ENVIRONMENTAL PERFORMANCE INDEX FOR ABU DHABI EMIRATE

FINAL REPORT

2 APRIL 2009

Prepared by: AGEDI – Abu Dhabi Global Environmental Initiative

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LIST OF ACRONYMS

GENERAL ACRONYMS:

AD	Abu Dhabi
ADE	Abu Dhabi Emirate
ADEG	Abu Dhabi Environment Group
AD-EPI	Abu Dhabi Environmental Performance Index
ADWC	Abu Dhabi Waste Management Center
ADWEA	Abu Dhabi Water and Electricity Authority
AGEDI	Abu Dhabi Global Environment Initiative Data
APHA	American Public Health Association
CAS	American Chemical Society
CBD	United Nations Convention on Biological Diversity
CDM	Clean Development Mechanism
CEE	India Center for Environment Education
CIESIN	Center for International Earth Science Information Network
CLRTPA	Convention on Long-Range Transboundary Air Pollution
COPs	Conference of Parties
DESD	Decade of Education for Sustainable Development (UN Resolution)
EAD	Environment Agency of Abu Dhabi
EDGAR	Emission Database for Global Atmospheric Research
EEA	European Environment Agency
EEPPS	Emirate Environment Health and Safety Protection Policies
EEZ	Exclusive Economic Zone
EHSMS	Environment Health Safety Management System of Abu Dhabi
EIM	Emirates Internet and Multimedia
ENHG	Emirates Natural History Group
EPA	United States Environmental Protection Agency
EPI	Environmental Performance Index
ERWDA	Environmental Research and Wildlife Development Agency
EUROSTAT	Statistical Office of the European Communities

EWS	Emirates Wildlife Society
FAO	Food and Agricultural Organization
FEA	United Arab Emirates Federal Environmental Agency
GIS	Geographic Information System
GLASOD	Global Assessment of Human Induced Soil Degradation
GPS	Global Positioning System
GTZ	German Agency for Technical Cooperation
GWA	Groundwater Assessment
GOW	Groundwater Observation Well
GWAP	Groundwater Assessment Study (EAD)
HAAD	Health Authority of Abu Dhabi
IAEA	International Atomic Energy Agency
IAH	International Association of Hydrogeologists
ICBA	International Center for Biosaline Agriculture
ICEE	Indian Council for Economic Education
ICP	European International Cooperative Program
IEEP	International Environmental Education Programme (UNESCO - UNEP)
IGRAC	International Groundwater Resources Assessment Center
IHP	International Hydrologic Programme
IPCC	Intergovernmental Panel on Climate Change
IPCC-AR4	Intergovernmental Panel on Climate Change Fourth Assessment
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management Programme (United Nations)
LADA	Land Degradation Assessment in Dry Lands (FAO)
MERC	Marine Environment Research Center of Abu Dhabi
MMPA	MERC Marine Protected Areas of Abu Dhabi
NAAQS	National Ambient Air Quality Standards
NDC	National Drilling Company (USGS)
OECD	Organization for Economic Cooperation Development R
CRA	Resource Conservation and Recovery Act (EPA)
SAICM	Strategic Approach to International Chemicals Management
SBS	Sick Building Syndrome

SoE	State of the Environment
TNC	The Nature Conservancy
UAE	United Arab Emirates
UNCCD	United Nations Convention to Combat Desertification
UNECE	United Nations Economic Commission for Europe
GEMS	United Nations Environment Programme, Global Environment Monitoring System
UNEP	United Nations Environmental Programme
GLCN	UNEP - Global Land Cover Network
GRID	UNEP - Global Resource Information Database
UNESCO	United Nations Educational Scientific and Cultural Organizational
UNFCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WFD	Water Framework Directive
WHO	World Health Organization
AQG	WHO - Air Quality Guidelines
WISE	Water Information System for Europe
WWAP	World Water Assessment Programme
WWF-UAE	World Wide Fund for United Arab Emirates

TECHNICAL ACRONYMS:

AOT40	Accumulated Exposure Over a Threshold of 40ppb
BOD	Biological Oxygen Demand
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CFCs	Chlorofluorocarbons
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO2	Carbon Dioxide
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen

GDP	Gross Domestic Product
GHG	Greenhouse Gas
HCFCs	Hydrochlorofluorocarbons
IDW	Inverse Distance Weighting
MOZART-2	Model for Ozone And Related Chemical Tracers version 2
NMHC	Non-Methane HydroCarbons
NO2	Nitrogen Dioxide
NOx	Nitrogen Oxides
O3	Ozone
PM10	Particulate Matters of 10 micrometers or less
PM2.5	Particulate Matters of 2.5 micrometers or less
POP	Particulate Organic Phosphate
Sea-WiFS	Sea Wide Field-of-View Sensor
SO2	Sulfur Dioxide
TDS	Total Dissolved Solids
UV	Ultraviolet
VOC	Volatile Organic Compounds

INDICATOR ACRONYMS:

CCC	Chlorophyll a concentrations
DALY	Disability Adjusted Life Year
FiB	Fishing in Balance
FRS	Fishing Resource Status
GWL	Groundwater Level
GWS	Groundwater Salinity
HABPROT	Habitat Protection
MTI	Marine Trophic Index
PM10	Particulate Matter
SBR	Spawning Biomass Per Recruit
TMS	Status of Threatened Marine Species
U5MR	Under 5 Mortality Rate
WPC	Water Consumption per Capita
WSI	Water Stress Index

EXECUTIVE SUMMARY

Data and indicators are increasingly critical for environmental policy making. Without them it is impossible to measure progress towards policy goals. The Environmental Performance Index (EPI), developed by a CIESIN at Columbia University and the Yale Center for Environmental Law and Policy, represents one approach to measure progress towards established policy targets. This report provides the results of an effort, begun in July 2008, to apply the EPI methodology to environmental issues that are established priorities for the Environment Agency of Abu Dhabi (EAD).

The report was developed in close consultation with EAD staff and the Abu Dhabi Global Environmental Data Initiative (AGEDI). The purpose is to provide a tool for assessing progress towards established targets, for priority setting, and potentially for resource allocation. The EPI framework groups indicators in two main policy objective areas, Environmental Health and Ecosystem Vitality, and then in a number of policy categories under them. The Abu Dhabi EPI has identified nine categories related to policy priorities and strategic plans. Raw data for each indicator are transformed into a proximity to target score from 0 (lowest possible) to 100 (highest possible). The main conclusions of this effort are as follows:

- There are a number of issue areas identified as important priorities for the Emirate that have insufficient data, or data in the wrong kinds of formats, to be useful for measuring proximity to targets.
- Owing to its scarce water resources, Abu Dhabi has significant challenges in water consumption, and in 67% of its territory is experiencing annual declines in water tables of greater than 0.2m. Abu Dhabi's domestic consumption is above the per-capita levels of many water-rich European countries, so the Emirate has considerable potential for reducing water use.
- The Emirate's population is exposed to very high concentrations of particulate matter, with a proximity to target score of 41.86 out of 100. On the other hand, ozone concentrations during non-summer months (excluding June-August) are generally acceptable, and do not pose a risk to human health.
- In terms of protected areas coverage for terrestrial habitats, the Emirate is nearly one-third of the way towards the target of 12% protection across all habitats
- Marine water quality in the coastal zone, as measured by chlorophyll-a concentrations, in 2007 declined to its lowest levels in a 10-year time series.
- Abu Dhabi's fisheries have actually improved slightly in the past few years as measured by the trophic level at which fishing is taking place. Fish stocks of two large fish have improved, but one has declined.

This report points out a number of the data gaps which remain to be filled in order to construct an aggregated index or an annual or bi-annual EPI report that would allow the EAD to track progress towards major targets.

