern part of the country, where natural processes still dominate the evolution of the coast, in the southern part of Kuwait Bay and the south-eastern part of Kuwait, the coastal evolution is heavily constrained by hard engineering methods used for the construction of marinas, ports, jetties, seawalls, slipways for boats, seawater intakes (Neelamani et al., 2011).

During the period 1989 – 2007, Neelamani and co-authors found that a sand spit developed and blocked the mouth of Khor Iskandar in southern Kuwait to the point that beach house owners are only able to take their boats out at sea only during high tide conditions. Another accreting coastal area was identified around the Az-Zour power plant intake location, where the coastal zone was stabilised by rip raps. A sand spit has also developed at Ras Az-Zour (Neelamani et al., 2011).

9.6.2.3 Assessment

Recent studies have found that environmental hazards can be attributed to erosion caused by a higher sea level, waves and currents, as well as to changes in storm characteristics and driven by climate change. Extensive areas in the southern coast of Kuwait Bay and significant areas on the northern coast would be at risk of coastal flooding, as well as almost all of Failaka Island. Several areas are below the present sea level and will be the most vulnerable to the risk of sinking in case of sea level rising.

Removal of coastal sand dunes may trigger another hazard. These dunes represent the first natural defence line against coastal erosion (Fouad et al., 2016). Coastal Erosion and accretion patterns have changed across years depending on the coastal management measures taken to counteract the adverse effects on shoreline dynamics (Baby, 2013).

9.6.2.4 Conclusions

Unpublished data by Al-Sarawi from 1980s indicate that private small coastal structures, such as ramps for boats, sea walls, private shore-protection structures of waterfront villas stretching across the beach, have an adverse impact on littoral transport and lead to many localised erosions of the beach on their down drift sides (Khana and Al-Sarawi, 1988). Figure 9-5 (fRakkha et al, 2008) shows images of erosional beaches with several small boat ramps and shore-protection structures across the beach.

Other areas in the southern coast show an erosional trend with a retreat of the coastline of the order of 150 m, such as the coastal side of the Pearl City residential complex and Khor Al-Mufatah. Satellite images of this area seem to show evidences of beach renourishment in 2015 and 2016, indicating that the erosional trend is still ongoing in this area while surrounding coastal stretches are interested by accretion. These contrasting trends of coastal change in contiguous coastal areas are again explained by the presence of coastal structures that act as groynes to trap sediment and favour accretion even on a large scale, protecting the coast from wave-induced erosion (Figure 9-6).

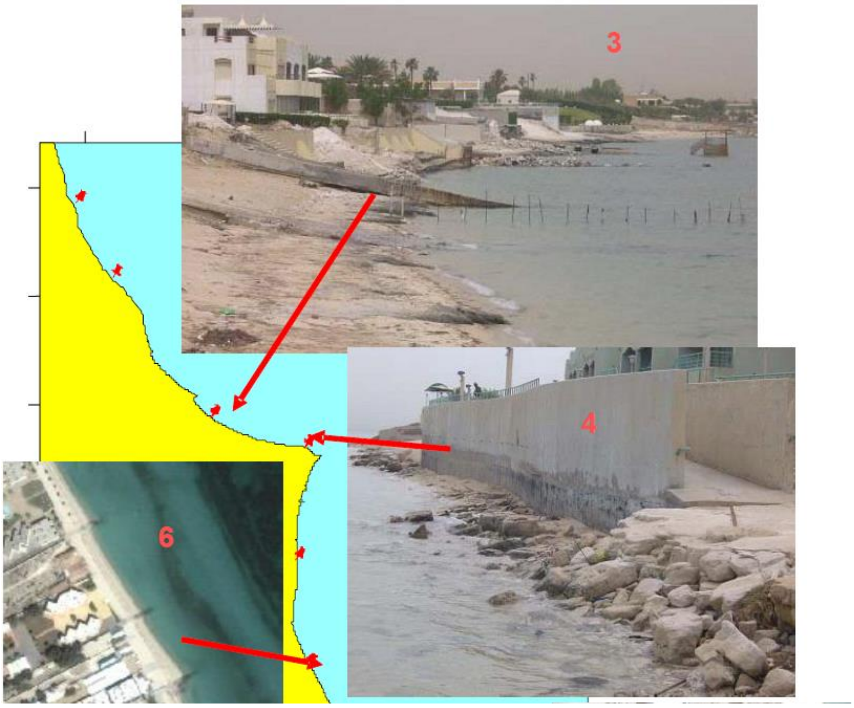


Figure 9-5 Images of erosional beaches with several small boat ramps and shore-protection structures across the shore, north and south of Kuwait Navy Base coastal area (From Rakha et al., 2008).

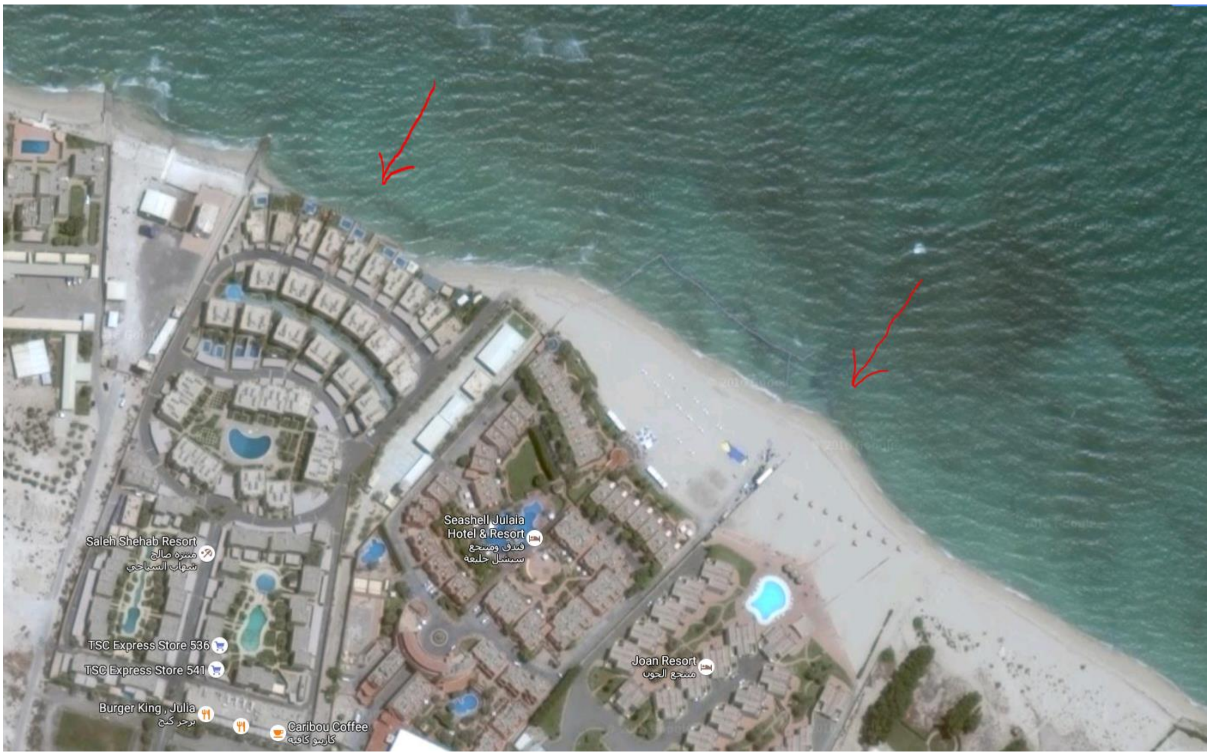


Figure 9-6 Example of neighbouring beach sectors showing erosional (left arrow) or accretional (right arrow) trend.

10 Emerging issues for future SOMER reporting.

10.1 Climate change

10.1.1 Background to issue

The Arabian Gulf is a semi-enclosed sea, surrounded by deserts (AGEDI, 2015a). The winds in the region affect the circulation pattern in the Arabian Sea, leading to seasonal stratified areas in summer and mixed waters in the winter. Changes in meteorological conditions in the region could have knock-on effects to oceanography and biological processes. For example, peak winds (Shamals) alter water currents, and subsequently sea temperatures, salinities and affect coral larval transport between different reefs (Cavalcante et al., 2016). Between 1973 and 2012, air temperatures increased an average of 0.8 °C, and an increase in Shamal events was seen (Al Senafi and Anis, 2015). Sea temperatures increased by 0.18 °C from 1982 to 2006, and increased evaporation over the last 30 years led to a salinity increase of 0.5-1% (IPCC, 2014).

To determine how climate change might affect the marine climate in the region, a Regional Ocean Model System (ROMS) was used to dynamically downscale a global climate model for the Arabian Gulf (AGEDI, 2015a). The RCP8.5 "business as usual" scenario was used for the future climate projections. The modelling shows that the Arabian Gulf will gradually freshen, owing to an increase in Arabian Sea inflow to the Gulf and an increase in rainfall. The results also show that there is an increase in sea temperature of between 1 and 2 °C, and up to 2.8 °C in some areas. The increase in temperature in the sea around Kuwait in particular shows an increase of between 2 and 3 °C (see Figure 10-1). Temperature changes are projected to cause changes in vertical overturning processes. Sea level rise in the Gulf is considered to be up to 4 cm by the end of century, with the Kuwait area experiencing approximately 3 cm. In contrast to the recent period, Shamal wind intensity is projected to decrease by the end of century.

Oxygen levels can also be affected by climate change (Matear and Hirst, 2003) and hypoxic conditions have been reported in the Arabian Sea in recent decades (Weeks et al., 2002). Rainfall is projected to increase over the Arabian Peninsula, although with local variations (AGEDI, 2015b).

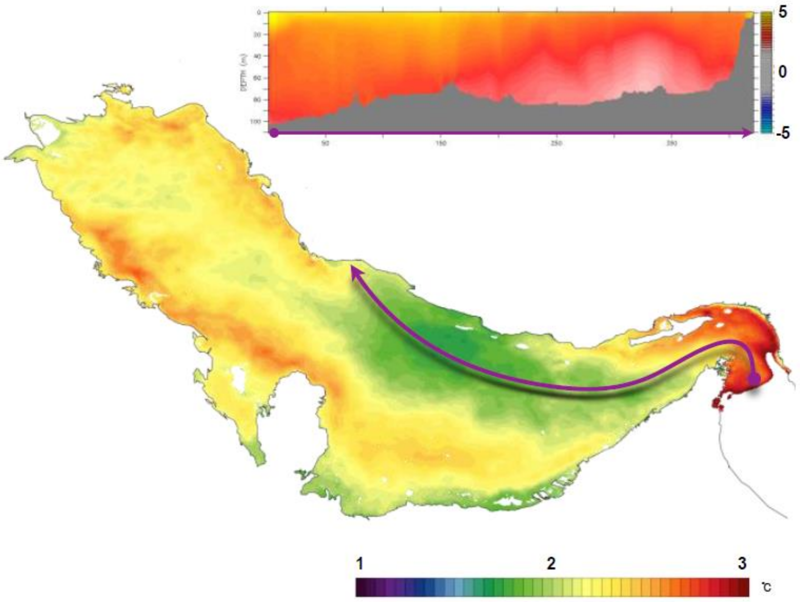


Figure 10-1: The sea surface difference between late and early 21st century in the Arabian Gulf. The location of the section is shown by the purple arrow. Taken from AGEDI (2015a).

10.1.2 Impacts on fisheries

Species distribution modelling carried out by the United Arab Emirates Local, National, and Regional Climate Change Programme (LNRCC) and presented in the Draft Visualizations report project showed that priority fish species will face high rates of extinction in the Arabian Gulf by 2090, but that in the seas around Kuwait, suitable habitat for these species may actually increase rather than decrease. An assessment of 50 priority fish species showed that certain areas of the northern Arabian Gulf are projected to show an increase in species richness by 2090, in contrast to the majority of the Gulf, which will show a loss in richness of these species. The project states that the increase in richness in the northern area is a result of the projected decreased salinity and slightly lower temperature increase compared with the south. The LNRCC report shows that Kuwait could experience a slight increase in their fish catch as a result of climate change, in comparison to most other countries in the Gulf, which are projected to experience a decrease. Indeed, the report ranks Kuwait as the country that is the least vulnerable to the effects of climate change on fisheries within the region.

Changes to oxygen levels in the Arabian Sea could have implications for economically significant fish populations, as they experience respiratory stress (Koslow et al., 2011). The effects of oxygen on fish populations is unclear however as fish show different sensitivities and tolerances (Townhill et al., 2016).

10.1.3 Impacts to other marine species

Habitat suitability is projected to decrease for the dugong and green turtle in the Arabian Gulf, although suitability is projected to increase in Kuwait (LRNCC report). A large increase in habitat suitability is projected for Indo-Pacific dolphins. For other non-fish marine species modelled, Kuwait showed an increase in habitat suitability. A decease in pH is expected to have negative effects on calcified marine species such as molluscs, echinoderms and crustaceans (IPCC, 2014). Harmful algal blooms are also associated with increases in temperature in the Gulf, although there may be other influencing factors. An increase in blooms can have consequences for human health as well as affecting fish and shellfish production (IPCC, 2014).

10.1.4 Marine habitats

In general, it is considered that increasing sea temperatures and decreasing pH in the oceans will result in a large decrease in coral reefs by the middle of the century (IPCC, 2014). In the southern Gulf, where sea surface temperatures and salinity are higher, and where mass bleaching events are more frequent, the corals have slower growth rates and higher mortality rates (Baunam et al., 2013). There are also differences in size structure between the southern and eastern Gulf, thought to be a result of the differences in environmental conditions and disturbance events. The IPCC (2014) describes recent changes associated with temperature in the region such as in 1996 and 1998 when there were mass coral bleaching events caused by elevated sea temperatures. This has subsequently caused loss of invertebrate-feeding fish and an increase in herbivores and planktivores.

Sea level rise in the region could increase coastal erosion and so reduce areas of beach, mangrove and salt marsh (IPCC, 2014). Increases in precipitation can also affect these habitats by increasing run-off from land, affecting water quality, sedimentation and freshwater inputs to coastal areas (IPCC, 2014). LRNCC modelling projects a slight increase in habitat suitability for seagrass for Kuwait by 2090. Indeed, it is thought that seagrass may benefit from reduced pH in some areas (Hall-Spencer et al., 2008; IPCC, 2014). Changes to reefs, mangroves and seagrass are likely to have knock-on effects on the fish and invertebrate communities that are supported by these habitats. Reduced fisheries production in coastal coral reefs and other habitats can decrease food security in affected areas (IPCC< 2014).

10.1.5 Conclusions

There is evidence that temperature in Kuwait coastal waters are affected by the high density of urban development of anthropogenic activity at the coast. The urbanisation and industrialisation of the southern part of Kuwait Bay is likely to be responsible for the higher temperatures recorded than on the norther side of the bay (Al-Rashidi et al., 2009). In recent years, concerns have been raised of the effect of several power and desalination facilities on the Sulaibikhat Bay thermal ecosystem, within Kuwait Bay. Thermal discharge from the cooling water outfalls raise water temperature and impact the ecosystem of the Bay (Al-Banaa, K. Rakha, 2009). Seasonal average temperature measurements inside the Bay also exhibit the trend of increasing temperature.

By examining LandSat images between 1985 and 2002, Al-Rashidi et al. (2009) found that sea water temperature in the Kuwait Bay has increasing at a rate three times higher than global estimates (0.6 (±0.3)°C/decade). Besides global and regional effects, such as El-Nino and warming as a result of global climate change, the authors attributed 17% of the warming trend to local forcing related to human activities along the Kuwait coastline. Power and desalinisation plants generate thermal plumes in coastal zones that contribute 1.1°/decade to the temperature trends of the in the Northern Arabian Gulf. Urban storm drain runoff and treated sewage discharged (untreated in regard to temperature) are also contributing to SST rises in areas of restricted circulation such as Kuwait Bay. Al-Rashidi et al. (2007) found that there is a high correlation between human activities in the coastal zone and the increase of SST.

Al-Banaa and Rakkha, 2009, found sea temperatures higher than expected during winter and the coldest months in Kuwait Bay, particularly in the region adjacent to the area of influence of the outfall. Temperatures can reach values elevated above ambient by up to 5°C in summer and 4°C in winter coincident with the bi-modal peaks in power demand of the city. The effect is exacerbated during low tide when tidal currents advects the thermal plume towards the measurement location (Al-Banaa and Rakkha, 2009).

Water masses in the northern Arabian Gulf and those local in Kuwait Bay are believed to be well-mixed. Local CTD measurements by Al-Banaa and Rakkha, 2009, found winter stratification during certain tidal conditions, where temperature at the bed is some 0.5-1.0°C higher than at the surface (The authors attribute this stratification to the dense, saline water (salt plume) discharged from the power plant driving a density flow at the bed.