Lastly, a number of innovative measures were developed in this report, some of them in close collaboration with EAD experts. The details of the indicator construction are contained in the technical annex.

INTRODUCTION

PURPOSE OF ENVIRONMENTAL PERFORMANCE INDICATORS

Environmental policymakers are increasingly integrating rigorous data-driven and quantitative approaches into the priority-setting process and methods to tracking progress. Data collection and performance indicators are fully integrated in decision-making processes of other branches of government such as economic and fiscal policy, health systems, and education. Their application to environmental policy has lagged for a number of reasons, including the relatively late emergence of government agencies charged with environmental management and inadequate investment in environmental monitoring. However, as the awareness of environmental degradation and related problems has gained the attention of national governments and increased in international prominence, so have efforts to collect data and to monitor environmental changes.

The 2008 global Environmental Performance Index (EPI) brings a data-driven, fact-based empirical approach to environmental protection and global sustainability (Esty et al., 2008). The EPI is based on the assumption that quantitative, comparative data allow for performance benchmarking and tracking of progress toward targets, while spurring competition to improve environmental conditions (Esty, 2002). By design, the global EPI addresses environmental issues at the national scale. While aggregated, composite indices at the national level provide an overview of a country's environmental performance as compared to that of peers, the EPI has a number of limitations for national or sub-national scales of analysis. It largely fails to reflect spatially differentiated conditions within large countries that have diverse environmental conditions, it is not tailored to the needs of individual countries that may be facing a particular set of environmental challenges, and it does not reflect national or sub-national environmental policy priorities. In Abu Dhabi, hyper-arid climate conditions generate a unique set of environmental conditions. Particularities in natural conditions suggest a need to refine the EPI calculation methodology to be sensitive to different climatic limitations as well as being adapted to support specific national targets. This process also identifies ways that the Government of Abu Dhabi can improve their data collection around a variety of environmental sectors.

This paper provides an analytical framework for an Emirate-level analysis of environmental performance indicators that can provide the Environment Agency- Abu Dhabi (EAD) and its partners with a concise and relevant management tool to support the Emirate's own strategic goals and policy objectives.

Any multi-issue environmental performance measurement system can be characterized largely in terms of how it achieves two core functions: specifying an architecture that identifies constituent high-priority issues; and calculating metrics on a common scale. The Ecological Footprint, for example, is based on an architecture that includes resources that are related to natural resource consumption but omits non-consumption issues such as pollution and waste management. The metric it relies on is land area associated with the consumption processes. Green GDP or Environmental Accounts are based on architectures that include environmental assets that are commercially exploited. The metric they rely on is economic value expressed in units of currency. The EPI, by contrast, relies on an architecture that incorporates all high-priority issues, including resource consumption, depletion of environmental assets, pollution, waste management, species loss, and so on.

It is flexible enough to incorporate almost any issue deemed to be a high priority, for example environmental values and education. It is able to be flexible in this regard because the metric it relies on is proximity to target, as opposed to land area or economic value.

None of these three approaches is uniformly superior to the others. They function best in complement to each other.

ABU DHABI MEASUREMENT AND DECISION TOOLS

ROLE OF AD EPI WITHIN THE EAD STAKEHOLDER COMMUNITY

Modern industrial societies are under increasing pressure to document the environmental dimensions of their activities. Requirements from multilateral environmental treaties and specialized agencies of the United Nations are growing in number and complexity. Non-governmental reporting initiatives such as the Ecological Footprint and Environmental Performance Index are adding to the information requirements. In addition to these external pressures, there are increasing demands within Abu Dhabi for environmental information.

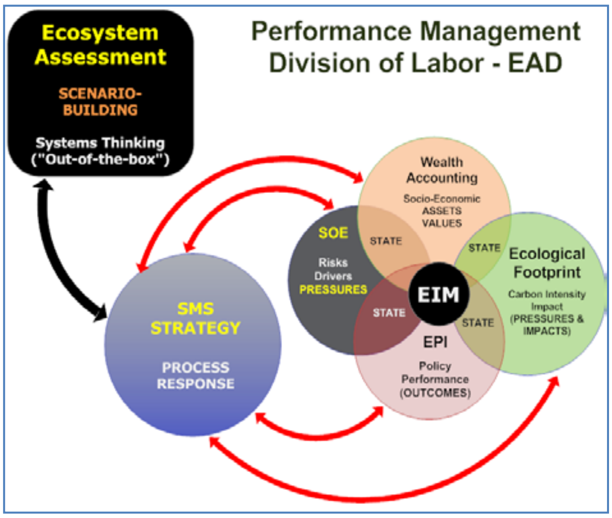


Figure 1: Performance Management Division of Labor within the Environmental Agency of Abu Dhabi Emirate

Such information is critical for state of the environment reporting, for sector strategy processes, and for long-term sustainability planning. Accordingly, it is crucial that these various monitoring and reporting initiatives build from a common information base that is comprehensive, robust and responsive. These needs have been taken into account in evaluating candidate indicators in this report.

PROJECT OBJECTIVES

The EPI pursues two overarching environmental objectives: reducing environmental stresses to human health; and promoting ecosystem vitality and sound natural resource management. These two objectives are achieved by improving performance in nine specified policy categories related to a core set of environmental policy goals. When indicators for Abu Dhabi are available in all categories, they will be aggregated to produce an overall score for the Abu Dhabi Environmental Performance Index (AD-EPI). The current pilot effort incorporates the same proximity-to-target methodology as the global EPI, but because of indicator gaps, does not attempt to aggregate results into an overall index.

2008 AD-EPI SCOPE AND PROCESS

A conceptual framework was developed through an iterative process between EAD experts and CIESIN. The process was initiated at the Environmental Performance Indicators Workshop held during July 28-30, 2008 in Abu Dhabi city, where CIESIN described the EPI approach to a group of international experts, AGEDI consultants and EAD staff. The workshop was followed by a detailed evaluation of the environmental related geospatial and tabular data available at EAD, carried out by CIESIN in collaboration with the AGEDI/EIM team throughout the months of September and October, 2008. The results of this evaluation, and additional interviews with EAD issue area experts further refined the AD-EPI conceptual framework, and identified data availability and gaps for each proposed indicator (see Annex A). Information gathered during this exercise lead to a refined Scope of Work outlining the deliverable feasible within the 2008 program. The first efforts of data collection effort, analysis, descriptive background papers and progress towards targets were discussed in a new meeting between AGEDI/EIM, CIESIN and EAD held in November, 2008. Following this meeting, CIESIN began processing the available data and write up the descriptive reports of environmental performance areas measured, with assistance and advice from EAD and regional experts.

AD-EPI CONCEPTUAL FRAMEWORK

The EPI focuses on measureable outcomes that can be linked to policy targets and tracked over time. The index builds from two core objectives:

- reducing environmental stress to human health; and
- protecting ecosystems and natural resources

With the help of expert advice, available reports outlining the EAD priorities and the global EPI, we identified nine key policy categories, related subcategories and specific issues within these two core objectives, which are presented in detail in Annex A of this report.

INDICATOR SELECTION AND TARGETS

For each indicator developed, CIESIN has identified a relevant long-term public health or ecosystem sustainability goal to guide measurement of performance. These targets are drawn from EAD policy documents, internationally agreed upon goals, standards set by international organizations, leading national regulatory goals, or consensus from scientific experts. Priority was given to strategic goals and targets set within Abu Dhabi. Each indicator target is sensitive to local conditions and particularities, such as naturally occurring high levels of particulate matter. Where necessary, CIESIN worked with EAD experts to align international agreed upon target levels with local conditions and government policies.

The indicators use proximity-to-target values calculated based on the distance of the current results to the identified policy target. Each indicator is measured on within a range of 0 to 100. An effort was made to explain and identify discrepancies between Abu Dhabi target levels and those used by the international community or the Global EPI.

Indicators are sought that cover the full spectrum of issues presented within the policy categories.

DATA GAPS AND DATA COVERAGE

Availability of data remains a serious obstacle for aligning policy priorities with reliable performance measures in Abu Dhabi. This year's EPI builds upon the best environmental data available for the identified nine categories although there remains some data gaps.

Several of the categories are close to integration into the next iteration of the Abu Dhabi EPI. For instance, environmental education and waste management are close to completing data collection and compilation and have several proposed indicators. Categories such as water resources have significant information, but missing data from the overall datasets are a source of uncertainty. This pilot effort can be used as a tool to identify data collection needs to help support the development and monitoring of policy areas. Figure 1 depicts in red some of the gaps in policy subcategories. More work is required to fill gaps in available information and data sets related to key policy areas.

Figure 2 Summary of Category Data and Policy Availability

<table>
<tr><th>Objectives</th><th>Categories</th><th>Sub-Categories</th><th>Category Design</th><th>Targets Identified</th><th>Baseline Data</th><th>Continued Measurements</th><th>Indicator Construction</th></tr>
<tr><td rowspan="6">Environmental Health</td><td rowspan="3">Human health, well-being and safety</td><td>Human health and safety</td><td>Need to choose how broadly to frame the category</td><td>No</td><td colspan="3">Gaps regarding worker safety and disaster risk</td></tr>
<tr><td>Water quality (effects on humans)</td><td>Yes</td><td colspan="4">No</td></tr>
<tr><td>Air quality (effects on humans)</td><td colspan="5">Yes</td></tr>
<tr><td>Waste control/reduction</td><td>Waste control/reduction</td><td colspan="2">Yes</td><td colspan="3">No</td></tr>
<tr><td>Cultural/aesthetic values/assets</td><td>Cultural/aesthetic values/assets</td><td colspan="5">No</td></tr>
<tr><td>Educational awareness</td><td>Educational awareness</td><td colspan="3">Yes</td><td colspan="2">No</td></tr>
<tr><td rowspan="3">Ecosystem Vitality</td><td>Air quality (effects on nature)</td><td>Air quality (effects on nature)</td><td colspan="4">Yes</td><td>Partial</td></tr>
<tr><td rowspan="2">Sustainable water resource management (effects on nature)</td><td>Water quantity</td><td colspan="2">Yes</td><td colspan="3">Inconsistent reporting</td></tr>
<tr><td>Water quality</td><td>Yes</td><td colspan="4">Partial</td></tr>
</table>

	Conservation/protection of ecosystem and natural living resources(biotic)	Habitat protection and effective conservation	Yes		No	Yes
		Species/Fauna protection and conservation	Yes		No	Yes
		Species/Flora protection and conservation	Yes	No		
		Productive Natural Resources	Need to choose how to take into account irrigation	Partial	Gap in vegetation cover, pecticide, and subsidizes	
		Ecosystem restoration and rehabilitation (Land use management)	No			
	Sustainable land use resources and land cover (abiotic)	Surface resources	Yes	No		
		Sub-surface resources	No			
	Climate vulnerability adaptation and mitigation	GHG emissions	Yes	Yes	No	
		Increased energy efficiency	No			
		Climate adaptation	No			
		Climate policy engagement	No			

ABU DHABI FRAMEWORK

The following provides the layout of the overall AD-EPI conceptual framework. This table also includes suggestions on future indicators associated with each category (cells in black).

April, 2009 AD-EPI

Future efforts

Figure 3. AD-EPI Framework and Results for Selected Indicators

Note: Proximity to target scores are measured on a 0 (lowest) to 100 (highest) scale.

INDEX	OBJECTIVE	EPI CATEGORY	EPI SUB-CATEGORY	INDICATOR	SCORE	YEAR	TARGET	POOR PERFORMANCE BENCHMARK	PROXIMITY TO TARGET SCORE
AD-EPI	Environmental Health	Human health, well-being and safety	Human health and safety	Environmental Burden of Diseases (DALY)					
				Under - 5 Mortality Rate (U5MR)	10.70	2007	3	84 (Easter Mediterranean average , 2006)	90.49
				Access to sanitation			100%		
				Occupational Health			0 persons injured		
				Vulnerability to natural disasters			0 persons at risk		

INDEX	OBJECTIVE	EPI CATEGORY	EPI SUB-CATEGORY	INDICATOR	SCORE	YEAR	TARGET	POOR PERFORMANCE BENCHMARK	PROXIMITY TO TARGET SCORE
			Water quality (effects on humans)	Quality of water for domestic consumption - Total Coliform, Faecal Coliform, Pathogens, POPs, Turbidity			100%		
			Air quality (effects on humans)	Particulate matter concentrations (PM10)	24.75	2007/08	0 exposure >150µg/m^3, 24h, population weighted	64.38 (the maximum monthly mean exceedance, July 2007)	61.55
				PM2.5					
				Ozone concentrations with effects on humans (OZONE_H)	0.00	2007/08	0 population exposure >200µg/m^3,	Not established	100
				SO2		2001	0 population exposure >350µg/m^3,		
				NO2		2001	0 population exposure >400µg/m^3, 1h		
				CO		2007/08	0 population exposure >30µg/m^3, 1h		
				Indoor Air Pollution					
		Waste control/reduction	Waste reduction	Change in Waste Generation(municipal, construction, hazardous, medical)			trend <=0		
				Total Municipal Waste			300kg/capita		

INDEX	OBJECTIVE	EPI CATEGORY	EPI SUB-CATEGORY	INDICATOR	SCORE	YEAR	TARGET	POOR PERFORMANCE BENCHMARK	PROXIMITY TO TARGET SCORE
				Generation/capita			(EEA, 2008)		
				Relative Recycling			25%		
				Ratio of waste generated to waste treatment			1		
			Waste control	Marine dumping violations			0		
		Cultural/aesthetic values/assets	Cultural/aesthetic values/assets	Percent of Cultural Heritage Resources Protected			100%		
		Educational awareness	Educational awareness	Percent Awareness about Important Environmental Concerns (EDUC)	48.9	2008	100%	0%	48.9
			Attitudes and behaviors	Percent Behavior Change about Important Environmental Concerns(EDUC)	43.8	2008	100%	0%	43.8
	Ecosystem Vitality	Air quality (effects on nature)	Air quality (effects on nature)	Ozone concentrations with effects on ecosystems (crop cultivated areas) (OZONE_E)	50,942	2007/08	0 cumulative exceedance above 18,000 $\mu g/m^{3,}$ area weighted	The values are very high, so they currently represent the poor performance benchmarks	0
				Ozone concentrations with effects on ecosystems (forest plantations) (OZONE_E)	32,064	2007/08	0 cumulative exceedance above 30,000 $\mu g/m^{3,}$ area weighted	The values are very high, so they currently represent the poor performance benchmarks	0
				SO2 per vegetated areas		2001	0 exceedance above 5$\mu g/m^3$		