Climate modelling is becoming more advanced for the Arabian Sea, and so the understanding of how changes will affect the marine environment in future decades is starting to become clearer. However there is still a lack of information regarding how these changes will affect the ecosystems within the Arabian Sea and around Kuwait, when compared to some other regions of the world. Research to date suggests that the northern Arabian Sea may be less affected by climate change than the southern areas, and that the ecosystems and marine species may also be less impacted (particularly from findings of the UAE LNRCC project). However the IPCC (2014) states that more investigation is required of the physical, chemical and biological responses to climate change in the region.

10.2 Underwater noise

10.2.1 Introduction

Underwater noise pollution from human activities (including pilipng, shipping, seismic survey and military sonar to name but a few) is a growing environmental concern worldwide, as it can have a range of negative effects on marine life. Governments and international bodies are beginning to act to monitor and mitigate underwater noise, and to regulate activities which produce high noise levels. This document provides a brief, high-level overview of the issue of underwater noise and possible approaches to monitoring and management.

10.2.2 Underwater noise sources

Sources of underwater noise can be categorised as *continuous* and *impulsive*. Continuous sources include activities such as shipping, dredging, and drilling operations, and are characterised by a relatively constant level of noise output. Impulsive sources are loud, brief, and often repetitive sounds, such as impact pile driving, geophysical surveys using seismic airguns, explosions, and some types of military sonar. Sound travels much further and much faster underwater than in air (around 1500 m/s compared to 343 m/s in air), which means that noise sources can have a noise 'footprint' that extends over many kilometres.

10.2.3 Effects of underwater noise

In the most extreme cases, underwater noise has been linked to mortality of marine animals, both stranding of marine mammals from naval sonar exposure (Evans and England, 2001) and direct mortality of fish from impulsive sounds (Govoni *et al.*, 2003). A less severe and more common risk is permanent or temporary hearing damage (see Figure 10-2), which has been studied experimentally in marine mammals and fish. As sound can travel much further than light underwater, sound is often more effective than light for communication, navigation, and predator or prey detection. Damage to the auditory system can therefore have serious consequences for affected animals.

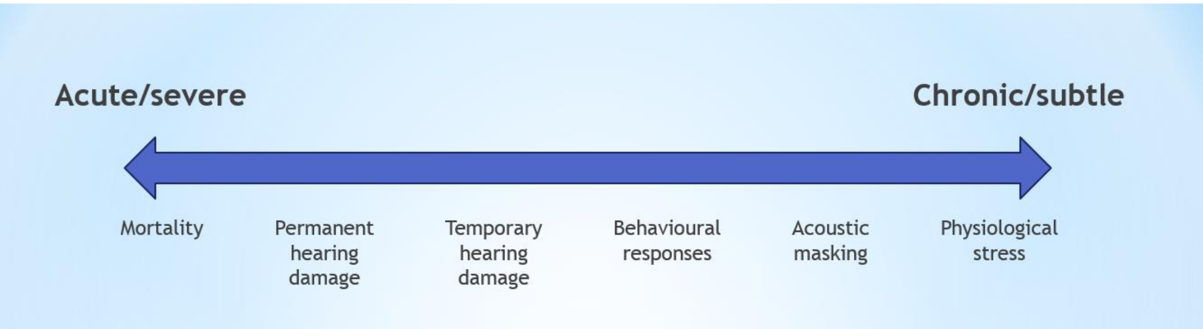


Figure 10-2. Levels of effect from underwater noise exposure, ranging from short-term and severe to long-term and subtle.

Exposure to underwater noise can cause behavioural reactions in marine animals, such as avoidance (Weilgart, 2007) and changes in normal behaviour patterns (Picciulin *et al.*, 2010). The presence of noise in the environment can also interfere with the detection of important sound cues through *acoustic masking* (see Figure 10-3). For example, noise from a passing ship may 'drown out' communication signals or predator/prey sounds. Finally, exposure to noise can increase levels of physiological stress, which could have significant long-term health effects through repeated exposures (Rolland *et al.*, 2012).

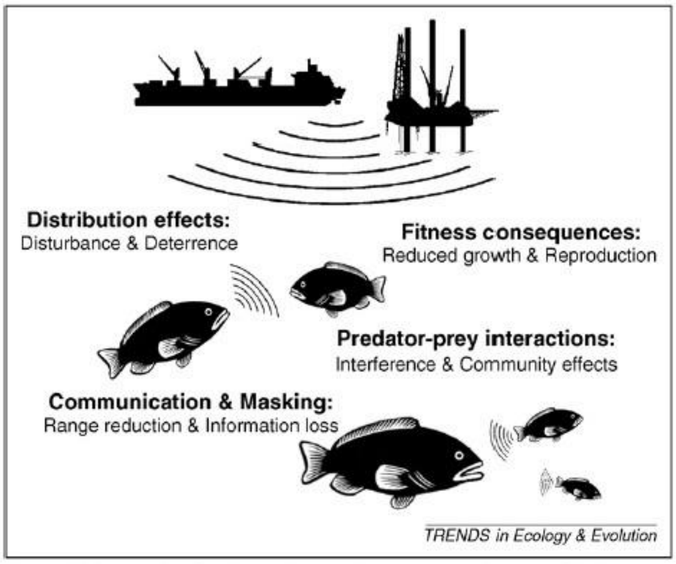


Figure 10-3. Examples of noise effects on fish (Slabbekoorn *et al.*, 2010).

Each of the effects described above apply to individual animals, but there is also concern that the rising levels of underwater noise in the marine environment could lead to effects at the population scale, affecting marine mammal populations and fish stocks. A modelling framework is being developed to predict the population consequences of acoustic disturbance (PCAD), which aims to understand how disturbance to individuals may scale up to changes in population growth rates (Figure 10-4).

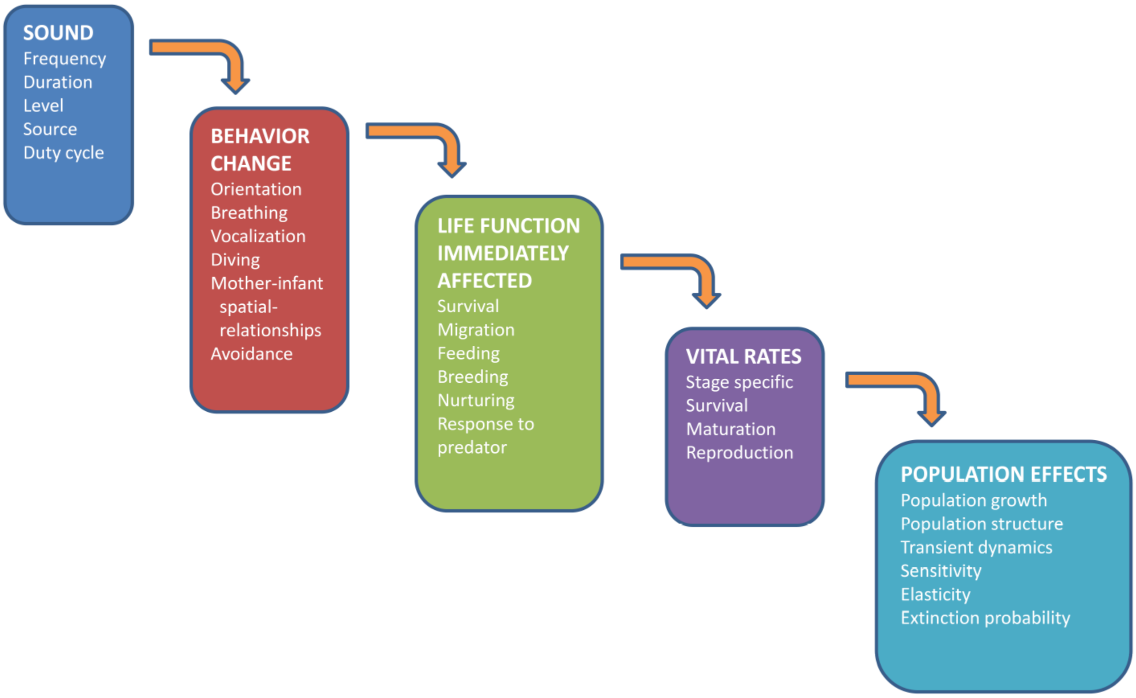


Figure 10-4. Schematic showing the PCAD framework (National Research Council, 2005).

10.2.4 Environmental impact assessment and noise mitigation

Many countries now have regulations that govern the licensing of marine developments, and consider underwater noise pollution in the consenting process. To predict whether a development may have negative effects on marine life, environmental impact assessments usually include underwater noise models that predict the noise levels that will be generated by the activity. These noise level predictions are then combined with thresholds which have been developed for marine mammals (Southall *et al.*, 2007) and fish (Popper *et al.*, 2014) to show the areas where effects, such as temporary hearing damage, are expected. Based on these predictions, the regulatory agency will decide whether to approve the development, and whether to require any noise mitigation measures.

There are a number of ways that underwater noise exposure can be mitigated (Cefas, 2015):

- **Marine spatial planning**. Avoiding noise-generating activities in key habitats and during periods when animals have a greater vulnerability to noise pollution (e.g. mating season).
- **Mitigation equipment**. Physical barriers to reduce noise produced by activities (e.g. bubble curtains for pile driving operations) and devices to displace marine fauna to reduce risk of high noise exposures (e.g. acoustic deterrent devices, ADDs).
- **Source quieting**. Using alternative methods with lower noise emission (e.g. vibration piling rather than impact piling) or modifying existing noise sources (e.g. ship quieting technology).

- **Real-time mitigation**. Delay or interruption of noise generating activities if at-risk species are sighted in the vicinity (e.g. marine mammal sightings).

10.2.5 Marine policy and underwater noise

In addition to regulation at a national level, a number of national and international policy initiatives are being developed to address underwater noise pollution. As underwater noise can spread across national boundaries, and noise sources such as shipping also travel internationally, management of underwater noise requires a coordinated international approach. In Europe, the Marine Strategy Framework Directive is a piece of environmental legislation which includes a requirement that underwater noise should be at levels that do not harm the ecosystem. The way in which this legislation will be implemented is still in development, and includes Indicators for impulsive and continuous noise which will be monitored across European waters (Dekeling *et al.*, 2014). Similar legislation may be developed in other parts of the world.

One way of managing underwater noise pollution is through marine spatial planning, whereby the timing and location of noise generating activities is planned so that disturbance to marine life is minimised. To inform this process, large-scale maps of noise levels can be produced using modelling (**Figure 10-5**a). These maps can then be combined with distributions of sensitive marine species (**Figure 10-5**b) to identify 'hotspots' where there is overlap (**Figure 10-5**c) and noise mitigation may be needed.

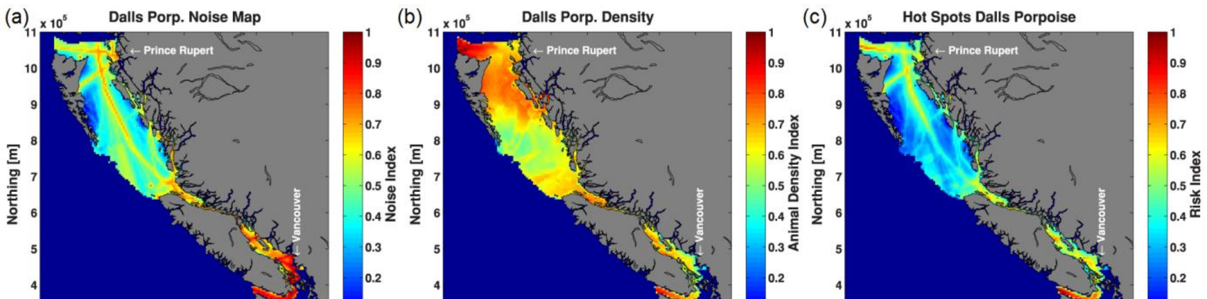


Figure 10-5. (a) Map of modelled noise levels off the coast of western Canada; (b) Map of porpoise density; (c) Map of hotspots where there is most overlap; (Erbe et al., 2014).

10.3 Marine Litter

10.3.1 Definition of Marine Litter

The term “Marine Litter” or “Marine Debris” has been introduced to describe discarded, disposed of, or abandoned man-made objects present in the marine and coastal environment. It consists of articles that have been made or used by people and, subsequently, deliberately discarded or accidentally lost. They originate from ocean-based or land-based sources and can be found in marine environments around the globe, posing environmental, economic, health and aesthetic problems. Most sources of marine pollution are land based. Marine litter, mainly plastic, poses a serious environmental threat to marine organisms, as well as a series of economic and social problems. The majority of marine debris is comprised of plastic materials—60-80% overall and 90% of floating debris so a continuous input of large quantities of these items results in a gradual build-up in the marine and coastal environment. Poor practices of solid waste management, lack of infrastructure and a lack of awareness of the public at large about the consequences of their actions aggravate substantially the situation. Microplastics (in principle items smaller than 5mm) are of particular concern due to their potential toxicity and size, and consequent harm to the animals that ingest them. Although the consequences of plastic build-up in the food chain are not fully known, human-health concerns are being raised, since many of the marine animals affected end up on our plates as seafood. Taking into account its accumulation and dissemination, marine litter may be one of the fastest growing threats to the health of the world's oceans.

10.3.2 Main sources of marine litter:

Land-based activities:

- land-fills
- rivers and floodwaters
- industrial outfalls
- discharge from storm water drains
- untreated municipal sewerage
- littering of beaches, coastal areas (tourism)

Marine based activities:

- fishing industry
- shipping (e.g. transport, tourism, fishing)
- offshore mining and extraction
- illegal dumping at sea
- discarded fishing gear

10.3.3 Marine Litter in the Middle East & Arabian Gulf

Disposal of plastic waste has emerged as an important environmental challenge in the Middle East where plastics make up as much as one-tenth of the solid waste stream. In affluent GCC nations, plastic waste composition in municipal solid waste is around 12 – 16 percent. Plastic waste in the region is continuously increasing due to increasing use of plastics in daily life. UAE has witnessed rapid growth in the last decade or so. This has been in terms of population as well as GDP per capita, both of which have more than doubled in this period (National Bureau of Statistics UAE, 2013). The above two factors result in higher consumer spending. Moreover, the latter translates to greater importance, given to ‘convenience and hygienic shopping’ resulting in higher demand for plastics in packaging and shopping.

All this consequently leads to increased waste generation. From the supply side also, plastic manufacture (for all purposes including packaging) is a booming industry in UAE and rest of Gulf, one factor for it being abundance of petrochemicals, the raw material for plastics, in this region (Yousef, 2011). Nowadays, the Middle East is responsible for about 8 percent of the global plastic production. The gross urban waste generation from all Middle East countries exceeds 150 million tons per annum, out of which 10-15 percent is contributed by plastic wastes. A typical UAE resident uses 450 plastic water bottles on an average in a single year. With the equivalent of 43 gallons on an average per person in 2011, the United Arab Emirates had the fourth-highest level of bottled water consumption in the world (Todorova, 2011).

11 billion plastic bags are used annually, according to statistics from UAE’s Ministry of Environment and Water. This goes on to add up to an annual overall waste of 912.5 kilogram per capita (The National, 2013). These statistics reflect on the extent of use of plastic bags and bottles in UAE and the consequent generation of plastic waste. Estimates suggest that 50 percent of the camels that die every year in the UAE die from ingesting them which can lead to massive calcified balls of plastic in the stomachs that eventually kill the animals (Emirates247, 2013).

Plastic waste is a source of greenhouse gas emissions, economic and ecological damage. The majority of the items found on beaches across the region contain plastic which pose a serious danger to marine life. Plastic waste disposal is a major challenge due to non-biodegradable nature of plastics and such wastes are visibly present in landfill sites for a long time.

The frequency of occurrence, composition, and distribution of litter accumulating in the marine environment of the Middle East is relatively unknown. Only a limited amount of peer reviewed literature is available and most information comes from clean-up activities.

Marine litter abundance was investigated on western and eastern beaches of the Arabian Gulf and the Gulf of Oman, UAE, by Khordagui & Abu-Hilal (1994). In this study 27000 m2 of UAE beaches were examined and 22771 items noted. An estimated 13.5×106 man-made items are stranded along 800 km of Arabian Gulf and Gulf of Oman shorelines. Plastic fragments constituted 27.1% of the total items encountered. A strong correlation was found between plastic fragments and plastic bottles. Fishing floats and nettings represented 16.9% of the total items examined. A highly significant correlation (r=0.89) existed between the number of polystyrene blocks used as fishing floats and ropes, and nettings washed ashore. The west coast on the Arabian Gulf exhibited a much higher level of pollution by man-made debris than the east coast on the Gulf of Oman.

A study of beaches along the Omani coast in the Gulf of Oman in 2002 reported densities of marine debris ranging from 0.43 to 6.01 items/m, mean 1.79 items/m (Claereboudt, 2004). The plastic debris appeared to be mainly of local origin or discarded fishing gear. A study of beaches along the Jordanian coast of the Gulf of Aqaba recorded debris densities of 5 and 3 items/m2 in 1994 and 1995 respectively (Abu-Hilal and Al-Najjar, 2004). When wood was excluded from the debris, the most abundant items were plastic which appeared to be largely of local origin. Fishing-related debris on average accounted for 25% of the debris.

More recently, in 2016, Castillo et al. investigated the presence of microplastics in Qatar waters. In total 30 microplastic polymers were identified with an average concentration of 0.71 particles m −3 (range 0– 3 particles m −3). Polypropylene, low density polyethylene, polyethylene, polystyrene, polyamide, polymethyl methacrylate, cellophane, and acrylonitrile butadiene styrene polymers were characterized with majority of the microplastics either granular shape, sizes ranging from 125 μm to 1.82 mm or fibrous with sizes from 150 μm to 15.98 mm. The microplastics are evident in areas where nearby anthropogenic activities, including oilrig installations and shipping operations are present.

10.3.4 Initiatives in the Middle East

Plastic recycling is still in nascent stages in the Middle East. Some countries have started plastic waste collection programs but their efficacy is yet to be ascertained as most of the collected waste is still sent to countries, like China and India, for recycling. In recent years, several government initiatives have been launched and plastic recycling centers have been established in UAE, Saudi Arabia, Qatar etc. which is a welcome development. The emirate of Ajman introduced 'a Day Without Plastic Bags' in May 2012 to encourage replacement of plastic bags with those made up of cloth, paper or other eco-friendly material.

Realizing the flip-side of high use of plastics, UAE has initiated definitive corrective measures. The Ministry of Environment and Water has reported that it will ban circulation and marketing of non-biodegradable plastic products in UAE from early next year (Salma, 2013). In that direction, Dubai Municipality have launched a “Say No to Plastic Bags” campaign starting May 2013 targeting a 20 per cent reduction in the estimated 2.9 billion plastic bags used annually in the emirate, by the end of this year. This is to be done by means of creating consumer-awareness and offering reusable and recyclable alternatives like jute and paper bags in major supermarkets (Baldwin, 2013).

In 2013, the Gulf Petrochemicals and Chemicals Association (GPCA) worked together with leading chemical and petrochemical companies in the region to promote a better understanding of the value of plastics, and to encourage a more responsible attitude towards recycling & litter disposal. The “Clean Up the Gulf” Initiative aims to highlight the problems associated with litter and calls the community to action to unite and tackle it head on. Over 2,500 volunteers participated across the six sites, collecting approximately 10 tons of waste. As part of a pilot project in Dubai, the waste material was sent to a recycling company where the material was sorted and recycled and a waste management audit report produced. GPCA will conduct the Clean Up the Gulf event annually which will make it the largest environmental awareness campaign to be executed in the Arabian Gulf region.

In Sharjah, a private company, in partnership with Sharjah Municipality, is working towards a 100% landfill diversion target set for the Emirate of Sharjah by the end of the first quarter of 2015 (Bee`ah, 2013). This is being done through development of waste management infrastructure on one hand and community education of the importance of environment principle of 3Rs – Reduce, Reuse and Recycle. The Government of Abu Dhabi has established ‘The Center for Waste Management’ (CWM) to control and coordinate all activities related to sustainable waste management. Several non-government organisations as well as community groups are also working towards the goal of better plastic waste management in UAE.

The Kuwait Dive Team “Guardians of the Sea” is one of the new members to the International Coastal Cleanup network in 2015. For years the Kuwait Dive Team has been the go-to group in the nation for removal of sunken vessels and large debris – work that spans Kuwait’s entire coastline and offshore islands. They also monitor coral reef ecosystems and rescue entangled marine life. Like Ocean Conservancy, they are involved with outreach and education and even have a “Beach Cleanup Mobile Unit” van that has brought cleanup resources and environmental education to hundreds of students. What’s more, in August 2015, the Kuwait Dive Team created the Global Environmental Guardian Network that seeks to foster collaboration and cooperation among environmental organizations and teams that carry out similar missions. In 2015, 900 people took part in the International Coastal Cleanup, removing 1,133,074 kg along 15km of Kuwait`s coastline.

The World Plastics Council (WPC) held its 2nd General Assembly on 19 November 2015, hosted by the Gulf Petrochemicals and Chemicals Association (GPCA), in Dubai, UAE. Chaired by Abdulrahman Al-Fageeh, executive vice president at SABIC, top executives of the world’s largest polymer producers attended the meeting, underpinning the industry’s commitments to improving sustainability and constructively addressing key challenges. The WPC is initially focusing on improving sustainability by tackling marine debris and promoting efficient waste management practices. With this focus in mind, the General Assembly voted to promote marine litter solutions by joining the Trash Free Seas Alliance (TFSA), an initiative launched by Ocean Conservancy, one of the leading organizations working to solve plastic waste in the ocean. As leaders in the global plastics industry, WPC members recognize that used plastic doesn’t belong in the ocean. They are committed to work with their global partners, including governments, NGOs and other industry partners, to do their part to help solve this problem. Participation in the important work of the TFSA is an important part of their commitment. The meeting also provided an excellent occasion to present the newly-launched WPC website; WorldPlasticsCouncil.org, enabling stakeholders to learn more about the global plastics industry, including their values and commitments.

Apart from infrastructural roadblocks, lack of awareness and low level of community participation are major factors behind increasing generation of plastic wastes. The staggering amount of plastic wastes generated in the Middle East demands a concerted effort from policy-makers and urban planners to devise an effective plastic waste collection and recycling strategy to tackle the menace of plastic wastes.

11 References

11.1 Biodiversity

11.1.1 Alien species

Adams NM, (1983). Checklist of marine algae possibly naturalised in New Zealand. New Zealand Journal of Botany, 21:1-2.

Al-Yamani, F. Y., Skryabin, V., & Durvasula, S. R. V. (2015). Suspected ballast water introductions in the Arabian Gulf. Aquatic Ecosystem Health & Management, 18(3), 282-289.

Arndt, E. A. (1984). Ecological niche of Cordylophora caspia (Pallas, 1771). Limnologica. 15, 469-477.

Balart, E.F., Pérez-Urbiola, J.C., Campos-Dávila, L., Monteforte, M. & Ortega-Rubio, A. (2009). On the first record of a potentially harmful fish, Sparus aurata in the Gulf of California. Biological Invasions, 11: 547–550.

Bishop Museum. 2002. Schizoporella errata (Waters, 1878), Guidebook of introduced marine species of Hawaii. Hawaii Biological Survey, Bishop Museum.

Carlton, J.T. and Geller, J.B. (1993). Ecological Roulette: the global transport or nonindigenous marine organisms. Science, 261:78-82.

Canonico, Gabrielle C, Angela Arthington, Jeffrey McCrary and Michele L. Thieme., (2005). The effects of introduced tilapias on native biodiversity. Aquatic Conserv: Mar. Freshw. Ecosyst. 15: 463–483.

Clark P.F., Abdul-Sahib I.M. and Al-Asadi M.S. (2006). The first record of Eriocheir sinensis H. Milne Edwards, 1853 (Crustacea: Brachyura: Varunidae) from the Basrah Area of Southern Iraq. Aquatic Invasions 1, 51–54.

Folino, N.C. (2000). The freshwater expansion and classification of the colonial hydroid Cordylophora (Phylum Cnidaria, Class Hydrozoa). In Pederson, J. (ed.) Marine Bioinvasions: Proceedings of the First National Conference, January 24-27, 1999. Massachusetts Institute of Technology Sea Grant College Program, Cambridge, MA. pp. 139-144.

Glibert PM, Landsberg JH, Evans JJ, Al-Sarawi MA, Muna Faraj, Al-Jarallah MA, Haywood A, Shahnaz Ibrahem, Klesius P, Powell C, Shoemaker C, (2002). A fish kill of massive proportion in Kuwait Bay, Arabian Gulf, 2001: the roles of bacterial disease, harmful algae, and eutrophication. Harmful Algae, 1(2):215-231.

Grabe, S. A. (1989). Some aspects of the biology of Rhopalophthalmus tattersallae Pillai, 1961 (Crustacea, Mysidacea) and extension of range into the khor al sabiya, Kuwait (Arabian Gulf). Proc. Biol. Soc. Wash. 102(3): 726-731.

Hallegraeff GM, McCausland MA, Brown RK, (1995). Early warning of toxic dinoflagellate blooms of Gymnodinium catenatum in southern Tasmanian waters. J. Plankton Res, 17:1163-1176.

Hallegraeff GM, Bolch CJ, (1992). Transport of dinoflagellate cysts in ship's ballast water: Implications for plankton biogeography and aquaculture. J. Plankton Res, 14:1067-1084.

Haywood, A. J., Steidinger, K. A., Truby, E. W., Bergquist, P. R., Bergquist, P. L., Adamson, J., & Mackenzie, L. (2004). Comparative morphology and molecular phylogenetic analysis of three new species of the genus karenia (dinophyceae) from new zealand. Journal of Phycology, 40(1), 165-179.

Hashim A.A. (2010). Occurrence of the Chinese mitten crab Eriocheir sinensis (H. Milne Edwards) in South Iraq. Mesopotamian Journal of Marine Science 25, 31–36.

McDonald, E. Michael., (1987). Interactions between a phytoplanktivorous fish, Oreochromis aureus, and two unialgal forage populations. Environmental Biology of Fishes Vol. 18, No. 3. pp. 229-234. l987.

Molnar, J. L.; Gamboa, R. L.; Revenga, C.; Spalding, M. D. (2008). Assessing the global threat of invasive species to marine biodiversity. Frontiers in Ecology and the Environment. 6(9): 485-492.

Naderloo, R. (2014). Invasive Hepu mitten crab, Eriocheir hepuensis (Crustacea: Decapoda: Brachyura: Varunidae) from the Iranian marshland in the northern Persian Gulf estuarine system. Marine Biodiversity Records, 7, e23

Naser, M. D., Rainbow, P. S., Clark, P. F., Yasser, A. G., & Jones, D. S. (2015). The barnacle Amphibalanus improvisus (Darwin, 1854), and the mitten crab Eriocheir: one invasive species getting off on another! BioInvasions Records, 4(3), 205-209.

Naser, M. D., Page, T. J., Ng, N. K., Apel, M., Yasser, A. G., Bishop, J. M., Ng, P.K.L. & Clark, P. F. (2012). Invasive records of Eriocheir hepuensis Dai, 1991 (Crustacea: Brachyura: Grapsoidea: Varunidae): implications and taxonomic considerations. BioInvasions Records, 1(1), 71-86.

Pierce, R. W., Carlton, J. T., Carlton, D. A., & Geller, J. B. (1997). Ballast water as a vector for tintinnid transport. Marine Ecology Progress Series, 149, 295-297.

Pullin RS, Palmares ML, Casal CV, Dey MM, Pauly D, (1997). Environmental impacts of tilapias. In: Fitzsimmons K, ed. Proceedings of the Fourth International Symposium on Tilapia in Aquaculture. Ithaca, NY, USA: Northeast Regional Agricultural Engineering Service, 554-572.

Richlen, M. L., Morton, S. L., Jamali, E. A., Rajan, A., & Anderson, D. M. (2010). The catastrophic 2008–2009 red tide in the Arabian Gulf region, with observations on the identification and phylogeny of the fish-killing dinoflagellate Cochlodinium polykrikoides. Harmful algae, 9(2), 163-172.

Saburova, M., Polikarpov, I., & Al-Yamani, F. (2012). First record of Kryptoperidinium foliaceum (Dinophyceae: Peridiniales) from a hypersaline environment in Kuwait, north-western Arabian Gulf. Marine Biodiversity Records, 5.

Salman, S.D. and Bishop, J.M. (1990). Exopalaemon styliferus (H. Milne Edwards, 1840) in the Northern Arabian Gulf and the inland waters of Iraq. (Decapoda, Caridea, Palaemonidae). Crustaceana, 95:281-288.

Smith, D.G., S.F. Werle, and E. Klekowski. (2002). The rapid colonization and emerging biology of Cordylophora caspia (Pallas, 1771) (Cnidaria: Clavidae) in the Connecticut River. Journal of Freshwater Ecology 17(3):423-430.

11.1.2 Commercial Invertebrates

Anderson, F.E., Engelke, R., Jarrett, K., Valinassab, T., Mohamed, K.S., Asokan, P.K., Zacharia, P.U., Nootmorn, P., Chotiyaputta, C. and Dunning, M. 2011. Phylogeny of the Sepia pharaonis species complex (Cephalopoda: Sepiida) based on analyses of mitochondrial and nuclear DNA sequence data. Journal of Molluscan Studies 77: 65-73.

Al-Attar, M.H., 1984a. Kuwait Bay: A nursery area for penaeid shrimp: I Penaeus semisulcatus. In: Mathews, C.P. (Ed.,) Proceedings, Third Shrimp and Fin Fisheries Management Workshop, Fin Fisheries Session 4–5 December 1982, Final Report (MB-41), vol. 1. Kuwait Institute for Scientific Research Report No. 1156, pp. 85–112.

Al-Husaini, M., Bishop, J.M., Al-Foudari, H.M., Al-Baz, A.F. 2015. A review of the status and development of Kuwait's fisheries. Marine Pollution Bulletin 100; 597-606

Barratt, I. & Allcock, L. 2012. Sepia pharaonis. The IUCN Red List of Threatened Species 2012: e.T162504A904257.

Chembian, A. John; Mathew, Saleena (2011). "Migration and spawning behavior of the pharaoh cuttlefish Sepia pharaonis Ehrenberg, 1831 along the south-west coast of India". Indian Journal of Fisheries. 58 (3): 1–8. Retrieved 2016-03-24.

Chen, W., Almatar, S., Alsaffar, A., Yousef, A.R. 2013. Retained and discarded bycatch from Kuwait's shrimp fishery. Aquatic Science and Technology 1;1 http://dx.doi.org/10.5296/ast.v1i1.2778

Farmer, A.S.D., Ukawa, M., 1986. A provisional atlas for the commercially important penaeid shrimps of the Arabian Gulf. Kuwait Bull. Mar. Sci. 7, 23–44.

Gutowska, M.A., Melzner, F., Portner, H.O. and Meier, S. 2010. Cuttlebone calcification increases during exposure to elevated seawater pCO(2) in the cephalopod Sepia officinalis. Marine Biology 157: 1653-1663.

Mohamed, K.H., El-Musa, M., Abdul-Ghaffar, A.-R., 1981. Observations on the biology of an exploited species of shrimp, Penaeus. Semisulcatus De Haan, in Kuwait. Kuwait Bull. Mar. Sci. 2, 33–52.

Norman, M.D. 2003. Cephalopods A World Guide. ConchBooks, Hackenheim, Germany.

Jones, C.M. 1993. Population structure of Thenus orientalis and T. indicus (Decapoda: Scyllaridae in northeastern Australia). Marine Ecology Progress Series, 97:143-155

Jones, D., Al-Attar, M.H., 1982. Observation on the post-larval and juvenile habitats of Penaeus semisulcatus in Kuwait Bay and adjacent waters. In: Mathews, C.P. (Ed.), Revised Proceedings, Shrimp Fisheries Management Workshop, Final Report (MB-32). Kuwait Institute for Scientific Research Report No. KISR670, pp. 112–133.

Pauly, D., Palomares, M.L. 1987. Shrimp consumption by fish in Kuwait water: a methodology, preliminary results and their implications for management and research. Kuwait Bulletin of Marine Science (9): 101-125

Reid, A., Jereb, P. and Roper, C.F.E. 2005. Family Sepiidae. In: P. Jereb and C.F.E Roper (eds), Cephalopods of the World. An Annotated and Illustrated Catalogue of Cephalopod Species Known to Date. Volume 1. Chambered Nautiluses and Sepioids (Nautilidae, Sepiidae, Sepiolidae, Sepiadariidae, Idiosepiidae and Spirulidae), pp. 54-152. FAO, Rome.

Salman, S.D., Ali, M.H. & Al-Adhub, A.H.Y. 1990. Abundance and seasonal migrations of the penaeid shrimp Metapenaeus affinis (H. Milne-Edwards) within Iraqi waters. Hydrobiologia 196: 79. doi:10.1007/BF00008895

11.1.3 Marine Mammals

Anon. 1986. Report of the First Meeting of Experts on Mortality of Marine Mammals. Kuwait, November 22-23, 1980. Regional Organisation for the Protection of the Marine Environment, Kuwait. 29 pp.

Anon, 1994. Report of the workshop on mortality of cetaceans in passive fishing nets and traps. In: W. F. Perrin, G. P. Donovan & J. Barlow (eds). Gillnets and Cetaceans. Sci. Rep. Int. Whalg. commn. Special Issue 15. 629 pp.

Aspinall, S., Baldwin, R. 1999. The Finless Porpoise, Neophocaena phocaenoides (Cuvier, 1829) in the Arabian Gulf. Tribulus: 9, 1:13-15.