INDEX	OBJECTIVE	EPI CATEGORY	EPI SUB-CATEGORY	INDICATOR	SCORE	YEAR	TARGET	POOR PERFORMANCE BENCHMARK	PROXIMITY TO TARGET SCORE
				NO2 per vegetated areas		2001	0 exceedance above 3µg/m^3		
		Sustainable water resource management (effects on nature)	Water quantity	Groundwater level (GWL)	67.29	2003, 2007	0% area w/ decrease in water level >0.2m	100% decrease over the entire territory	32.71
				Water Consumption in Domestic Sector - WPC (liters/person/day)	697.63	2006	350 liters/person/year	698 (largest in the world)	0
				Water Stress Index –WSI (use as % of renewable resources)	261.96	2006	100	394 (highest annual value, 2002)	44.86
			Water quality	Groundwater Salinity – GWS (mg/liter)	55.00	2003, 2008	0% area w/ increase in salinity	100 (total areas with salinity measurements)	45.00
				Agriculture water quality index(Nutrients, Nitrogen, Phosphorus, Salinity, Chlorophyll A, Pathogens)			100		
				Municipal/Industrial Water quality index: BOD, COD, Heavy Metals(particularly in sediment)			100		
				Ecosystem Stability Water Quality Index: Temperature, pH – acidity, conductivity, major ions, oxygen, suspended solids, biodiversity			100		

INDEX	OBJECTIVE	EPI CATEGORY	EPI SUB-CATEGORY	INDICATOR	SCORE	YEAR	TARGET	POOR PERFORMANCE BENCHMARK	PROXIMITY TO TARGET SCORE
				Tourism and recreation: Parasites and Pathogens			100		
				Marine water quality		2004-07	100% compliance with objectives	0	
				Coastal Chlorophyll-a Concentration - CCC (µg/l)	1.58	1998-2007	1.29 µg/l	1.29µg/l	0
			Habitat Protection and Effective Conservation	Protected Area Conservation by Habitat – HABITPROT (% of habitat areas)	3.75	2008	12%	0%	31.25
			Species/Fauna protection and conservation	Evolution of Estimated Population of Threatened Species - TMS (Dugongs)	0.84 (ratio of 2004 to 2001 density)	2001, 2004	1	0	84
				Evolution of Estimated Population of Threatened Species – TMS (Marine Turtles)	0.68 (ratio of 2004 to 2001 density)	2001, 2004	1	0	68
			Species/Flora protection and conservation	Evolution of Threatened Species					
			Productive Natural Resources	Percent Increase in the Area of Citizen Farms	-0.56	2006	<=0% yearly expansion	23.54%(highest rate of change, 1986-2006)	100
				Forest areas expansion		trend<=0			
				Percent area with pesticide residue			0		

INDEX	OBJECTIVE	EPI CATEGORY	EPI SUB-CATEGORY	INDICATOR	SCORE	YEAR	TARGET	POOR PERFORMANCE BENCHMARK	PROXIMITY TO TARGET SCORE
				Annual agriculture and forestry subsidies			0		
				Marine Trophic Index (MTI)	0.01	2005 -08	slope >=0		100
				Relative Spawner Biomass per Recruit –SBR (Epinephelus coioides)	13.29%	2008	40%		33.23
				Relative Spawner Biomass per Recruit – SBR (Lethrinus nebulosus)	35.30%	2008	40%		88.25
				Relative Spawner Biomass per Recruit –SBR (Diagramma pictum)	8.60%	2008	40%		21.50
		Sustainable land use resources and land cover (abiotic)	Surface resources						
			Sub-surface resources						
		Climate vulnerability adaptation and mitigation	GHG emissions	GHG emissions by sector					
				Emissions Per capita					
			Energy efficiency						
			Climate adaptation						
			Climate policy engagement						

DATA AGGREGATION AND WEIGHTING

The calculated indicators are measured on a proximity-to-target scale ranging from 0 (lowest possible score) to 100 (highest possible score). Prior to calculating the indicator scores, we review the distribution of each indicator to prevent extreme values from skewing the aggregations.

This year's Abu Dhabi EPI does not aggregate any of the indicators. Various aggregation methods exist and require sensitivity to the purpose and nature of the specific project. The weighting of the global EPI is driven by specific global environmental goals, data constraints and judgments about the quality and policy importance of available indicators. For example, the global EPI weights the two main objectives of environmental health and ecosystem vitality equally, and within the environmental health objective, the environmental burden of disease indicator was given half the overall weight, even though there are five other indicators, because it is widely recognized as the most comprehensive measure of environmental health burdens. Careful discussions on weighting among relevant stakeholders will be required when Abu Dhabi's EPI has a more comprehensive set of indicators.

DOCUMENT STRUCTURE

This report is structured to present both the results and analysis of the available data collected by the EAD. The report details each of the nine categories, presenting background information on the status within Abu Dhabi, major policies and strategic goals, as well as relevance to the broader international agreements and best practices. Where indicators were calculated or could be recommended, they are summarized and linked to EAD objectives. The last section presents the results, conclusions and recommendations for future EPI projects. An annex provides detailed indicator profiles on the steps required to calculate the indicators.

THE ABU DHABI EPI CATEGORIES OVERVIEW

ENVIRONMENTAL HEALTH

IMPROVED HUMAN HEALTH, WELL-BEING AND SAFETY

General overview

Ecosystem services are closely intertwined with protecting human health and well-being. Policy-makers require accurate information on human health in order to carefully analyze challenges and understand casual complexity between human health symptoms and environmental influences. They also provide clarity on changing performance from past baseline levels. The World Health Organization estimates that 24% of the global disease burden and 23% of all deaths can be attributed to environmental factors (Pruss-Ustun 2006, 9).

There are several approaches used to analyze the relationship of these areas. The Millennium Environment Assessment presents health indicators as a subset of the different ways ecosystems impact well-being (Hassan 2005, 54). The WHO guideline documents present disability adjusted life years (DALYs) attributable to environmental factors through complex relationships. Changes in the ecosystem create insecurity and present new health risks, raising instances of morbidity, non-communicable diseases, or potential physical threats from natural disasters. Therefore policy on health and ecosystems must consider interrelationships.

The EPI aims at measuring the core environmental performance indicators that are linked to potential human health risks.

HUMAN HEALTH POLICY REVIEW

OVERVIEW OF THE HUMAN HEALTH CATEGORY IN ABU DHABI EMIRATE

The rapid urbanization that has marked the growth in Abu Dhabi also creates new threats to public health. These concerns range from protecting the quality and quantity of water resources to preventing respiratory diseases caused by poor air quality to reducing risks in workplace and from natural hazards.

Abu Dhabi's population growth and changes in standards of living are reflected in the growing rate of per capita water use which far outpaces increases in available naturally recharged water supply. To compensate, large-scale desalination plants produce the majority of water for domestic consumption and agriculture. But the desalination process requires large energy inputs and releases air pollutants detrimental to human health. There is currently no clear pricing mechanism in Abu Dhabi to encourage efficiency of water use.

According to the WHO/UNICEF Joint Monitoring Programme which tracks global progress towards achieving the Millennium Development Goals, the United Arab Emirates has 100% improved water and 98% improved sanitation (WHO/UNICEF, 2008). More than coverage rates, the population is at risk from the limited natural replenishment of water supplies.

In terms of air pollution, there is concern about the concentrations of NOx, SO2 and particulates (PM10, defined as all particles equal to and less than 10 microns in aerodynamic diameter). PM10 results from multiple sources including dust from crustal material, motor vehicles, and industrial sources. The oil and gas industry is the main source of air pollution, followed by the power and transportation sectors. Several cities and monitoring stations report pollutant levels exceeding nationally regulated levels. In addition, elevated ambient particulate concentrations, mainly due to soil erosion and strong wind patterns, are expected as the climate is generally hot and humid combined with strong winds (EAD, 2007).

Remedial efforts have centered on tracking and reducing industrial use of fossil fuels. But, given the high reliance on fossil fuels as an energy source and increasing energy demands, emissions are likely to increase. The electricity demand is projected to continue growing by between 4.6% and 7.3% per annum until 2015 (EAD 2007). High energy use is also linked to desalination technology, the primary source of domestic water supplies.