Baldwin, R., Cockcroft, V.G. Are dugongs, Dugong dugong, in the Arabian Gulf safe? Aquatic mammals, 23.2, 73-74

Baldwin, R. M., M. Collins, K. Van Waerebeek and G. Minton. 2004. The Indo - Pacific Humpback Dolphin of the Arabian Region: A status review. Aquat. Mamm., 30 (1): 111 - 124.

Baldwin, R.M. 1995. Whales and Dolphins of the United Arab Emirates. 111 pp., Emirates Printing. Press, Dubai.

Baldwin, R.M., Gallagher, M., van Waerebeek, K.[unknown]. A Review of Cetaceans from Waters off the Arabian Peninsula. Grey literature.

Beech, M. 2010. Mermaids of the Arabian Gulf: Archaeological evidence for the exploitation of dugongs form prehistory to the present. Journal of the National Centre for Documentation and Research, 2(3), 3-18.

Burahmah, I. 2013. Video of orca in Kuwait waters. https://www.youtube.com/watch?v=AcHDafyiao0

Bishop, J. M. and A. H. Alsaffar. 2008. Quantitative observations on marine mammals and reptiles of Kuwait's Boubyan Island. Zoology in the Middle East, 43: 3 - 12.

Bohadi, Y. 2015. Mysteries and negligence: The state of cetaceans in Kuwait waters. Grey literature.

Convention on the Conservation of Migratory Species of Wild Animals.2015. http://www.cms.int/dugong/en/news/how-abu-dhabi-saving-dugong

Clayton, D. 1983. Kuwait's natural history: an introduction. Kuwait Oil Co., Kuwait City, Kuwait.

Jefferson, T. A. and L. Karczmarski. 2001. Sousa chinensis. Mamm. Spec., 655: 1 - 9.

Jefferson, T.A., S. Leatherwood and M.A. Webber 1993 FAO species Identification Guide: Marine Mammals of the World. Rome, FAO. 320 p. + 587 figures

Leatherwood, S., McDonald, D., Prematunga, W.P., Girton, P., Ilangakoon, A. & McBrearty, D. (1991). Records of the 'Blackfish' (Killer, False Killer, Pilot, Pygmy Killer and Melon-headed Whales) in the Indian Ocean, 1772-1986. UNEP, Marine Mammal Technical Report 3: 33-65.

Morzer-Bruyns, W.F.J. 1971. Field guide of whales and dolphins. Tor/ c.a. Mees, Amsterdam. 258pp.

Nithyanandan, M. 2010. Opportunistic sightings of Indo-Pacific dolphin Sousa chinensis from Kuwait waters with notes on their behaviour. Journal of the marine biological association of India., 52(1) 19-23.

Preen, A. 1989a. Dugongs. Volume 1. The status and conservation of dugongs in the Arabian Region. MEPA Coastal and Marine Management Series, Report No. 10.

Meteorological and Environmental Protection. Administration, Jeddah, Saudi Arabia, 200 pp.

Preen, A. 2004. Distribution, abundance and conservation status of dugongs and dolphins in the southern and western Arabian Gulf. Biological Conservation 118: 205-218.

Price, A.R.G., Sheppard, C.R.C., Roberts, C.M. (1993a). The Gulf: Its Biological Setting. Marine Pollution Bulletin 27: 9-15 1993.

Price, A.R.G. 1993. The Gulf: Human Impacts and Management Initiatives. Marine Pollution Bulletin 27: 17-27 1993.

Wang J.Y, Yang A.C. 2009. Indo-Pacific bottlenose dolphin (Tursiops aduncus). In: Encyclopedia of marine mammals, 2nd Ed. (Perrin WF, Würsig B, Thewissen JGM, eds.) Academic Press, Amsterdam, pp. 602-608

Wilson, S.C. 2000. Northwest Arabian Sea and Gulf of Oman. In Sheppard, C.R.C. (Ed) Seas at the Millenium: An Environmental Evaluation: Volume II Regional Chapters: The Indian Ocean to the Pacific pp. 17-33. Oxford, Pergamon Press, Elsevier Science.

11.1.4 Turtles

Bjorndal, K.A. 1997. Foraging ecology and nutrition of sea turtles. In: Lutz, P.L. and Musick, J. (Eds.). The Biology of Sea Turtles. Boca Raton, FL: CRC Press, pp. 199–232.

Ficetola, F.F. 2008. Impacts of human activities and predators on the nest success of hawksbill turtle Eretmochelys imbricata in the Arabian Gulf. Chelonian conservation and biology 7(2), 255-257

Kamel, S.J. and Mrosovsky, N. 2006. Deforestation: risk of sex ratio distortion in hawksbill sea turtles. Ecological Applications 16:923–931.

Meakins, R.H. and Al Mohanna, S.Y. 2004. Sea Turtles of Kuwait. Centre for Research and Studies on Kuwait, Kuwait City, 177 pp.

Meakins, R.H. and Al Mohanna, S.Y. 2000. Sea turtles in Kuwait after the Gulf War. Marine Turtle Newsletter 88:7– 8.

Papathanasopoulou, N. 2015a. Kuwait Turtle Conservation Project Progress Report May 2015.

Papathanasopoulou, N. 2015b. Kuwait Turtle Conservation Project Progress Report June 2015.

Papathanasopoulou, N. 2015c. Kuwait Turtle Conservation Project Progress Report July 2015.

Pilcher, N.J. 2000. The green turtle, Chelonia mydas in the Saudi Arabian Gulf. Chelonian Conservation Biology 3(4):730–734.

Rincon-Diaz, M.P., Diez, C.E., Van Dam, R.P., Sabat, A.M. 2011. Foraging Selectivity of the Hawksbill Sea Turtle (Eretmochelys imbricata) in the Culebra Archipelago, Puerto Rico. Journal of Herpetology 45 (3) 277-282.

Rees, A.F., Al Hafez, A., Lloyd, J.R., Papathansopoulou, N., Godley, B.J. 2013. Green turtles in Kuwait- Nesting and movements. Chelonian conservation and biology 12(1):157-163. 2013.

Rincon-Diaz, M.P., Diez, C.E., Van Dam, R.P., Sabat, A.M. 2011. Foraging Selectivity of the Hawksbill Sea Turtle (Eretmochelys imbricata) in the Culebra Archipelago, Puerto Rico. Journal of Herpetology 45 (3) 277-282.

Seminoff, J.A., Resendiz, A., Nichols, W.J. 2002. Home range of green turtles Chelonia mydas at a coastal foraging area in the Gulf of California, Mexico. Marine Ecology Progress Series 242:253–265.

Unknown. 2010. http://www.treehugger.com/clean-technology/90-of-coral-reefs-have-died-mysteriously-along-kuwaits-coast.html

11.1.5 Seabirds

Agreement on the Conservation of Albatross and Petrels United Nations. 2015. Treaty Series, vol. 2258, No. 40228.

Ajawin, A.Y., Alcala, A.C., Bernal, P., Calumpong, H.P., Araghi, P.E., Green, S.O., Harris, P., Kamara, O.K., Kohata, K., Marschoff, E., Martin, G., Ferreira, B.P., Park, C., Payet, R.A., Rice, J., Rosenberg, A.,

Al-Husaini, M., Bishop, J.M., Al-Foudari, H.M., Al-Baz, A.F. 2015. A review of the status and development of Kuwait's fisheries. Marine Pollution Bulletin 100, 597-606.

Baby, S. 2011. Assessing and Evaluating Anthropogenic Activities Causing Rapid Evolution in the Coastal Morphological Landscape Changes (CMLC) of Kuwait Using RIAM. Environment and Natural Resources Research 1;1

BirdLife International. 2016. Species list for Kuwait with conservation status http://datazone.birdlife.org/species/results?thrlev1=&thrlev2=&kw=&fam=0&gen=0&spc=&cmn=&reg=0&cty=114- Accessed 10/11/2016

Glibert, P, J Evans, and J Landsberg. 2001. The 2001 fish kill in Kuwait Bay: questions, causes, commentary. Report prepared for Environment Public Authority, Kuwait. Univ. Maryland Center for Environmental Science, Cambridge, MD, 69 pp.

Kuwaitbirds.org.2016. http://www.kuwaitbirds.org/conservation/protecting-species Accessed 8/11/2016.

Lascelles, B., Sciara, G.N.D., Agardy, T., Cuttelod, A., Eckert, S., Glowka, L., Hoyt, E., Llewellyn, F., Louzao, M., Ridoux, V. & Tetley, M.J. 2014. Migratory marine species: their status, threats and conservation management needs. Aquatic Conservation: Marine and Freshwater Ecosystems: 24: 111–127

Ruwa, R., Tuhumwire, J.T., Van Gaever, S., Wang,J., Węsławski, J.M. 2016. The First Global Integrated Marine Assessment World Ocean Assessment I. United Nations General Assembly Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects. Chapter 38 Seabirds.

11.1.6 Habitats

Abd El-Wahab R H. (2015). Species richness, structure, and conservation of *Nitraria retusa* communities in the coastal salt marshes of Kuwait. Regional Environmental Change, 15(5): 1–12.

Abd El-Wahab R H. (2016). Plant assemblages and diversity variation with human disturbance in coastal habitats of the Western Arabian Gulf. Journal of Arid Land, 8(4): xxx–xxx. doi: 10.1007/s40333-016-0084-x

Al-Dousari A M, Ahmed M, Al-Senafy M. (2008). Characteristics of nabkhas in relation to dominant perennial plant species in Kuwait. Kuwait Journal of Science & Engineering, 35: 129–150.

Al-Sawari. M., Gundlach. E. R., Baca. B. J. (1985). Sensitivity of coastal environments and wildlife to spilled oil. Kuwait: An atlas of shoreline types and resources. pp 49.

Almulla L., Bhat. N., Thomas B., Rajesh L., Ali. S. & George P. (2013) Assessment of existing mangrove plantation along Kuwait coastline. Biodiversity Journal, 2013, 4 (1): 111-116.

Baby S, Nathawat M S, Al-Sarawi M A. (2014). Major impacts from anthropogenic activities on landscape carrying capacity of Kuwaiti Coast. Polish Journal of Environmental Studies, 23(1): 7–17.

Halwagy R, Halwagy M. (1977). Ecological studies on the desert of Kuwait. III. The vegetation of the coastal salt marshes. Kuwait Journal of Science & Engineering, 4: 33–74.

Loughland R A, Al-Abdulkader K A, Wyllie A. (2012). Anthropogenic induced geomorphological change along the western Arabian Gulf coast. In: Piacentini T, Miccadei E. Studies on Environmental and Applied Geomorphology. Rijeka: InTech, pp191-218.

Omar. S. A and Roy W. Y. (2013). Ecology and environment of Boubyan island. Kuwait Institute for Scientific Research. pp 292.

11.2 Food and human health

11.3 Eutrophication and HABS

de Jonge, V.N., Elliott, M., 2002. Causes, historical development, effects and future challenges of a common environmental problem: eutrophication. Hydrobiologia 475/476, 1-19.

Cloern, J.E., 2001. Our evolving conceptual model of the coastal eutrophication problem. Mar. Ecol. Prog. Ser. 210, 223e253.

Devlin, M.J., Bricker, S., Painting, S., 2011. Comparison of five methods for assessing impacts of nutrient enrichment using estuarine case studies. Biogeochemistry 106, 177-205.

Devlin, M.J., Foden, J.,Council of European Communities (CEC) (1991a) Council Directive of 21 May 1991 concerning urban waste water treatment (91/271/EEC). Off J Eur Commun L135:40–52 (30.5.91)

Council of European Communities (CEC) (1991b) Council Directive of 31 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC). Off J Eur Commun L375:1–8

Council of European Communities (CEC) (1992) Habitats Directive

Council of European Communities (CEC) (2000) Council Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy. Off J Eur Commun L327:1–73

Council of European Communities (CEC) (2008) Council Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)

OSPAR Commission (2003a) The OSPAR Integrated Report 2003 on the Eutrophication Status of the OSPAR Maritime Area based upon the first application of the comprehensive procedure. OSPAR Publication 2003, ISBN:1-904426-25-5

OSPAR Commission (2003b) Strategies of the OSPAR Commission for the protection of the marine environment of the north-east Atlantic (Reference number: 2003-21). EUC 03/17/1-E Annex 31, p 22

Abaychi, J.K., Darmoian, S.A., DouAbul, A.A., 1988. The Shatt al-Arab River: A nutrient salt and organic matter source to the Arabian Gulf. Hydrobiologia 166, 217-224.

Abdullah, A.D., Masih, I., Van Der Zaag, P., Karim, U.F., Popescu, I., Al Suhail, Q., 2015. Shatt al Arab River system under escalating pressure: a preliminary exploration of the issues and options for mitigation. International Journal of River Basin Management 13, 215-227.

Al-Abdulghani, E., El-Sammak, A., Sarawi, M., 2013. Environmental assessment of Kuwait Bay: an integrated approach. J Coast Conserv 17, 445-462.

Al-Ajmi, D., Al-Rayes, N., Zorba, M., 1988. Status of pollutants based on marine pollution projects in KISR. .

Al-Ghadban, A., Al-Majed, N., Al-Muzaini, S., 2002. The state of marine pollution in Kuwait: Northern Arabian Gulf. Technology-Elmsford journal of the Franklin Institute serving legislative regulatory and judicial systems. 8, 7-26.

Al-Ghadban, A., El-Sammak, A., 2005a. Sources, distribution and composition of the suspended sediments, Kuwait Bay, Northern Arabian Gulf. Journal of Arid Environments 60, 647-661.

Al-Ghadban, A., N Al-Majed, N., Al-Muzaini, S., 2001. The state of marine pollution in Kuwait: Northern Arabian Gulf, in: Al-Sarawi, M., Massoud, M. (Eds.), Proc. Intern. Conf on The Impact of Environmental Pollution on Development in the Gulf Region. Kuwait,. Environment Public Authority, Kuwait, pp. 97-131.

Al-Ghadban, A.N., El-Sammak, A., 2005b. Sources, distribution and composition of the suspended sediments, Kuwait Bay, Northern Arabian Gulf. Journal of Arid Environments 60, 647-661.

Al-Hassan, L., 1999. Shad of the Shatt Al-Arab River in Iraq. Shad Journal 4, 1-4.

Al-Husaini, M., Bishop, J., Al-Foudari, H., Al-Baz, A., 2015. A review of the status and development of Kuwait's fisheries. Marine pollution bulletin.

Al-Mussalam, F., Sarawi, M., Masood, M., 1999. Marine ecology and fisheries in Kuwait Bay with emphasis on the ecological impact of anthropogenic activities, Proceedings of the international conference on coastal zone management on development in the Gulf Region, pp. 135-152.

Al-Mutairi, N., Abahussain, A., Al-Battay, A., 2014. Environmental Assessment of Water Quality in Kuwait

Bay. International Journal of Environmental Science and Development, 5.

Al-Muzaini, S., Jacob, P., 1996. An assessment of toxic metals content in the marine sediments of the Shuaiba industrial area, Kuwait, after the oil spill during the Gulf War. Water Science and Technology 34, 203-210.

Al-Omran, L.A.G., 1998. Coprostanol in the intertidal sediments of Kuwait. Case study on urban sewage contamination. International Journal of Environmental Studies 55, 87-100.

Al-Rashidi, T.B., El-Gamily, H.I., Amos, C.L., Rakha, K.A., 2009. Sea surface temperature trends in Kuwait Bay, Arabian Gulf. Natural hazards 50, 73-82.

Al-Sarawi, H.A., Jha, A.N., Al-Sarawi, M.A., Lyons, B.P., 2015. Historic and contemporary contamination in the marine environment of Kuwait: An overview. Marine pollution bulletin.

Al-Sarawi, M.A., Massoud M.S., Khader S.R. and Bou-Olayan A.H. , 2001. Recent trace metal pollution in Sulaibikhat Bay, Kuwait. , in: M.A. Al-Sarawi, M.S., Massoud (Ed.), Proc. Intern. Conf on The Impact of Environmental Pollution on Development in the Gulf Region. Environment Public Authority, Kuwait, Kuwait, 15-17 March 1999, pp. 23-49.

Al-Yamani, F., 2008. Importance of the freshwater influx from the Shatt-Al-Arab River on the Gulf marine environment, Protecting the Gulf’s marine ecosystems from pollution. Springer, pp. 207-222.

Al-Yamani, F., Bishop, J., Al-Rifaie, K., Ismail, W., 2007. The effects of the river diversion, Mesopotamian Marsh drainage and restoration, and river damming on the marine environment of the northwestern Arabian Gulf. Aquatic Ecosystem Health & Management 10, 277-289.

Al-Yamani, F.Y., Bishop, J., Ramadhan, E., 2004. Oceanographic atlas of Kuwait's waters. Kuwait institute for scientific research.