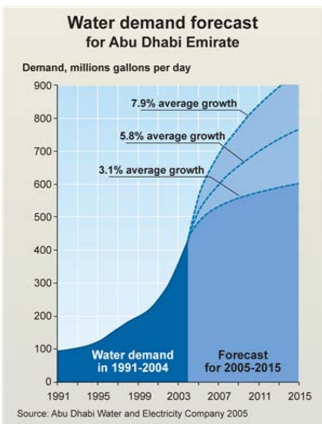
While there is a low risk to major natural disasters, potential for increased temperatures due to climate change poses risks to human health by contributing to photochemical smog and exacerbating the respiratory disease impacts of air pollution. This links closely to the climate change policy category.

Concerns over past unregulated dumping of solid and chemical waste poses threats to human health. Proper sanitation is the cornerstone for human health. Management of the various impacts involves the combined efforts of the Health Authority Abu Dhabi (HAAD), enforcement officials, and Department of Municipal Affairs. With little previous coordination, there is a need to improve practices that lead to harmful effects on human health.

EAD POLICY REVIEW PROCESS: PRIOR STATEMENTS, TARGETS AND STRATEGIC DIRECTIONS

The Environment, Health and Safety Management System (EHSMS) was created to integrate and coordinate the relevant components of health issues. This program developed for Abu Dhabi is intended to protect the environment and minimize hazards and risks to the health and safety of workers. The EAD and UAE's Federal Environmental Agency (FEA) have set specific targets for water quality levels through 2013 with a reduction of water salinity and nitrogen loading (EAD, 32). The goal of reducing demand – the average daily rate of consumption in Abu Dhabi currently published is 550 liters per person – will bring other benefits such as reducing groundwater salinity if extraction is limited. EAD has also targeted reductions in nitrate levels that are associated with fertilizers from farming and cause a health risk.

Figure 3 Water Demand Forecast



The Emirate Environment, Health and Safety Protection Policies (EEPPs), part of EHSMS, set management strategies to protect workers and citizens in areas related to air quality, noise, waste, hazardous materials, occupational health, and water resources.

In 2005 EAD gained responsibility for groundwater management, and in 2006 Law No. 6 enabled EAD to monitor and regulate groundwater drilling. The law set technical standards, established water conservation systems, and provided administrative methods for controlling waste water (EAD 2008, 25). For more information about water quality and quantity standards please refer to the Water Policy Paper (EAD, Effects on Nature).

Through a joint effort with the University of North Carolina, researchers are conducting a large study to explore the links between indoor air quality and health status as well as the impacts from changes in nutrition and rapid urbanization (DuBose, 2008). The analyses will estimate environmental exposure and the burden of disease caused by environmental risk factors. These risk factors specifically include indoor and outdoor air pollution, water pollution, and exposures to hazardous substances in the workplaces (DuBose, 2008).

Abu Dhabi set a the target of 70% compliance by 2012 with Air Quality Standards as listed by the Council of Ministers 2006 decree (EAD 2008, 40). EAD is currently implementing an emirate wide air quality monitoring and management project where they have collected baseline data, analyzed emissions and dispersion patterns, determined the optimal number and locations of monitoring stations, and established a monitoring network. The Masdar Initiative was established in 2006 to support alternative and sustainable energy production and use (EAD 2008, 38).

Abu Dhabi has initiated a climate change program, although the results were not available for this report. Previous assessments have suggested that many of the vulnerabilities have increasing risks due to changing climate conditions, as discussed in the climate category. Yet these changes also pose greater risks for human security and safety. The 2007/2008 Human Development Report discusses adaptation options such as insurance for social protection, access to information (demonstrated in the education section of this paper) or building infrastructure to protect vulnerable coastal areas of high population density or other locations at risk (Watkins 2008).

Table 2.1 EAD Strategic Plan for Improved Air Quality and EHSMS

EAD Priority	Target	Indicator	Target Results by 2013
Improve Air Quality	Ensure an average of 70% compliance with Air Quality Standards in the Council of Ministers Decree No. 12/2006 by the year 2013	PM10	70% Compliance
		SO2	100% Compliance
		NO2	100% Compliance
		CO and O3	100% Compliance
		Increase the % of cars transferred to CNG	20% Increase
		Increase % usage of cleaner Diesel containing sulfur less than 500ppm	100% Compliance

Environmental Health Safety Management System (EHSMS)	100% of Target Sectors EHSMS	Reduce Lost Time Injuries	30% of Baseline by

INTERNATIONAL PRACTICE IN HOW TO MEASURE PROGRESS IN THE POLICY AREA

Recent studies and research has established links between the state of ecosystems and the condition of the populations that depend on these services (Corvalan, 2005). Air quality standards and monitoring in Abu Dhabi are based on the United States Environmental Protection Agency (EPA) standards and guidance papers (EAD 2007, 8). The EPA provides monitoring guidelines, control strategies, and indicator selection (EPA Air Quality, 2008). For example the EPA sets annual target levels for sulfur dioxide at 0.03ppm. In contrast, the European Environment Agency (EEA) set sets sulfur dioxide targets as at a percentage point reduction compared to the previous year. There are several approaches to reducing and regulating pollutant levels.

The Europe Union also sets limits on emissions and air quality standards codified in the Fourth Daughter Directive. This agreement specifies objectives for particulates and other pollutants. The European Air Quality Framework Directive sets a common strategy for assessing ambient air quality and monitors information on air quality in member states (European Union- Air, 2008).

Other references include the World Health Organization papers detailing recommended air quality guidelines including criteria used to establish the values, techniques for setting national standards, and descriptions of guidelines for protecting the public health (WHO Air Quality Guidelines, 2008). The World Health Organization has created key guidelines and recommended standards for preventing environmental based health impacts. The WHO has created metrics and measurement tools to quantify the amount of human disease caused by environmental risks. Their papers also calculate the environmental burden of disease using the exposure approach (WHO, 2002).

The Global EPI utilizes air pollutant data from multiple sources, including data on indoor air pollution by Smith et al. (2004), urban particulate concentrations produced by the World Bank, and modelled ozone data from the MOZART-2 model.

A general policy recommendation from this literature relating specifically to human health, highlights the need for governmental agencies and structural divisions create programs or communication to address interdepartmental concerns. This could mean reducing barriers for cooperation between ministries, departments, programs.

The global EPI utilizes the UNICEF and WHO Joint Monitoring Program indicator for access to water and sanitation. This globally accepted indicator measures access to water supply and sanitation in terms of the types of technology and levels of service available. The indicator measures the national access to water-supply services. Access is defined as at least 20 liters per person per day from an "improved" source within 1 kilometer of the user's dwelling. (WHO 2000)

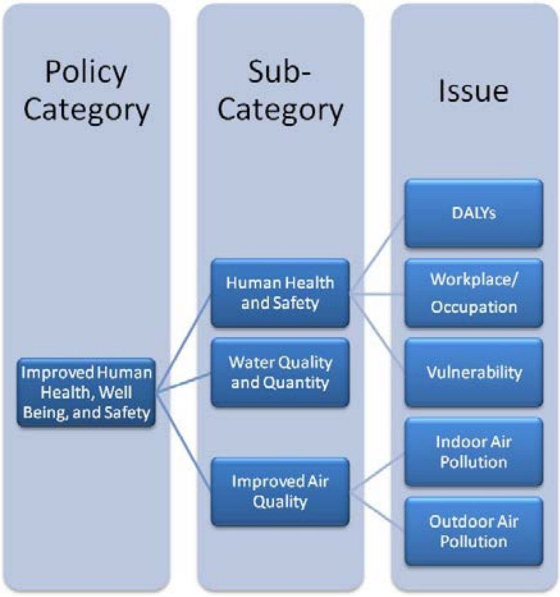
Global EPI Targets

Table 2.2 Global EPI Indicators for Human Health

Parameter	Target	Details
Disability Adjusted Life Years (Environmental Burden of Disease)	0	Prevent all loss of life due to water and air pollution.
Access to Drinking Water/Adequate Sanitation	100% coverage rates	Derived from the global MDG 7, target 10
Indoor Air	0 %	Reflects danger posed by solid fuel use indoors
Urban Particulates	20ug/m^3	Minimize small particles
Local Ozone	85pbb	0 exceedance above this target

AD-EPI INDICATORS AND INTERPRETATION

Human Health and Safety



There are numerous other environmental threats to human safety and well-being. The WHO developed a measure to capture loss of life and productivity due to environmental impacts. The disability adjusted life year (DALY) calculates the sum of the number of life years lost due to premature mortality or years of life lost due to disability caused by an environmentally related disease. Human health and safety also considers natural hazards and vulnerability to natural disasters, and workplace injuries. According a WHO report, 44% of unintentional injuries arising from workplace hazards, radiation, and industrial accidents are attributable to environmental factors. These can also occur in the household or school setting.