Al-Zaidan, A., Al-Sarawi, H., Massoud, M., Al-Enezi, M., Smith, A., Bignell, J., Green, M., Askem, C., Bolam, T., Barber, J., Bersuder, P., Lyons, B., 2015. Histopathology and contaminant concentrations in fish from Kuwait’s marine environment. Marine pollution bulletin.

Alshemmari, H., Alotaibi, Y., Owens, R., 2010. Trace metal concentrations in the surface sediments of Sulaibihkat Bay, Kuwait. Kuwait J. Sci. Eng. 37, 87-110.

Anon, 2013. R development core team. A language and environment for statistical computing. . Vienna, Austria. .

Banat, I.M., Hassan, E.S., El-Shahawi, M.S., Abu-Hilal, A.H., 1998. Post-Gulf-War assessment of nutrients, heavy metal ions, hydrocarbons, and bacterial pollution levels in the United Arab Emirates coastal waters. Environment international 24, 109-116.

Brewer, P., Dyrssen, D., 1985. Chemical oceanography of the Persian Gulf. Essays on Oceanography: A Tribute to John Swallow, 41-55. Prog. in Oceanogr 14, 1-4.

Bricker, S.B., Longstaff, B., Dennison, W., Jones, A., Boicourt, K., Wicks, C., Woerner, J., 2008. Effects of nutrient enrichment in the nation's estuaries: a decade of change. Harmful Algae 8, 21-32.

Burt, J., Al-Harthi, S., Al-Cibahy, A., 2011. Long-term impacts of coral bleaching events on the world’s warmest reefs. Marine environmental research 72, 225-229.

Burt, J.A., 2013. The growth of coral reef science in the Gulf: A historical perspective. Marine pollution bulletin.

Burt, J.A., Al-Khalifa, K., Khalaf, E., AlShuwaikh, B., Abdulwahab, A., 2013. The continuing decline of coral reefs in Bahrain. Marine pollution bulletin 72, 357-363.

Carpenter, K.E., 1997. Living marine resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates. Food & Agriculture Org.

Collos, Y., Harrison, P.J., 2014. Acclimation and toxicity of high ammonium concentrations to unicellular algae. Marine pollution bulletin 80, 8-23.

Devlin, M., Barry, J., Painting, S., Best, M., 2009. Extending the phytoplankton tool kit for the UK Water Framework Directive: indicators of phytoplankton community structure. Hydrobiologia 633, 151-168.

Devlin, M., Best, M., Coates, D., Bresnan, E., O'Boyle, S., Park, R., Silke, J., Cusack, C., Skeats, J., 2007. Establishing boundary classes for the classification of UK marine waters using phytoplankton communities. Marine pollution bulletin 55, 91-103.

Dugdale, R.C., Wilkerson, F.P., Hogue, V.E., Marchi, A., 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine, Coastal and Shelf Science 73, 17-29.

El-Sammak, A., Karam, Q., Bu Shaiba, A., 2005. Preliminary Assessment of the Geological and Water Environments in Kuwait Bay: Identification of Hot-Spot Areas. Kuwait Institute for Scientific Research, Report No. KISR 7665.

Foda, M., Khalaf, F., Al-Kadi, A., 1985. Estimation of dust fallout rates in the northern Arabian Gulf. Sedimentology 32, 595-603.

Gevao, B., Beg, M.U., Al-Ghadban, A.N., Al-Omair, A., Helaleh, M., Zafar, J., 2006. Spatial distribution of polybrominated diphenyl ethers in coastal marine sediments receiving industrial and municipal effluents in Kuwait. Chemosphere 62, 1078-1086.

Glibert, P.M., Landsberg, J.H., Evans, J.J., Al-Sarawi, M.A., Faraj, M., Al-Jarallah, M.A., Haywood, A., Ibrahem, S., Klesius, P., Powell, C., Shoemaker, C., 2002. A fish kill of massive proportion in Kuwait Bay, Arabian Gulf, 2001: the roles of bacterial disease, harmful algae, and eutrophication. Harmful Algae 1, 215-231.

Heil, C.A., Glibert, P.M., Al-Sarawl, M., Faraj, M., Behbehani, M., Husain, M., 2001. First record of a fish-killing Gymnodinium sp bloom in Kuwait Bay, Arabian Sea: chronology and potential causes. Marine Ecology-Progress Series 214, 15.

Jeffrey, S.t., Humphrey, G., 1975. New spectrophotometric equations for determining chlorophylls a, b, c1 and c2 in higher plants, algae and natural phytoplankton. Biochem Physiol Pflanz BPP.

Khalaf, F., Al-Ajmi, D., 1993. Aeolian processes and sand encroachment problems in Kuwait. Geomorphology 6, 111-134.

Khalaf, F., Al-Bakri, D., Al-Ghadban, N., 1984a. Sedimentological characteristics of the surficial sediments of the Kuwait marine environment, northern Arabian Gulf. Sedimentology, 31, 531-545 31, 531 - 545.

Khalaf, F., Al-Bakri, D., AL-GHADBAN, A., 1984b. Sedimentological characteristics of the surficial sediments of the Kuwaiti marine environment, northern Arabian Gulf. Sedimentology 31, 531-545.

Kim, Y.J., Gu, C., 2004. Smoothing spline Gaussian regression: more scalable computation via efficient approximation. Journal of the Royal Statistical Society: Series B (Statistical Methodology) 66, 337-356.

Literathy, P., 1993. Considerations for the assessment of environmental consequences of the 1991 Gulf War. Marine pollution bulletin 27, 349-356.

Lyons, B., Devlin, M., Hamid, S.A., Al-Otiabi, A., Al-Enezi, M., Massoud, M., Al-Zaidan, A., Smith, A., Morris, S., Bersuder, P., 2015. Microbial water quality and sedimentary faecal sterols as markers of sewage contamination in Kuwait. Marine pollution bulletin.

Lyons, B., Smith, A., Morris, S., Devlin, M., 2013. An evaluation study of the contemporary environmental conditions and health of the biotic compartments of the marine and coastal waters of Kuwait., in: Centre for Environment, F.a.A.S. (Ed.), Contract Report for C6061, UK.

Massoud, M.S., Al-Abdali, F., Al-Ghadban, A.N., 1998. The status of oil pollution in the Arabian Gulf by the end of 1993. Environment international 24, 11-22.

Massoud, M.S., Al-Abdali, F., Al-Ghadban, A.N., Al-Sarawi, M., 1996. Bottom sediments of the Arabian Gulf—II. TPH and TOC contents as indicators of oil pollution and implications for the effect and fate of the Kuwait oil slick. Environmental pollution 93, 271-284.

Moore, A.B., Bolam, T., Lyons, B.P., Ellis, J.R., 2015. Concentrations of trace elements in a rare and threatened coastal shark from the Arabian Gulf (smoothtooth blacktip Carcharhinus leiodon). Marine pollution bulletin.

Nasrallah, H.A., Nieplova, E., Ramadan, E., 2004. Warm season extreme temperature events in Kuwait. Journal of Arid Environments 56, 357-371.

Ostendorf, B., 2011. Overview: Spatial information and indicators for sustainable management of natural resources. Ecological Indicators 11, 97-102.

Parsons, T.R., Maita, Y, Lalli, C.M., 1984. A manual of chemical and biological methods for seawater analysis. Pergamon, New York.

Price, A.R.G., 1998. Impact of the 1991 Gulf War on the coastal environment and ecosystems: Current status and future prospects. Environment international 24, 91-96.

Price, A.R.G., Robinson, J.H., 1993. Preface. Marine pollution bulletin 27, vii-viii.

Riegl, B., Purkis, S., 2012. Coral Reefs of the Gulf.

Robinson, A.R., Brink, K.H., 2006. The global coastal ocean: interdisciplinary regional studies and syntheses. Harvard University Press.

Saad, M., Kell, V., 1975. Observations on some environmental conditions as well as phytoplankton blooms in the lower reaches of Tigris and Euphrates. Wiss. Z. Univ. Rostock 24, 781-787.

Saad, M.A., 1978. Seasonal variations of some physicochemical conditions of Shatt al-Arab estuary, Iraq. Estuarine and Coastal Marine Science 6, 503-513.

Saeed, T., Al-ABloushi, A., Abdullah, H., Al-Khabbaz, A., Jamal, Z., 2012. Preliminary assessment of sewage contamination in coastal sediments of Kuwait following a major pumping station failure usng fecal sterol markers. Aquatic Ecosystem Health and Management Socieity 15:sup 1, 25-32.

Sen Gupta, R., Fondekar, S.P., Alagarsamy, R., 1993. State of oil pollution in the northern Arabian Sea after the 1991 Gulf oil spill. Marine pollution bulletin 27, 85-91.

Sheppard, C., Al-Husiani, M., Al-Jamali, F., Al-Yamani, F., Baldwin, R., Bishop, J., Benzoni, F., Dutrieux, E., Dulvy, N.K., Durvasula, S.R.V., 2010a. The Gulf: a young sea in decline. Marine pollution bulletin 60, 13-38.

Sheppard, C., Al-Husiani, M., Al-Jamali, F., Al-Yamani, F., Baldwin, R., Bishop, J., Benzoni, F., Dutrieux, E., Dulvy, N.K., Durvasula, S.R.V., Jones, D.A., Loughland, R., Medio, D., Nithyanandan, M., Pilling, G.M., Polikarpov, I., Price, A.R.G., Purkis, S., Riegl, B., Saburova, M., Namin, K.S., Taylor, O., Wilson, S., Zainal, K., 2010b. The Gulf: A young sea in decline. Marine pollution bulletin 60, 13-38.

Sheppard, C.R.C., 1993. Physical environment of the Gulf relevant to marine pollution: An overview. Marine pollution bulletin 27, 3-8.

Smith, A.J., McGowan, T., Devlin, M.J., Massoud, M.S., Al-Enezi, M., Al-Zaidan, A.S., Al-Sarawi, H.A., Lyons, B.P., this issue. Screening for contaminant hotspots in the marine environment of Kuwait using ecotoxicological and chemical screening techniques. Marine pollution bulletin.

Stentiford, G., Massoud, M., Al-Mudhhi, S., Al-Sarawi, M., Al-Enezi, M., Lyons, B., 2014. Histopathological survey of potential biomarkers for the assessment of contaminant related biological effects in species of fish and shellfish collected from Kuwait Bay, Arabian Gulf. Marine environmental research.

Subba Rao, D., Al-Yamani, F., 2000. The Arabian Gulf. Pergamon: Amsterdam.

UNEP, 2001. (United Nations Environment Program) Overview of the socio-economic aspects relatd to the management of municipal wastewater in west Asia (including all countries bordering the Red Sea and Gulf of Aden), UNEP Regional Sea Reports and Studies.

Wood, S., 2006. Generalized Additive Models: an introduction with R. . Chapman and Hall/CRC, London. .

11.4 Pollution

Al-Abdali, F., Massoud, M.S., Al-Ghadban, A.N. (1996). Bottom sediments of the Arabian Gulf-III. Trace metal contents as indicators of pollution and implications for the effect and fate of the Kuwait oil slick. Environmental Pollution. 93, 285-301.

Al-Abdulghani, E., El-Sammak, A., Sarawi, M. (2013). Environmental assessment of Kuwait Bay: an integrated approach. Journal of Coastal Conservation 17, 445-462.

Al-Ghadban, A.N., Al-Majed, N., Al-Muzaini, S. (2002). The state of marine pollution in Kuwait: Northern Arabian Gulf. Technology 8, 7-26.

Al-Ghadban, A.N., El-Sammak, A. (2005). Sources, distribution and composition of the suspended sediments, Kuwait Bay, Northern Arabian Gulf. Journal of Arid Environments, 60, 647-661.

Al-Rifaie, K.S., Al-Yamani, F.Y., Morgan, G., Jawad, M.A., Behbehani, M., Ismail, W. (2007). A strategic plan for the sustainable use for Kuwait's marine environment. International Journal of Oceans and Oceanography 2(1), 117-124.

Al-Sarawi, H.A, Jha, A.N., Al-Sarawi, M.A. Lyons, B.P. (2015). Historic and contemporary contamination in the marine environment of Kuwait: an overview. Marine Pollution Bulletin. 100 (2), 621-628.

Beg, M.U., Gevao, B., Al-Jandal, N., Beg, K.R., Butt, S.A., Ali, L.N., Al-Hussaini, M. (2009). Polycyclic aromatic hydrocarbons in three varieties of fish from Kuwait bay. Polycyclic Aromatic Compounds, 29 (2), 75-89.

Bu-Olayan A.H., Thomas, B.V. (2014). Dispersion model and bioaccumulation factor validating trace metals in sea bream inhabiting wastewater drain outfalls. International Journal . Environmental Science and Technology 11, 795–804.

de Mora, S., Tolosa, I., Fowler, S. W., Villeneuve, J-P., Cassi, R., Cattini, C. (2010). Distribution of petroleum hydrocarbons and organochlorinated contaminants in marine biota and coastal sediments from the ROPME sea area during 2005. Marine Pollution Bulletin. 60, 2323-2349.

EPA, (2001). Environment Public Authority Decision No. 210/2001 Pertaining to the Executive By-Law of the Law of Environment Public Authority.

Ghannoum, M.A., Al-Sarawi, M., Abo Alyan, A., Baca, B. (1991). Microbiological water quality along the Kuwait waterfront project. International Journal of Environmental Studies 37, 65-71.

Lyons, B.P., Devlin, M.J., Abdul Hamid, S.A., Al-Otiabi, A.F., Al-Enezi, M., Massoud, M.S., Al-Zaidan, A.S., Smith A.J., Morris, S., Bersuder, P., Barber, J.L., Papachlimitzou, A., Al-Sarawi, H.A. (2015). Microbial water quality and sedimentary faecal sterols as markers of sewage contamination in Kuwait. Marine Pollution Bulletin. 100 (2), 689-698.

Readman, J.W., Fillmann, G., Tolosa, I., Bartocci, J., Mee, L.D. (2005). The use of steroid markers to assess sewage contamination of the Black Sea. Marine Pollution Bulletin 50, 310–318.

Readman, J.W., Fowler, S.W., Villeneuve, J.P., Cattini, C., Oregioni, B., Mee, L.D. (1992). Oil and combustion-product contamination of the Gulf marine environment following the war. Nature 358, 662-664.

Readman, J.W., Bartocci, J., Tolosa, I., Fowler, S.W., Oregioni, B., Abdulraheem, M.Y. (1996). Recovery of the Coastal Marine Environment in the Gulf Following the 1991 War-Related Oil Spills. Marine Pollution Bulletin 32, 493-498.

Saeed, T., Al-Bloushi, A., Abdullah, H.I., Al-Khabbaz, A., Jamal, Z. (2012). Preliminary assessment of sewage contamination in coastal sediments of Kuwait following a major pumping station failure using faecal sterol markers. Aquatic Ecosystem Health and Management 15, 25-32.

Tarique, Q., Burger, J., Reinfelder, J. (2012). Metal Concentrations in Organs of the Clam Amiantis umbonella and Their Use in Monitoring Metal Contamination of Coastal Sediments. Water Air and Soil Pollution 223, 2125-2136.

Tarique, Q., Burger, J., Reinfelder, J. (2013). Relative Importance of Burrow Sediment and Porewater to the Accumulation of Trace Metals in the Clam Amiantis umbonella. Archives of Environmental Contamination Toxicology 65, 89–97.

Al-Abdulghani, E., El-Sammak, A., Sarawi, M. (2013). Environmental assessment of Kuwait Bay: an integrated approach. Journal of Coastal Conservation 17, 445-462.

Al-Abdali, F., Massoud, M.S., Al-Ghadban, A.N. (1996). Bottom sediments of the Arabian Gulf-III. Trace metal contents as indicators of pollution and implications for the effect and fate of the Kuwait oil slick. Environmental Pollution 93, 285-301.

Al-Majed N.B., Preston, M.R. (2004). The distribution and inventory of total and methyl mercury in Kuwait Bay. Marine Pollution Bulletin 49, 930-937.

Al-Sarawi, M.A., Massoud, M.S., Khader, S.R. (2002). Recent trace metal pollution in bottom sediments of Sulaibikhat Bay, Kuwait. Technology 8, 38-50.

Alshemmari, H., Alotaibi, Y., Owens, R. (2010). Trace metal concentrations in the surface sediments of Sulaibikhat Bay, Kuwait. Kuwait Journal Science and Engineering 37, 87-110.

Beg, M.U., Al-Ghadban, A.N. (2003). Impact of draining of Iraqi marshes on sediment quality of Kuwait's northern marine area. Bulletin of Environmental Contamination and Toxiology 71, 60-67.

Bou-Rabee, B., Al-Sarawi, M.A., Massoud, M.S., Al-Ghareeb Kh., Rajab, W., Marmoush, Y. (2006). Mercury pollution in the marine silt sediments of Al-Shuwaikh coast, Kuwait. Technology 9, 303-314.

CCME (1999). Canadian sediment quality guidelines for the protection of aquatic life: Polycyclic aromatic hydrocarbons (PAHs). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Damiano, S., Papetti, P., Menesatti, P (2011). Accumulation of heavy metals to assess the health status of swordfish in a comparative analysis of Mediterranean and Atlantic areas. Mar. Pollut. Bull., 62 (2011), pp. 1920–1925.

Leung, K.M.Y., Bjørgesæter, A., Gray, J.S., Li, W.K., Lui, G.C.S., Wang, Y., Lam P.K.S. (2005). Deriving sediment quality guidelines from field-based species sensitivity distributions. Environ. Sci. Technol., 39, 5148–5156.

Long, E. R., MacDonald, D.D. (1998). Recommended uses of empirically derived, sediment quality guidelines for marine and estuarine ecosystems. Human and Ecological Risk Assessment 4, 1019-1039.

Metwally, M.E.-S., Al-Muzaini, S., Jacob, P.G., Bahloul, M., Urushigawa, Y., Sato, S., Matsmura, A. (1997). Petroleum hydrocarbons and related heavy metals in the near-shore marine sediments of Kuwait. Environment International 23,115-121.

Zhang, L.P., Xin, Y., Huan, F., Jing, Y.H., Ouyang, T., Yu, X.T. (2007). Heavy metal contamination in western Xiamen Bay sediments and its vicinity China. Mar. Pollut. Bull., 54 974–982.

Al-Omran, L.A., Rao, C.V.N. (1997). Hydrocarbons in intertidal areas of Kuwait. International Journal of Environmental Studies 53, 31-41.

Beg, M.U., Saeed, T., Al-Muzaini, S., Beg, K.R., Al-Bahloul, M., (2003). Distribution of petroleum hydrocarbon in sediment from coastal area receiving industrial effluents in Kuwait. Ecotoxicology and Environmental Safety 54 (1), 47-55.

CCME (1999). Canadian sediment quality guidelines for the protection of aquatic life: Polycyclic aromatic hydrocarbons (PAHs). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

de Mora, S., Tolosa, I., Fowler, S. W., Villeneuve, J-P., Cassi, R., Cattini, C. (2010). Distribution of petroleum hydrocarbons and organochlorinated contaminants in marine biota and coastal sediments from the ROPME sea area during 2005. Marine Pollution Bulletin. 60, 2323-2349.

Fowler, S.W., Readman, J.W., Oregione, B., Villeneuve, J.-P., McKay, K. (1993). Petroleum Hydrocarbons and Trace Metals in Nearshore Gulf Sediments and Biota Before and After the 1991 War: An Assessment of Temporal and Spatial Trends. Marine Pollution Bulletin 27, 171-182.

Gorham-Test, C., Wade, T., Engle, V., Summers, K., & Hornig, E. (1999). Regional Environmental Monitoring and Assessment Program — Galveston Bay 1993. Proceedings, Galveston Bay Estuary Program, State of the Bay Symposium IV, January 28–29, Galveston, TX, 97–109.

Long, E.R., MacDonald, D.D., Smith, S.I., Calder, F.D. (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19, 18-97.

Long, E. R., MacDonald, D.D. (1998). Recommended uses of empirically dervived, sediment quality guidelines for marine and estuarine ecosystems. Human and Ecological Risk Assessment 4(5): 1019-1039.

Massoud, M.S., Al-Abdali, F., Al-Ghadban, A.N. (1998). The status of oil pollution in the Arabian Gulf by the end of 1993. Environment International, 24, 11-22.

Metwally, M.E.-S., Al-Muzaini, S., Jacob, P.G., Bahloul, M., Urushigawa, Y., Sato, S., Matsmura, A. (1997). Petrolum hydrocarbons and related heavy metals in the near-shore marine sediments of Kuwait. Environment International. 23,115-121.

Nicolaus, M.E.E., Law, R.J., Wright, S.R., Lyons, B.P. (2015). Spatial and temporal analysis of the risks posed by polycyclic aromatic hydrocarbon, polychlorinated biphenyl and metal contaminants in sediments in UK estuaries and coastal waters. Marine Pollution Bulletin, 95, 469-479.

Readman, J.W., Bartocci, J., Tolosa, I., Fowler, S.W., Oregioni, B., Abdulraheem, M.Y. (1996). Recovery of the Coastal Marine Environment in the Gulf Following the 1991 War-Related Oil Spills. Marine Pollution Bulletin 32, 493-498.

Saeed, T., Al-Ghadban, A.N., Al-Shimmari, H., Al-Hashash, H. (1999c). Preliminary assessment of the impacts of draining of Iraqi marshes on Kuwait northern marine environment. Part II. Sediment associated pollutants. Water Science and Technology 40, 89-98.

Simpson, C.D., Mosi, A.A., Cullen, W.R., Reimer, K.J. (1996). Composition and distribution of polycyclic aromatic hydrocarbon contamination in surficial marine sediments from Kitimat Harbour, Canada. Science of the Total Environment 181, 265-278.

Woodhead, R.J., Law, R.J., Matthiessen, P. (1999). Polycyclic aromatic hydrocarbons in surface sediments around England and Wales, and their possible biological significance. Marine Pollution Bulletin 38, 773-790.

11.5 Ecotoxicology

Aerni, H.R., Kobler, B., Rutishauser, B.V., Wettstein, F.E., Fischer, R., Giger, W., Hungerbühler, A., Marazuela, M.D., Peter, A., Schönenberger, R., Vögeli, A.C., Suter, M.J.-F., Eggen, R.I.L. (2004). Combined biological and chemical assessment of estrogenic activities in wastewater treatment plant effluents. Analytical and Bioanalytical Chemistry. Anal. Bioanal. Chem. 378 (3), 688–696.

Atkinson, S., Atkinson, M.J., Tarrant, A.M. (2003). Estrogens from sewage in coastal marine environments. Environmental Health Perspective. 111 (4), 531–535.

Backhaus, T., Karlsson, M. (2014). Screening level mixture risk assessment of pharmaceuticals in STP effluents. Water Research 49, 157–165.

Backhaus, T., Porsbring, T., Arrhenius, A., Brosche, S., Johansson, P., Blanck, H. (2011). Single-substance and mixture toxicity of five pharmaceuticals and personal care products to marine periphyton communities. Environmental Toxicology and Chemistry 30, 2030–2040.

Balaam, J.L., Grover, D., Johnson, A.C., Jürgens, M., Readman, J., Smith, A.J., White, S., Williams, R., Zhou, J.L. (2010). The use of modelling to predict levels of estrogens in a river catchment: how does modelled data compare with chemical analysis and in vitro yeast assay results? Science of the Total Environment 408, 20–26.

Beck, I., Bruhn, R., Gandrass, J. (2006). Analysis of estrogenic activity in coastal surface waters of the Baltic Sea using the yeast estrogen screen. Chemosphere 63 (2006), 1870–1878.

Beg, M.U., Al-Ghadban, A.N. (2003). Impact of draining of Iraqi marshes on sediment quality of Kuwait's northern marine area. Bulletin of Environmental Contamination and Toxicology. 71, 60–67.

Devlin, M.J., Le Quesne, W.J.F., Lyons, B.P. (2015). The Marine Environment of Kuwait Emerging issues in a rapidly changing environment. Marine pollution bulletin 95 (100), 593-596.

Desbrow, C., Routledge, E.J., Brighty, G.C., Sumpter, J.P., Waldock, M. (1998). Identification of estrogenic chemicals in STW effluent. 1. Chemical fractionation and in vitro biological screening. Environ. Sci. Technol. 32 (11), 1549–1558.

Galluba, S., Oehlmann, J., (2012). Widespread endocrine activity in river sediments in Hesse, Germany, assessed by a combination of in vitro and in vivo bioassays. Journal Soils Sediments 12 (2), 252.

Gaw, S., Thomas, K.V., Hutchinson, T.H., 2014. Sources, impacts and trends of pharmaceuticals in the marine and coastal environment. Philosophical transactions of the Royal Society of London. Series B Biological Science 369, 1656.

Harries, J.E., Sheahan, D.A., Jobling, S., Matthiessen, P., Neall, P., Routledge, E., Rycroft, R., Sumpter, J.P., Tylor, T. (1996). A survey of estrogenic activity in United Kingdom inland waters. Environ. Toxicol. Chem. 15, 1993–2002.

Jobling, S., Nolan, Monique, Tyler, Charles R., Brighty, Geoff, Sumpter, John P. (1998). Widespread sexual disruption in wild fish. Environ. Sci. Technol. 32 (17), 2498–2506.

Lyons, B.P., Goodsir, F., Taylor, N.G.H., Thain, J.E. (2013). Do UK coastal and estuarine water samples pose a phototoxic threat? Marine pollution bulletin 68 (1), 13-20.

Matthiessen, P., Thain, J.E., Law, R.J., Fileman, T.W. (1993). Attempts to assess the environmental hazard posed by complex mixtures of organic chemicals in UK estuaries. Marine Pollution Bulletin 26 (2), 90–95.

Prasse, C., Schlusener, R., Schultz, T.A., Ternes, T.A. (2010). Antiviral drugs in wastewater and surface waters: a new pharmaceutical class of environmental relevance? Environmental Science and Technolnolgy 44, 1728–1735.

outledge, E.J., Sumpter, J.P. (1996). Estrogenic activity of surfactants and some of their degradation products assessed using a recombinant yeast screen. Environmental Toxicology And Chemistry 15 (3), 241–248.

Thain, J.E. (1991). Biological effects of contaminants: the oyster (Crassostrea gigas) embryo bioassay. ICES Techniques in Marine Environmental Sciences 11 (12 pp.).

Thomas, K.V., Balaam, J., Hurst, M.R., Thain, J.E. (2004). Identification of in vitro estrogen and androgen receptor agonists in North Sea offshore produced water discharges. Environ. Toxicol. Chem. 23 (5), 1156–1163.

Breivik ., Sweetman, A., Pacyna, J.M., Jones, K.C. (2007). Towards a global historical emission inventory for selected PCB congeners — A mass balance approach. Science of Total Environment (2-3), 296-307.

de Mora, S., Fowler, S. W., Wyse, E., Azemard, S. (2004). Distribution of heavy metals in marine bivalves, fish and coastal sediments in the Gulf and Gulf of Oman. Marine Pollution Bulletin 49, 410–424.

de Mora, S., Tolosa, I., Fowler, S. W., Villeneuve, J-P., Cassi, R., Cattini, C. (2010). Distribution of petroleum hydrocarbons and organochlorinated contaminants in marine biota and coastal sediments from the ROPME sea area during 2005. Marine Pollution Bulletin. 60, 2323-2349.

Fowler, S.W. (2002). Agrochemicals. In: Khan, N.Y., Munawar, M., Price, A.R.G. (Eds), The Gulf Ecosystem: Health and Sustainability. Backhuys Publishers, Lieden, pp.193-204.

Gevao, B., Aba, A.A., Al-Ghadban, A.N., Uddin, S. (2012). Depositional history of polychlorinated biphenyls in a dated sediment core from the northwestern Arabian Gulf. Archives of Environmental Contamination and Toxicology 62 (4), 549-556.

Gevao, B., Beg, M.U., Al-Omai, A., Helaleh M., Zafar, J. (2006). Spatial Distribution of Polychlorinated Biphenyls in Coastal Marine Sediments Receiving Industrial Effluents in Kuwait. Archives of Environmental Contamination and Toxicology 50 (2), 166-174.

OSPAR, (2008). Co-ordinated Environmental Monitoring Programme – Assessment manual for contaminants in sediment and biota ISBN 978-1-906840-20-4, Publication Number No. 379/2008.

11.5.1 Water - Metals

Al-Abdulghani, E., El-Sammak, A., Sarawi, M. (2013). Environmental assessment of Kuwait Bay: an integrated approach. Journal of Coastal Conservation 17, 445-462.

Al-Rifaie, K.S., Al-Yamani, F.Y., Morgan, G., Jawad, M.A., Behbehani, M., Ismail, W. (2007). A strategic plan for the sustainable use for Kuwait's marine environment. International Journal of Oceans and Oceanography 2, 117-124.

Al-Sarawi, M.A., Massoud, M.S., Khader, S.R. (2002). Recent trace metal pollution in bottom sediments of Sulaibikhat Bay, Kuwait. Technology 8, 38-50.

Bu-Olayan A.H., Thomas, B.V. (2014). Dispersion model and bioaccumulation factor validating trace metals in sea bream inhabiting wastewater drain outfalls. International Journal of Environmental Science and Technology 11, 795–804.

EPA, (2001). Environment Public Authority Decision No. 210/2001 Pertaining to the Executive By-Law of the Law of Environment Public Authority.

Nicolaus, E. E. M., Law, R. J., Wright, S. R. and Lyons, B. P. (2015). Spatial and temporal analysis of the risks posed by polycyclic aromatic hydrocarbons, polychlorinated bipbenyl and metal contaminants in sediments in UK estuaries and coastal waters. Mar. Pollut. Bull., 95, 469-479.

Zhang, L.P., Xin, Y., Huan, F., Jing, Y.H., Ouyang, T., Yu, X.T. (2007). Heavy metal contamination in western Xiamen Bay sediments and its vicinity China. Mar. Pollut. Bull., 54, 974–982.

11.5.2 Sediment

Allchin, C.R., Law, R.J., Morris, S. (1999). Polybrominated diphenylethers in sediments and biota downstream of potential sources in the UK. Environmental Pollution 105, 197-207.

Gevao, B., Beg, M.U., Al-Ghadban, A.N., Al-Omai, A., Helaleh M., Zafar, J. (2006). Spatial distribution of polybrominated diphenyl ethers in coastal marine sediments receiving industrial and municipal effluents in Kuwait. Chemosphere 62, 1078-1086.

Gevao, B., Boyle, E.A., Aba, A.A., Carrasco, G.G., Ghadban, A.N., Al-Shamroukh, D., Alshemmari, H., Bahloul, M. (2014). Polybrominated diphenyl ether concentrations in sediments from the Northern Arabian Gulf: Spatial and temporal trends. Science of the Total Environment 491-492, pp. 148-153.

Luo, Q., Cai, Z.W., Wong, M.H., (2007). Polybrominated diphenyl ethers in fish and sediment from river polluted by electronic waste. Science of the Total Environment 383, 115–27.

Watanabe, I., Sakai, S. (2003). Environmental release and behaviour of brominated flame retardants. Environment International 29, 665-82.

Adnan, N.H., Zakaris, M.P., Juahir, H., Ali, M.M. (2012). Faecal sterols as sewage markers in the Langat River, Malaysia: Integration of biomarkers and multivariate statistical approaches. Journal of Environmental Sciences 24, 1600-1608.

Al-Abdulghani, E., El-Sammak, A., Sarawi, M. (2013). Environmental assessment of Kuwait Bay: an integrated approach. Journal of Coastal Conservation 17, 445-462.

Al-Ghadban, A.N., Al-Majed, N., Al-Muzaini, S. (2002). The state of marine pollution in Kuwait: Northern Arabian Gulf. Technology 8, 7-26.

Al-Omran, L.A.G. (1998). Coprostanol in the intertidal sediments of Kuwait. Case study on urban sewage contamination. International Journal of Environmental Studies 55, 87-100.

Al-Zaidan, A.S.Y, Al-Mohanna, S.Y, George, P. (2013). Status of Kuwait's fishery resources: Assessment and perspective. Marine Policy 38, 1-7.

Carreira, R.S., Wagener, A.L.R., Readman J.W. (2004). Sterols as markers of sewage contamination in a tropical urban estuary (Guanabara Bay, Brazil): space–time variations Estuarine, Coastal and Shelf Science 60, 587–598.

de Abreu-Mota, M.A., de Moura Barboza, C.A., Bícego, M.C., Martins, C.C. (2014). Sedimentary biomarkers along a contamination gradient in a human-impacted sub-estuary in Southern Brazil: A multi-parameter approach based on spatial and seasonal variability. Chemosphere 103, 156–163.

El-Desouki, M., Abdulraheem, M.Y. (1998). Domestic waste release into the ROPME Sea Area. ROPME/UNEP. Proceedings of ROPME workshop on coastal area development. UNEP Regional Sea Reports and Studies, 90, 1998.

González-Oreja, J.A., Saiz-Salinas, J.I. (1998). Short-term Spatio-temporal Changes in Urban Pollution by Means of Faecal Sterols Analysis. Marine Pollution Bulletin 36, 868-875.

Grimalt, J.O., Fernandez, P., Bayona, J.M. and Albaiges, J. (1990). Assessment of faecal sterols and ketones as indicators or urban sewage inputs to coastal waters. Environmental Science and Technology 24, 357-363.

Isobe, K.O., Tarao, M., Zakaria, M.P., Chiem, N.H., Minh, L.Y., Takada, H., (2002). Quantitative application of fecal sterols using gas chromatography–mass spectrometry to investigate fecal pollution in tropical waters: Western Malaysia and Mekong delta, Vietnam. Environmental Science and Technology 36, 4497– 4507.