Potable Water Quality

Globally, the burden of disease is largest from unsafe drinking water supplies and demonstrated through reported instances of diarrhea (Pruss-Ustun 2006, 11). Individuals in contact with polluted water sources are exposed to both short-term threats and long-term impacts. The two main components of this measure is to get complete coverage for sanitation services to the population and to ensure a safe quality of drinking water. WHO defines improved drinking water sources as piped water into a dwelling, plot, or yard (WHO, 2007). Abu Dhabi, the high level of access suggests more targeted indicators for water quality levels.

Air Quality

Air pollution issues been shown to have adverse health impacts ranging from respiratory allergies, lung and cardiac distress, aggravated asthma, to bronchitis. Indoor pollution is generated by inefficient ventilation at homes. Outdoor air pollutants include a wider range of air pollutants, caused naturally and by human-beings. The level of each pollutant recorded indicates potential health risks to human lungs, respiratory tracks, and long-term well-being.

INDICATORS FOR MEASURING POLICY PERFORMANCE AND RESULTS FOR DECISION-MAKING:

Table 2.3 AD-EPI Indicators for Human Well Being and Safety

Sub-category	Indicators	EPI Policy Goal and Description
Human Health	Child mortality under 5	Children's health in the first 5-years is closely linked to environmental variables. While not all deaths are environmentally caused, child mortality provides a key indicator for impact of several environmental indicators. The indicator is calculated as the number of deaths divided by the number of population at risk during a certain period of time. The target is to reduce child mortality rates from the baseline year until it reaches 3 per 1,000 live births. This is the lowest rate registered globally in year 2006.
	Environmental Burden of Disease	This measure captures environmental impacts on human morbidity and mortality rates. This measures the most direct impact on human health from environmental sources and is an important indicator for the aggregate impact of harmful environmental conditions for human health. This indicator will use an unweighted sum of air pollution, water pollution, and exposure to hazardous substances. The target has not been set.
	Access to sanitation	Improved sanitation technologies are defines as being connected to a public sewer, connection to septic system, pour-flush latrine, simple pit latrine, ventilated improved pit latrine. The excreta disposal system is considered adequate if it is private or shared (but not public) and if hygienically separates human excreta from human contact. "Not improved" are: service or bucket latrines (where excreta are manually removed), public latrines, latrines with an open pit. The target is 100% coverage.
	Occupational and home safety	According a WHO report, 44% of unintentional injuries arising from workplace hazards, radiation, and industrial accidents are attributable to environmental factors.
	Vulnerability to natural disasters	The largest urban areas of Abu Dhabi Emirate are located in the coastal zones, which makes them vulnerable to potential flood risk due to sea level rise.
Water Quality	Drinking-water quality index	Creating health-based targets is crucial for safe drinking water. These targets are guideline values of the substances or chemicals of concern. The indicator is constructed from measurements of microbial water quality and chemical water quality. This indicator looks for reductions of identified substances of concerned and effectiveness in preventing

		contamination. Quality of water for domestic consumption, according to GEMS/UNEP, include: Total Coliform, Faecal Coliform, Pathogens, POPs, Turbidity. WHO provides health guidelines for of nitrate, arsenic and fluoride for the potable water.
Air Quality	Indoor Air Pollution	The Indoor Air indicator is a measure of the percentage of a country's inhabitants using solid fuels indoors. The target for Indoor Air is set by expert judgment at zero, which reflects the opinion that any amount of solid fuel used indoors poses a significant risk to human health and is therefore considered undesirable.
	PM_{10}	Suspended particles in outdoor air can cause respiratory infections and cancer. Therefore reducing these particulates to the lowest level is ideal for human health. This indicator measure compliance with target reduction levels. The closer to the target the lower the risk of negative health impacts. This indicator accounts for exposure by using population-weighted daily concentration calculations. The Abu Dhabi target is 150 micrograms per cubic meter ($\mu g/m^3$). The Global EPI uses the WHO standard of 20 micrograms per cubic meter, but owing to wind-blown dust, Abu Dhabi has high naturally occurring levels already above this level.
	$PM_{2.5}$	Fine particulate matter less than or equal to 2.5 microns in diameter have greater health impact, and are generally from anthropogenic rather than natural sources. PM 2.5 should be measured in both short-term periods of 24-hour periods but also over the course of a year to determine potential long-term impacts. The WHO as well as United States EPA and European Environment Agency have target levels for PM2.5. There are two sets of Guidelines for PM2.5 from WHO: 10 µg/m3 annual mean, 25 µg/m3 24-hour mean.
	Human Health Ozone(O_3)	Ideally, individuals should not be exposed to any ozone concentration over the 170$\mu g/m^3$ (85 parts per billion) standard set forth by the EPA to prevent damage to respiratory system or even mortality. This is measured by population-weighted hourly concentrations of high level ozone above this threshold. In Abu Dhabi, the standard set by the FEA and agreed to by EAD is 200$\mu g/m^3$.
	NO_2 population weighted	Exposure to nitrogen dioxide severely damages the respiratory system. Therefore controlling short and long-term exposure is the goal. This indicator measures the danger of nitrogen dioxide levels above the 400$\mu g/m^3$. This is calculated through exceeding surface concentrations overlaid with populated areas. This increases the policy relevance by identifying potential risks to human constituents. The target is zero population exposed to NO_2 exceedance above 400$\mu g/m^3$.
	SO_2 population weighted	This indicator has a similar method of calculation as the nitrogen dioxide. Because of long-term damage it can cause to the human respiratory system, the target is set at 350$\mu g/m^3$. This indicator measures

		the exceedance values weighted by population. The target is zero population exposed to SO_2 exceedance above 350μg/m[3].
	CO population weighted	Carbon Monoxide poses serious threats human safety and can quickly kill individuals. This indicator will measure the population-weighted hourly concentration above the threshold of 30μg/m[3].

RESULTS

1. Human Health

We are able to calculate one of the 5 indicators proposed in human health area: Child mortality under 5 years old. Although this indicator is not a direct measure of environmental impacts on mortality, there is a high correlation between child mortality rates and environmental variables.

Under-five mortality rate was 10.7 per 1,000 live births in Abu Dhabi Emirate, slightly higher than the UAE-wide rate of 9 in the same year. Although the rate is smaller compared with the average under 5 mortality rate in the eastern Mediterranean region (i.e.84 per 1,000 live births), it is currently more than twice higher than the lowest global rate of 3. The proximity – to – target is 96.67

2. Potable water quality index

The potable water sources in Abu Dhabi Emirate are wells, desalination and imported water. Currently, there is no systematic method of measuring the level of nitrate, arsenic and fluoride in potable water sources.

3. Air Quality

We are able to calculate two out of five indicators proposed based on the available air quality data collected in AD: Particulate Matter and Human Health Ozone. The pending indicators are based on parameters that require more sophisticated modeling techniques, which are performed by NILU.

3.1 Indoor Air Pollution

The indoor air pollution indicator is usually a affected by the percentage of a country's inhabitants using solid fuels indoors, but in developed countries there are usually other sources of contaminants. Abu Dhabi Emirate is currently collecting the data needed for calculation of this indicator.

3.2 Outdoor Air Pollution

a. Particulate Matter (PM10)

Target: No exceedance above150μg/m^3 24-hour mean PM10 concentrations

To assess cumulative exposure to PM10 we used hourly monitoring station data for the Emirate from May 2007 to April 2008 and created a 500m gridded surface of concentrations using spatial interpolation methods.

In the first stage we computed the mean 24-hour PM10 concentrations, from which we subtracted the threshold value of 150μg/m^3. In order to generate mean daily surface of exceedance, we removed all negative values, then summed the daily exceedance (Table 2.4, column A) and divided by the number of days with exposure within the month (column B). The results are shown in column C from table 2.4.

We then assessed the population exposed to PM10 exceedance by tallying up the number of people in each grid cell. The cumulative monthly exceedance surfaces above 150μg/m^3 mean 24-hour PM10 was overlaid by population in order to estimate the population exposure. The population exposed at any level of exceedance above the threshold is shown in column D of table 2.4. The percentage of population exposed from the total emirate population is displayed in column E.

The population-weighted monthly concentration of PM10, displayed in column G of table 2.4, is calculated by multiplying the exceedance values by population exposed for each grid (column F), and dividing by the total number of population of AD Emirate (column D). The mean annual population weighted exceedance amount per day is 88.89μg/m^3.

Since small values for this indicator indicate better performance (i.e. ideally, we'd have 0 population exposed to above the threshold PM10 mean daily concentrations), the formula for calculation the distance to target is:

Proximity to target = 100 – [(score value – target value) x 100 / (maximum score value – target value)] (Esty et al., 2008).

Therefore, the PM10 proximity to target score = 100 - (88.89 – 0)*100/(152.89-0) = 41.86

As Table 2.4 shows, the PM10 concentration values are significantly higher in January, and reach the highest monthly mean concentration in the month of February 2008. The PM10 concentration exceeds the cutoff value for almost all stations on February 1st, 16th and 21st; these days are characterized by high winds, relatively high temperature, or both. During May, June and September of 2007, the entire population of Abu Dhabi Emirate was exposed to some PM10 exceedance.

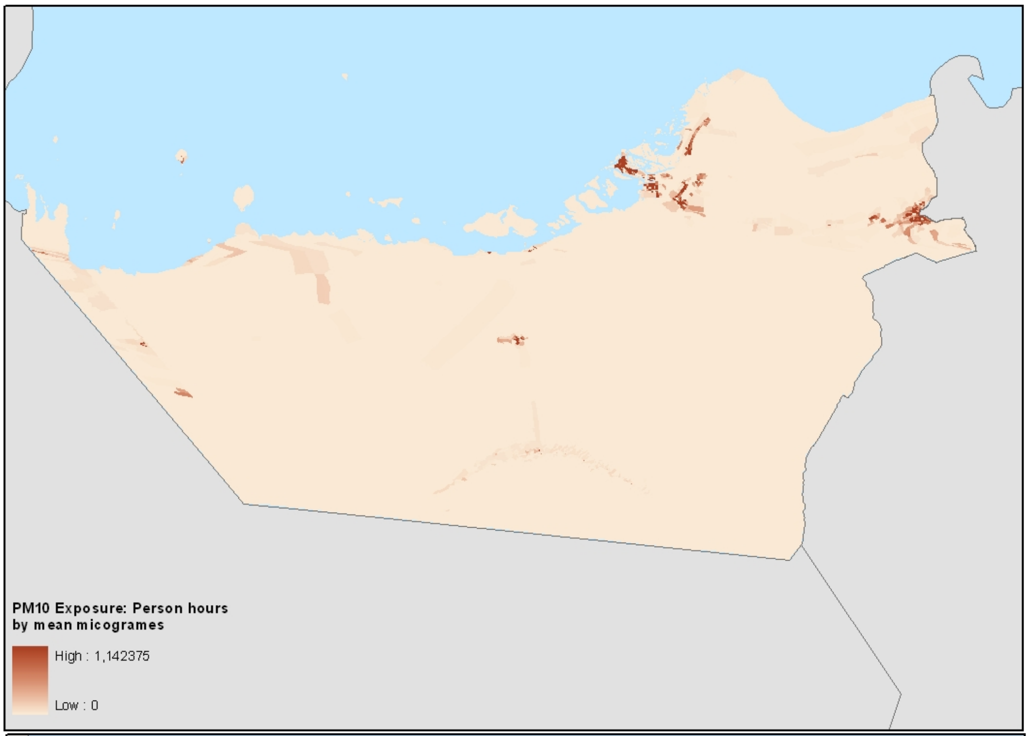
The target of 0 people exposed to 150μg/m^3 or higher 24-hour mean PM10 concentration was not met in any of the months. September mean daily concentrations were closest to the target (76.87 out of 100). The overall result is a proximity to target score of about 42 for PM10 during the period from May 2007 to April 2008.

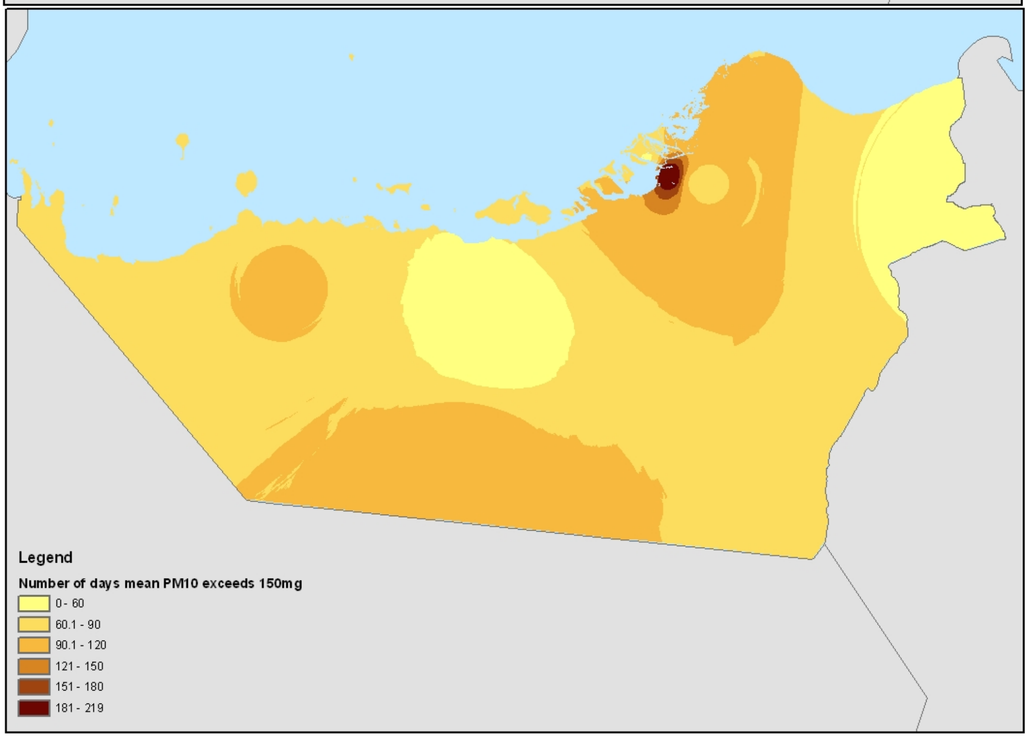
Table 2.4 PM 10 monthly and annual results and analysis