Leeming, R., Ball, A., Ashbolt, N., Nichols, P., (1996). Using faecal sterols from humans and animals to distinguish faecal pollution in receiving waters. Water Research 30, 2893–2900.

Martins, C.C., Cabral, A.C., Barbosa-Cintra, S.C.T., Dauner, A.L.L., Souza, F. (2014). An integrated evaluation of molecular marker indices and linear alkylbenzenes (LABs) to measure sewage input in a subtropical estuary (Babitonga Bay, Brazil). Environmental Pollution, 188, 71-80.

McCalley, D. V., Cooke, M. and Nickless, G. (1981) The effect of sewage treatment on fecal sterols. Water Research 15, 1019-1025.

Mudge, S.M., Seguel, C.G. (1999). Organic Contamination of San Vicente Bay, Chile. Marine Pollution Bulletin 38, 1011-1021.

Readman, J.W., Fillmann, G., Tolosa, I., Bartocci, J., Mee, L.D. (2005). The use of steroid markers to assess sewage contamination of the Black Sea. Marine Pollution Bulletin 50, 310–318.

Reeves, A.D., Patton, D. (2005). Faecal sterols as indicators of sewage contamination in estuarine sediments of the Tay Estuary, Scotland: an extended baseline survey. Hydrology and Earth Systems Sciences 9, 81-94.

Saeed, T., Al-Bloushi, A., Abdullah, H.I., Al-Khabbaz, A., Jamal, Z. (2012). Preliminary assessment of sewage contamination in coastal sediments of Kuwait following a major pumping station failure using fecal sterol markers. Aquatic Ecosystem Health and Management 15, 25-32.

Saeed, T., Al-Shimmari, F., Al-Mutairi, A., Abdullah, H. (2015). Spatial assessment of the sewage contamination of Kuwait’s marine areas. Marine Pollution Bulletin 94, 307-317.

Tolosa, I., Mesa, M., Alonso-Hernandez, C.M. (2014). Steroid markers to assess sewage and other sources of organic contaminants in surface sediments of Cienfuegos Bay, Cuba. Marine Pollution Bulletin 86, 84-90.

11.5.3 Faecal sterols

Adnan, N.H., Zakaris, M.P., Juahir, H., Ali, M.M. (2012). Faecal sterols as sewage markers in the Langat River, Malaysia: Integration of biomarkers and multivariate statistical approaches. Journal of Environmental Sciences 24, 1600-1608.

Al-Abdulghani, E., El-Sammak, A., Sarawi, M. (2013). Environmental assessment of Kuwait Bay: an integrated approach. Journal of Coastal Conservation 17, 445-462.

Al-Ghadban, A.N., Al-Majed, N., Al-Muzaini, S. (2002). The state of marine pollution in Kuwait: Northern Arabian Gulf. Technology 8, 7-26.

Al-Omran, L.A.G. (1998). Coprostanol in the intertidal sediments of Kuwait. Case study on urban sewage contamination. International Journal of Environmental Studies 55, 87-100.

Al-Zaidan, A.S.Y, Al-Mohanna, S.Y, George, P. (2013). Status of Kuwait's fishery resources: Assessment and perspective. Marine Policy 38, 1-7.

Carreira, R.S., Wagener, A.L.R., Readman J.W. (2004). Sterols as markers of sewage contamination in a tropical urban estuary (Guanabara Bay, Brazil): space–time variations Estuarine, Coastal and Shelf Science 60, 587–598.

de Abreu-Mota, M.A., de Moura Barboza, C.A., Bícego, M.C., Martins, C.C. (2014). Sedimentary biomarkers along a contamination gradient in a human-impacted sub-estuary in Southern Brazil: A multi-parameter approach based on spatial and seasonal variability. Chemosphere 103, 156–163.

El-Desouki, M., Abdulraheem, M.Y. (1998). Domestic waste release into the ROPME Sea Area. ROPME/UNEP. Proceedings of ROPME workshop on coastal area development. UNEP Regional Sea Reports and Studies, 90, 1998.

González-Oreja, J.A., Saiz-Salinas, J.I. (1998). Short-term Spatio-temporal Changes in Urban Pollution by Means of Faecal Sterols Analysis. Marine Pollution Bulletin 36, 868-875.

Grimalt, J.O., Fernandez, P., Bayona, J.M. and Albaiges, J. (1990). Assessment of faecal sterols and ketones as indicators or urban sewage inputs to coastal waters. Environmental Science and Technology 24, 357-363.

Isobe, K.O., Tarao, M., Zakaria, M.P., Chiem, N.H., Minh, L.Y., Takada, H., (2002). Quantitative application of fecal sterols using gas chromatography–mass spectrometry to investigate fecal pollution in tropical waters: Western Malaysia and Mekong delta, Vietnam. Environmental Science and Technology 36, 4497– 4507.

Leeming, R., Ball, A., Ashbolt, N., Nichols, P., (1996). Using faecal sterols from humans and animals to distinguish faecal pollution in receiving waters. Water Research 30, 2893–2900.

Martins, C.C., Cabral, A.C., Barbosa-Cintra, S.C.T., Dauner, A.L.L., Souza, F. (2014). An integrated evaluation of molecular marker indices and linear alkylbenzenes (LABs) to measure sewage input in a subtropical estuary (Babitonga Bay, Brazil). Environmental Pollution, 188, 71-80.

McCalley, D. V., Cooke, M. and Nickless, G. (1981) The effect of sewage treatment on fecal sterols. Water Research 15, 1019-1025.

Mudge, S.M., Seguel, C.G. (1999). Organic Contamination of San Vicente Bay, Chile. Marine Pollution Bulletin 38, 1011-1021.

Readman, J.W., Fillmann, G., Tolosa, I., Bartocci, J., Mee, L.D. (2005). The use of steroid markers to assess sewage contamination of the Black Sea. Marine Pollution Bulletin 50, 310–318.

Reeves, A.D., Patton, D. (2005). Faecal sterols as indicators of sewage contamination in estuarine sediments of the Tay Estuary, Scotland: an extended baseline survey. Hydrology and Earth Systems Sciences 9, 81-94.

Saeed, T., Al-Bloushi, A., Abdullah, H.I., Al-Khabbaz, A., Jamal, Z. (2012). Preliminary assessment of sewage contamination in coastal sediments of Kuwait following a major pumping station failure using fecal sterol markers. Aquatic Ecosystem Health and Management 15, 25-32.

Saeed, T., Al-Shimmari, F., Al-Mutairi, A., Abdullah, H. (2015). Spatial assessment of the sewage contamination of Kuwait’s marine areas. Marine Pollution Bulletin 94, 307-317.

Tolosa, I., Mesa, M., Alonso-Hernandez, C.M. (2014). Steroid markers to assess sewage and other sources of organic contaminants in surface sediments of Cienfuegos Bay, Cuba. Marine Pollution Bulletin 86, 84-90.

11.5.4 Fish disease

Ariese, F., Kok, J.K., Verkaik, M., Gooijer, C., Velthorst, N.H., Hofstraat, J.W. (1993). Synchronous fluorescence spectrometry of fish bile: a rapid screening method for the biomonitoring of PAH exposure, Aquatic Toxicology 26, 273–286.

Beg, M.U., Al-Jandal, N., Al-Subiai, S., Karam, Q., Husain, S., Butt, S.A., Ali, A., Al-Hasan, E., Al-Dufaileej, S., Al-Husaini, M., (2015a). Metallothionein, oxidative stress and trace metals in gills and liver of demersal and pelagic fish species from Kuwait's marine area. Marine Pollution Bulletin 100, 662–672.

Beg,M.U., Al-Subiai, S.N., Al-Jandal, N., Butt, S.A., Beg, K.R., Al-Husaini, M., (2015b). Seasonal effect on biomarkers of exposure to petroleum hydrocarbons in fish from Kuwait's marine area. Marine Pollution Bulletin 100, 673–680.

Beyer, J., Jonsson, G., Porte, C., Krahn, M.M., Ariese F. (2010). Analytical methods for determining metabolites of polycyclic aromatic hydrocarbon (PAH) pollutants in fish bile: A review. Environmental Toxicology and Pharmacology 30, 224–244.

Brooks, S., Lyons, B., Goodsir, F., Bignell, J., Thain, J. (2009). Biomarker responses in mussels, an integrated approach to biological effects measurements. Journal of Toxicology and Environmental Health Part A 72, 196-208.

Costa, P.M., Diniz, M.S., Caeiro, S., Lobo, J., Martins, M., Ferreira, A.M., Caetano, M., Vale, C., DelValls, T.A., Costa, M.H. (2009). Histological biomarkers in liver and gills of juvenile Solea senegalensis exposed to contaminated estuarine sediments: A weighted indices approach, Aquatic Toxicology 92, 202-212.

Davies, I.M., Vethaak, A.D. (2012). Integrated monitoring of chemicals and their effects. ICES Cooperative Research Report No. 315. 227pp.

Hinton, D.E., Lauren, O.J., (1990). Liver structural alterations accompanying chronic toxicity in fishes: potential biomarkers of exposure. In: (McCarthy, J.F., & Shugart, L.R. eds) Biomarkers of environmental contamination. Lewis Publishers, MI. pp.12-68.

Hinton, D.E., Baumen, P.C., Gardener, G.C., Hawkins, W.E., Hendricks, J.D., Murchelano, R.A., Okhiro, M.S., (1992). Histopathological biomarkers. In: (Huggett, R.J., Kimerle, R.A., Mehrle, P.M., & Bergman, H.L. eds) Biomarkers: biochemical, physiological and histological markers of anthropogenic stress. Lewis Publishers, MI. pp.155-210.

Hutchinson, T.H., Lyons, B.P., Thain, J.E., Law, R.J. (2013). Evaluating legacy contaminants and emerging chemicals in marine environments using adverse outcome pathways and biological effects-directed analysis. Marine Pollution Bulletin, 74 (2), 517-525.

Lyons, B.P., Stewart, C., Kirby, M.F., (1999). The detection of biomarkers of genotoxin exposure in the European flounder Platichthys flesus collected from the River Tyne Estuary. Mutation Research 446, 111–119.

Lyons B.P., Barber J.L, Rumney, H.S., Bolam. T.P.C., Bersuder, P., Law, R.J., Mason, C., Smith, A, Morris, S, Devlin, M.J., Al-Enezi, M., Massoud, M.S., Al-Zaidan, A., Al-Sarawi, H.A. (2015). Baseline survey of marine sediments collected from the State of Kuwait: PAHs, PCBs, brominated flame retardants and metal contamination. Marine Pollution Bulletin 100 (2), 629-636.

Moore, M.N., Simpson, M.G., (1992). Molecular and cellular pathology in environmental impact assessment. Aquatic Toxicology 22, 313-322.

Myers, M. S., Johnson, L. L., Hom, T., Collier, T. K., Stein, J. E. and Varanasi, U. (1998). Toxicopathic hepatic lesions in subadult English sole (Pleuronectes vetulus) from Puget Sound, Washington, USA: Relationships with other biomarkers of contaminant exposure. Marine Environmental Research 45, 47-67.

Oliva, M., Vicente-Matorell, J.J., Galindo- Riaño, M.D., Perales, J.A. (2013). Histopathological alterations in Senegal sole, Solea Senegalensis, from a polluted Huelva estuary (SW, Spain). Fish Physiology and Biochemistry 39, 523-545.

Stehr, C. M., Myers, M. S., Johnson, L. L., Spencer, S. and Stein, J. E. (2004). Toxicopathic liver lesions in English sole and chemical contaminant exposure in Vancouver Harbour, Canada. Marine Environmental Research 57, 55 - 74.

Stentiford, G.D., Bignell, J.P., Lyons, B.P., Thain, J.E., Feist, S.W. (2010). Effect of age on liver pathology and other diseases in flatfish: Implications for assessment of marine ecological health status. Marine Ecology Progress Series 411, 215-230.

Stentiford, G.D., Massoud, M.S. Al-Mudhhi, S., Al-Sarawi, M.A. Al-Enezi, M., Lyons, B.P. (2014). Histopathological survey of potential biomarkers for the assessment of contaminant related biological effects in species of fish and shellfish collected from Kuwait Bay, Arabian Gulf. Marine Environmental Research 98, 60-67.

Vethaak, A.D., Jol, J.G., Pieters, J.P.F., (2009). Long-term trends in the prevalence of cancer and other major diseases among flatfish in the southeastern North Sea as indicators of changing ecosystem health. Environmental Science and Technology 43, 2151-2158.

11.5.5 Environmental biota

Al-Majed N.B., Preston, M.R. (2004). The distribution and inventory of total and methyl mercury in Kuwait Bay. Marine Pollution Bulletin 49, 930-937.

Allchin, C.R., Law, R.J., Morris, S. (1999). Polybrominated diphenylethers in sediments and biota downstream of potential sources in the UK. Environmental Pollution 105, 197-207.

Beg, M.U., Gevao, B., Al-Jandal, N., Beg, K.R., Butt, S.A., Ali, L.N., Al-Hussaini, M. (2009). Polycyclic aromatic hydrocarbons in three varieties of fish from Kuwait Bay. Polycyclic Aromatic Compounds 29, 75-89.

Bu-Olayan, A.H., Al-Hassan, R., Thomas, B.V. (2001a). Trace metal toxicity to phytoplankton of Kuwait Coastal Waters. Ecotoxicology 10, 185-189.

Bu-Olayan, A.H., Al-Hassan, R., Thomas, B.V., Subrahmanyam, M.N.V. (2001b). Impact of trace metals and nutrient levels on phytoplankton from the Kuwait Coast. Environment International 26, 199-203.

Bu-Olayan A.H., Subrahmanyam M.N.V. (1997). Accumulation of copper, nickel, led and zinc by snail, Lunella coronatus and pearl oyster, Pinctada radiate from Kuwait coast before and after the gulf war oil spill. The Science of the Total Environment 197, 161-165.

Bu-Olayan A.H., Subrahmanyam M.N.V., Al-Sarawi, M. Thomas, B.V. (1998). Effects of the Gulf War oil spill in relation to trace metals in water, particulate matter and PAHs from the Kuwaiti coast. Environment International 24, 789-797.

Bu-Olayan A.H. and Thomas, B.V. (2001). Heavy metal accumulation in the gastropod Cerithium scabridum L., from the Kuwait coast. Environmental Monitoring and Assessment 68, 187-195.

Bu-Olayan, A.H., Thomas, B.V., (2004). Effects of trace metals, harmful algal blooms, nutrients and hydrological variables to mullet Liza klunzingeri in Kuwait Bay. Biosciences Biotechnology Research Asia 2, 1-8.

Bu-Olayan A.H., Thomas, B.V. (2014). Dispersion model and bioaccumulation factor validating trace metals in sea bream inhabiting wastewater drain outfalls. International Journal of Environmental Science and Technology 11, 795–804.

de Mora, S., Tolosa, I., Fowler, S. W., Villeneuve, J-P., Cassi, R., Cattini, C. (2010). Distribution of petroleum hydrocarbons and organochlorinated contaminants in marine biota and coastal sediments from the ROPME sea area during 2005. Marine Pollution Bulletin 60, 2323-2349.

Gevao, B., Jaward, F.M., Al-Bahloul, M., Mirza S., Beg, U., Zafar, J. (2011). Polybrominated Diphenyl Ethers in Three Commercially Important Fish from the Northwestern Arabian Gulf: Occurrence, Concentration, and Profiles. Archives of Environmental Contamination and Toxicology 60, 636-642.

Hale R.C., La Guardia M.J., Harvey E.P., Mainor T.M., Duff W.H., Gaylor M.O. (2001) Polybrominated diphenyl ether flame retardants in Virginia freshwater fishes (USA). Environmental Science and Technology 35, 4585–4591.

Naser, H.A., 2013. Assessment and management of heavy metal pollution in the marine environment of the Arabian Gulf: a review. Marine Pollution Bulletin 72, 6–13.

Tarique, Q., Burger, J., Reinfelder, J. (2012). Metal Concentrations in Organs of the Clam Amiantis umbonella and Their Use in Monitoring Metal Contamination of Coastal Sediments. Water Air and Soil Pollution 223, 2125-2136.

Tarique, Q., Burger, J., Reinfelder, J. (2013). Relative Importance of Burrow Sediment and Porewater to the Accumulation of Trace Metals in the Clam Amiantis umbonella. Archives of Environmental Contamination Toxicology 65,89–97.

11.6 Costal Processes

Al-Abdulghani, E., El-Sammak A. and Sarawi, M. (2013): Environmental assessment of Kuwait Bay: an integrated approach. J. Coast Conserv. DOI 10.1007/s11852-013-0242-7

Ali Dinar Abdullah, Ilyas Masih, Pieter Van Der Zaag, Usama F.A. Karim, Ioana Popescu & Qusay Al Suhail (2015): Shatt al Arab River system under escalating pressure: a preliminary exploration of the issues and options for mitigation, International Journal of River Basin Management, DOI: 10.1080/15715124.2015.1007870

A. Al-Marzouk, K. Duremdez, Y. Sameer, H. Al-Gharabally, and B. Munday, 2005: Fish kill of mullet Liza klunzingeri in Kuwait Bay: The role of Streptococcus agalactiae and the influence of temperature,‖ in Diseases in Asian Aquaculture, P. Walker, R. Lester, and M. G. Bondad-Reantaso, Eds. pp. 143-153, Manila.

Al-Mutairi, N., Abahussain, A. and Al-Battay, A. (2014): Environmental Assessment of Water Quality in Kuwait Bay. International Journal of Environmental Science and Development, Vol. 5, No. 6: 527-532

Al-Osairi, Y. (2011): Hydro-Environmental modelling of the Arabian Gulf and Kuwait Bay. MSc. Thesis Cardiff University.

Anderlini C, Jacob C, Lee W (1982) Atlas of physical and chemical oceanographic characteristics of Kuwait Bay, Final report of the oceanographic data project. Kuwait Institute for Scientific Research, Report No. KISR704, pp 15–66

Al-Banaa, K., Rakha, K., 2009. Seasonal Variability of Temperature Measurements in Shallow Bay. Journal of Coastal Research SI 56: 782-786.

Al-Ghadban, A.N., El-Sammak, A. 2005. Sources, distribution and composition of the suspended sediments, Kuwait Bay, Northern Arabian Gulf, Journal of Arid Environments 60-4, 647-661

Álvarez-Romero, J.G., Devlin, M., da Silva, E.T., Petus, C., Ban, N.C., Pressey, R.L., Kool, J., Roberts, J.J., Cerdeira-Estrada, S., Wenger, A.S. and Brodie, J., 2013. A novel approach to model exposure of coastal-marine ecosystems to riverine flood plumes based on remote sensing techniques. Journal of environmental management, 119, pp.194-207.

Al-Yamani, F. (2008): Importance of the freshwater influx from the Shatt-AlArab River on the Gulf marine environment. Protecting the Gulf’s Marine Ecosystems from Pollution Edited by A.H. Abuzinada, H.-J. Barth, F. Krupp, B. Böer and T.Z. Al Abdessalaam © 2008 Birkhäuser Verlag/Switzerland

Al-Yamani F, James B, Essa R, Al-Husaini M, Al-Ghadan A (2004) Oceanographic atlas of Kuwait’s waters. KISR publication, Kuwait, pp 81–191

Bacon, J.C. and Phillips, R. (2014): Rehabilitaion of Impacted Marine Areas in Kuwait. Cefas interim report: Numerical modelling of Kuwait Bay.

Saji Baby1, Mahendra S. Nathawat3 , Mohammad A. Al-Sarawi, 2013, Major Impacts from Anthropogenic Activities on Landscape Carrying Capacity of Kuwaiti Coast, Pol. J. Environ. Stud. Vol. 23, No. 1 (2014), 7-17)

Brandimarte, L., Popescu, I. and Neamah, K. (2015): Analysis of fresh-saline water interface at the Shatt Al-Arab estuary. Intl. J. River Basin Management Vol. 13, No. 1 (March 2015), pp. 17–25

Bower, A. S., H. D. Hunt, and J. F. Price (2000), Character and dynamics of the Red Sea and Persian Gulf outflows, J. Geophys. Res., 105(C3), 6387–6414, doi:10.1029/1999JC900297.

M.J. Devlin, M.S. Massoud, S.A. Hamid, A. Al-Zaidan, H. Al-Sarawi, M. Al-Enezi, L. Al-Ghofran, A.J. Smith, J. Barry , G.D. Stentiford, S. Morris, E.T. da Silva, B.P. Lyons (2015): Changes in the water quality conditions of Kuwait's marine waters: Long term impacts of nutrient enrichment. Marine Pollution Bulletin 100: 607–620

Elhakeem, A., Elshorbagy, W. and Bleninger, T. (2015): Long-term hydrodynamic modeling of the Arabian Gulf. Marine Pollution Bulletin.

ESRI, 2010. ArcGIS 10.0. Environmental Systems Research Institute (ESRI), Redlands, CA.

Fouad et al., 2016. Monitoring the Environmental Changes on Coasts and Islands in State of Kuwait. International Journal of Scientific and Engineering Research 7(5) · April 2016

Hassanzadeh , S., Hosseinibalam F. and Rezaei-Latif, A. (2011): Numerical modelling of salinity variations due to wind and thermohaline forcing in the Persian Gulf. Applied Mathematical Modelling, 35: 1512–1537

Isave, V.A. and Mikhailova, M.V., 2009. The hydrography, evaluation, and hydrological regime of the mouth area of the Shatt Al-Arab river. Water Resources, 36 (4), 402–417.

Jones, D. A., Clayton, D. (1983). The systematics and ecology of crabs belonging to the genera Cleistostoma DeHaan and Paracleistostoma DeMan on Kuwait mudflats. Crustaceana 45: 183-199

Kampf, J. and Sadrinasab, M., 2006. The circulation of the Persian Gulf: a numerical study. Ocean Sci., 2, 27–41.

Khana and Al-Sarawi. 1988. Kuwait. In Artificial Structures and Shorelines, edited by H. Jesse Walker, 1988.

Naser, H.A. 2014. Marine ecosystem diversity in the Arabian Gulf: Threats and conservation. In "Biodiversity - The Dynamic Balance of the Planet", book edited by Oscar Grillo, ISBN 978-953-51-1315-7, Published: May 14, 2014 297-327

Tanuspong Pokavanich and Yousef Alosairi (2014) Summer Flushing Characteristics of Kuwait Bay. Journal of Coastal Research: Volume 30, Issue 5: pp. 1066 – 1073.

K.A. Rakha, K. Al-Banaa, A. Al-Ragum, and S. Neelamani. Sediment budget for the Southern shoreline of Kuwait. uNKNOWN PAPER

Rakha, K.A., Al-Salem, K, Neelamani, S., 2007. Hydrodynamic atlas for Kuwaiti territorial waters. Kuwait Journal of Science & Engineering 34(1A): 143-156.

Rakha, K.A., Al-Banaa, K., Al-Hulail, F., 2010. Flushing characteristics of Kuwait Bay. Kuwait Journal of Science and Engineering 37(1A): 111-125.

Reynolds, M. 1993. Physical oceanography of the Gulf, Strait of Hormuz, and the Gulf of Oman: Results from the Mt. Mitchell Expedition. Marine Pollution Bulletin, 27: 35- 59

Saad, M.A.H. 1978: Seasonal variations of some physiochemical condition of Shatt-alArab estuary, Iraq, Estuarine and Coastal Marine Science, 6: 503–513.

Sadrinasab, M. and Poorkiani, K. (2011): A Three-dimensional Numerical Modeling of Contaminant

Dispersion from Arvand Rood River into the Persian Gulf. Journal of the Persian Gulf (Marine Science)/Vol. 2/No. 4/June 2011/7/19-26.

Tanuspong Pokavanich1 , Igor Polikarpov2 , Alan Lennox2 , Faisal Al-Hulail3 , Turki Al-Said2 , Eqbal AlEnezi4 , Faiza Al-Yamani2 , Nikolai Stokozov2 and Bassam Shuhaibar (2013). COMPREHENSIVE INVESTIGATION OF SUMMER HYDRODYNAMIC AND WATER QUALITY CHARACTERISTICS OF DESERTIC SHALLOW WATER BODY: KUWAIT BAY. Coastal Dynamics 2013.

Tanuspong Pokavanich, Yousef Alosairi, Reimer de Graaff, Robin Morelissen, Wilbert Verbruggen, Kholood Al-Refail, Altaf Taqi, Turki Al-Said, 2014. THREE-DIMENSIONAL HYDRO-ENVIRONMENT CHARACTERIZATION AND MODELING OF THE NORTHERN ARABIAN GULF. Coastal Engineering Proceedings.
DOI: http://dx.doi.org/10.9753/icce.v34.management.41

Tanuspong Pokavanich and Yousef Alosairi (2014) Summer Flushing Characteristics of Kuwait Bay. Journal of Coastal Research: Volume 30, Issue 5: pp. 1066 – 1073.

TAQI, A. ALOSAIRI Y.& POKAVANICH T. 2015- A NUMERICAL STUDY TO ASSESS THE EFFECT OF DESALINATION PLANT LOCATION IN KUWAIT BAY. E-proceedings of the 36th IAHR World Congress 28 June – 3 July, 2015, The Hague, The Netherlands.

Tapper, J. 2016. Think you're hot? Spare a thought for Kuwait, as mercury hits record 54C. The Guardian, The Observer. 23 July 2016. https://www.theguardian.com/uk-news/2016/jul/23/think-youre-hot-spare-a-thought-for-kuwait-as-mercury-hits-record-54c

Wright, J.L. 1974. A hydrographic and acoustic survey of the Persian Gulf, MSc Thesis, Nav. Postgrad. Sch., Monterey, California, USA.

https://www.dredgingtoday.com/2013/11/18/kuwait-subiya-dredging-project-underway/, accessed on 18/10/2016

https://www.dredgingtoday.com/2015/03/10/picture-of-the-day-athena-in-kuwait/, accessed on 18/10/2016

https://www.dredgingtoday.com/2016/08/30/van-oord-delivers-ground-improvement-project-in-kuwait/, accessed on 18/10/2016

11.7 Noise

Cefas. 2015. Impacts of noise and use of propagation models to predict the recipient side of noise. Report prepared under contract ENV.D.2/FRA/2012/0025 for the European Commission. Centre for Environment, Fisheries & Aquaculture Science, UK. 27 pp.

Dekeling, R., Tasker, M., Van der Graaf, A. J., Ainslie, M., Andersson, M., André, M., Castellote, M., et al. 2014. Monitoring Guidance for Underwater Noise in European Seas. JRC Scientific and Policy Report EUR 26557 EN, Publications Office of the European Union, Luxembourg, 2014.

Erbe, C., Williams, R., Sandilands, D., and Ashe, E. 2014. Identifying modeled ship noise hotspots for marine mammals of Canada’s Pacific region. PloS one, 9: e89820.

Evans, D. L., and England, G. R. 2001. Joint interim report Bahamas marine mammal stranding event of 15-16 March 2000. US Department of Commerce, US Secretary of the Navy: 59.

Govoni, J. J., Settle, L. R., and West, M. A. 2003. Trauma to Juvenile Pinfish and Spot Inflicted by Submarine Detonations. Journal of Aquatic Animal Health, 15: 111–119.

National Research Council. 2005. Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects. National Academies Press, Washington, DC, USA.

Picciulin, M., Sebastianutto, L., Codarin, A., Farina, A., and Ferrero, E. A. 2010. In situ behavioural responses to boat noise exposure of Gobius cruentatus (Gmelin, 1789; fam. Gobiidae) and Chromis chromis (Linnaeus, 1758; fam. Pomacentridae) living in a Marine Protected Area. Journal of Experimental Marine Biology and Ecology, 386: 125–132.

Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D. A., Bartol, S., Carlson, T. J., Coombs, S., et al. 2014. ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards committee S3/SC1 and registered with ANSI. American National Standards Institute. 87 pp.

Rolland, R. M., Parks, S. E., Hunt, K. E., Castellote, M., Corkeron, P. J., Nowacek, D. P., Wasser, S. K., et al. 2012. Evidence that ship noise increases stress in right whales. Proceedings of the Royal Society B: Biological Sciences, 279: 2363–8.

Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C., and Popper, A. N. 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. Trends in Ecology & Evolution, 25: 419–27.

Southall, B., Bowles, A., Ellison, W., Finneran, J. J., Gentry, R., Greene, C. R. J., Kastak, D., et al. 2007. Marine mammal noise-exposure criteria: initial scientific recommendations. Aquatic Mammals, 33: 411–521.

Weilgart, L. S. 2007. A brief review of known effects of noise on marine mammals. International Journal of Comparative Psychology, 20.

11.8 Climate change

AGEDI (2015a) Regional Ocean Modeling for the Arabian Gulf Region-Future Scenarios and Capacity Building. LNRCCP. CCRG/USP.

AGEDI (2015) Regional Atmospheric Modeling for the Arabian Gulf Region- Future Scenarios and Capacity Building. LNRCCP. NCAR/CCRG

Al Senafi, F., Anis, A. (2015) Shamals and climate variability in the Northern Arabian/Persian Gulf from 1973 to 2012.

Baunam, A.G., Pratchett, M.S., Baird, A.H., Riegi, B., Heron, S.F., Feary, D.A. (2013) Variation in the size structure of corals is related to environmental extremes in the Persian Gulf. Marine Environmental Research 84: 43-50.

Cavalcante, G.H., Feary, D.A., Burt, J.A. (2016) The influence of extreme winds on coastal oceanography and its implications for coral population connectivity in the southern Arabian Gulf. Marine Pollution Bulletin 105: 489-497.

Hall-Spencer, J.M., Rodolfo-Metalpa, R., Martin, S., Ransome, E., Fine, M., Turner, S.M., Rowley, S.J., Tedesco, D., Buia, M.-C. (2008) Volcanic carbon dioxide vents show ecosystem effects of ocean acidification. Nature 454: 96-99.

IPCC (2014) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 688 pp.

Koslow, J.A., Goericke, R., Lara-Lopez, A., Watson, W. (2011) Impact of declining intermediate-water oxygen on deepwater fishes in the California Current.

Marine Ecology Progress Series 436: 207-218.

LNRCC Research Report. Marine Biodiversity & Climate Change. Draft Visualizations from AGEDI's Local, National, and Regional Climate Change Programme.

Matear, R. J. & Hirst, A. C. (2003). Long-term changes in dissolved oxygen concentrations in the ocean caused by protracted global warming. Global Biogeochemical Cycles 17:1125.

Townhill, B.L., Pinnegar, J.K., Righton, D.A., Metcalfe, J.D. (2016) Fisheries, low oxygen and climate change: how much do we really know? Journal of Fish Biology (2016) doi:10.1111/jfb.13203.

Weeks, S.J., Currie, B., Bakun, A. (2002) Satellite imaging: massive emissions of toxic gas in the Atlantic. Nature 415: 493-494.

11.9 Marine Litter

Khordagui, H.K. & Abu-Hilal, A.H. Water Air Soil Pollut (1994) 76: 343. doi:10.1007/BF00482711

Claereboudt MR1. (2004) Shore litter along sandy beaches of the Gulf of Oman. Mar Pollut Bull. Nov;49(9-10):770-7.

Castillo A.B., Al-Maslamani I., Obbard J.P. (2016) Article in Press: Prevalence of microplastics in the marine waters of Qatar. Mar Pol Bul

Todorova, V. (2011, July 31). http://www.thenational.ae/news/uae-news/environment/sharjah-landfills-bulge-with-plastic-water-bottles

Rodwan, J. (2011). Bottled Water 2011. http://www.bottledwater.org/economics/industry-statistics

The National. (2013, January 21). The National. http://www.thenational.ae/news/uae-news/environment/uae-uses-fewer-plastic-bags-but-shoppers-still-go-through-11bn-a-year#ixzz2RxyWrwe7

Bee'ah. (2010). Sustainability Report 2010. Bee'ah-UAE: http://www.beeah-uae.com/sites/default/files/Beeah_Sustainability%20Report%202010%20(LR).pdf

National Bureau of Statistics UAE. (n.d.). UAE in figures – 2001 and 2009. http://www.uaestatistics.gov.ae/PublicationEN/tabid/187/Default.aspx?MenuId=2

Yousef, D. (2011, December 18). Petrol to plastics: Bagging the future. GulfNews: http://gulfnews.com/business/general/petrol-to-plastics-bagging-the-future-1.952591

Time. (2013). The Global Warming Survival Guide. http://www.time.com/time/specials/2007/environment/article/0,28804,1602354_1603074_1603179,00.html

MoEW. (2013). http://www.moew.gov.ae/portal/en/search.aspx

California Coastal Commission. (2012, June 20). Public Education Program. http://www.coastal.ca.gov/publiced/marinedebris.html

Science for Environment Policy. (2011, November). Plastic Waste: Ecological and Human Health Impacts. http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR1.pdf

Salma, S. (2013, March 3). UAE bans non-biodegradable plastic products. GulfNews: http://gulfnews.com/news/gulf/uae/environment/uae-bans-non-biodegradable-plastic-products-1.1153432

Baldwin, D. (2013, April 23). Dubai Municipality launches campaign to slash 500m plastic bags. GulfNews: http://gulfnews.com/news/gulf/uae/environment/dubai-municipality-launches-campaign-to-slash-500m-plastic-bags-1.1174280

Bee'ah. (2013). http://www.beeah-uae.com/about-us

Emirates247 (16th September, 2013). 50 per cent of camels that die in UAE are due to ingesting plastics (http://www.emirates247.com/news/emirates/50-per-cent-of-camels-that-die-in-uae-are-due-to-ingesting-plastics-2013-09-16-1.521152)