Month	PM10 24-hour exceedance > 150µg/m³	Grid cell days with PM10 24-hour exceedance > 150µg/m³	Mean monthly exceedance amount per day	Population exposed at any level of exceedance	Percent of population exposed	Person days of exceedance per month	Mean monthly exceedance amount per day (population weighted)	Proximity to target
	$A = \Sigma(PM10_d - 150)_i$	$B = \Sigma days_i$	$C = mean(A_i / B_i)$	$D = \Sigma persons$, if $A > 0$	$E = D / max(D)*100$	$F = \Sigma(C_i \times \Sigma D_i)$	$G = F/D$	$H=100-(G-0)*100 / (maxG-0)$
May-07	493,492,763.75	3,657,462	133.20	1,287,389	100	186,548,890.45	144.90	5.22
Jun-07	386,633,913.21	5,188,058	73.28	1,287,389	100	84,505,062.16	65.64	57.07
Jul-07	486,537,203.67	6,482,828	71.25	962,705	74.78	90,538,770.70	94.05	38.49
Aug-07	195,968,573.17	3,353,251	61.59	1,286,447	99.93	58,778,114.68	45.69	70.12
Sep-07	66,148,758.33	1,625,538	51.24	1,287,389	100	45,530,450.76	35.37	76.87
Oct-07	13,184,355.25	287,301	42.05	359,681	27.94	34,699,232.77	96.47	36.90
Nov-07	5,136,918.46	159,451	24.66	319,592	24.82	17,978,746.99	56.26	63.21
Dec-07	569,224.62	22,636	12.73	549,775	42.70	39,982,029.57	72.72	52.43
Jan-08	155,720,788.40	997,657	148.22	1,144,804	88.92	123,024,559.80	107.46	29.71
Feb-08	461,616,214.57	2,856,669	169.03	1,264,822	98.25	193,378,571.16	152.89	0.00
Mar-08	22,778,071.46	377,837	56.31	802,164	62.31	71,341,326.91	88.94	41.83
Apr-08	45,577,518.04	678,791	48.72	1,075,335	83.53	89,980,388.69	83.68	45.27
Year total	**2,328,227,384.50**	**25,528,028**	**90.41**	**942,325**	**75.27**	**83,760,174.69**	**88.89**	**41.86**

d-day, i-grid

Figure 4 PM10 exposure and Number of day with PM10 exceedance, May 2007 – June 2008





b. Human Health Ozone (OZONE_H)

Target: No exceedance above 200μg/m^3

The cumulative exposure to Ozone is based on hourly monitoring station data for the Emirate from May 2007 to April 2008, gridded at 500m using spatial interpolation methods. There was no hourly exceedance of ozone over the critical level of 200μg/m^3 during the time under study. This indicator has a score of 0, which means that Abu Dhabi Emirate doesn't have ozone concentrations in exceedance of the critical level. The proximity to target for this indicator is 100.

DISCUSSIONS AND CONCLUSIONS

The above indicators support policy making at two levels: they address drivers of problems while also highlighting symptoms and impacts on human health. Therefore, the indicators measure the progress toward pollutant levels deemed safe for both short and long-term human health. In order to be relevant to climate conditions in Abu Dhabi, and particularly the existence of high concentrations of wind-blown dust, the targets are lower than those commonly used in Europe and North America.

Several of indicators require additional information and updated data before they can be integrated into the AD-EPI. Recommended future air quality studies include using PM2.5 instead of PM10 readings. PM2.5 measures smaller particles that pose greater health risks, and PM2.5 can be more consistently traced to anthropogenic rather than natural sources. Once these measurements are complete and available on an annual basis, the AD-EPI will switch to PM2.5.

The other major area not included in this year's EPI calculation is the Disability Adjusted Life Years (DALYs). This is critical indicator as it reflects the specific impacts of these environmental concerns on human health. EAD is currently in the process of collecting the data required include this as a measure. The description is included above after consultation with EAD.

Given the large population who spend the majority of time indoors, it is important to measure indoor air pollution. There is currently insufficient data to calculate this indicator, but EAD is funding research by experts from the University of North Carolina, which will examine the randomly selected homes for evidence of ailments caused by poor air quality, including sick building syndrome (SBS).

Other future indicators under discussion included vulnerability to natural disasters and risks as well as occupation and home safety. With more data and analysis these could be turned into potential valuable indicators for EAD policies. Attention should also be given to clarifying indicators between categories. For instance some vulnerabilities are part of risks posed by climate change and thus could fit into the Climate category. These categories are not in the global EPI so offer opportunities for new analysis and areas of data collection.

These variables are closely related to the global EPI indicators. While targets have been adjusted for case specific reasons, this data lays the framework for integration into international monitoring programs.

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WASTE MANAGEMENT

General overview

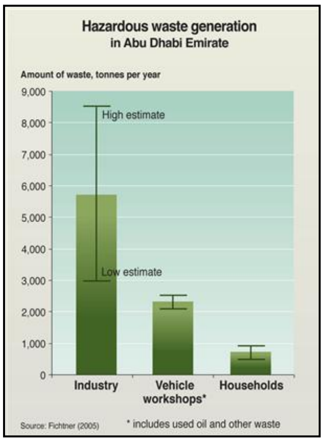
Waste management is an environmental, social, and economic challenge. Increasing industrialization and personal consumption result in the production of larger volumes of waste. This requires new approaches and techniques to waste reduction such as re-use, recycling, and energy recovery. The challenge is to reduce the detrimental environmental impact of resource use by ensuring safe and adequate disposal of the waste materials while supporting the growth of business opportunities and creation of jobs in the waste management sector.

Waste management is categorized by the characteristics of the material being disposed, ranging from waste water, medical waste, hazardous waste, chemical waste, to solid waste. Production processes can create large quantities of heavy metals and other environmentally hazardous chemicals. If not properly disposed of, they can contribute to acute and chronic impacts on human well-being and the natural environment. From hazardous waste generated by hospital byproducts to solid waste from construction projects, there is a need for defined management strategies and clear regulatory frameworks to prevent environmental degradation or deteriorating human health.

WASTE MANAGEMENT POLICY REVIEW

OVERVIEW OF THE WASTE MANAGEMENT IN ABU DHABI EMIRATE

Until recently, there has been little or no regulation for the disposal of waste materials in UAE Each Emirate has been responsible for the management of waste products, leaving little standardization or control at the federal level. With minimal official oversight and significant potential economic profit from removing waste, private companies have historically been the primary actors removing waste. With inexpensive transportation, dumping into the sea or in the desert was common (EAD 2008, 57). The 2008 creation of the Abu Dhabi Waste Management Center (ADWMC) under the supervision of EAD has created an entity responsible for waste management which has stated their goal that all of the waste generated in the Emirate will be reduced, recycled, and safely disposed of through a full cycle system (EAD, 2008) .



The primary types of waste production of concern are by-products from the petrochemical industry, solid and hazardous waste produced by the construction boom, and domestic waste. Improper disposal raises significant concerns for the safety of human communities.

> **Persisting Challenges in Abu Dhabi**
>
> - Concerns remain over appropriate lining in waste disposal sites to prevent leakages into groundwater.
> - With no center for treatment or disposal of hazardous waste from non-oil industry, environmental and health impacts must be monitored closely.
> - There is no tracking or recording of hazardous material through the Emirate.
> - Massive remediation projects are required to reclaim and prevent further pollution from previously uncontrolled dumping sites.
> - No current recycling or reuse education or strategy (EAD 2008, 52).

Another concern for waste management strategies is the rapid urbanization that has occurred over the past four decades. This change in lifestyle and population clusters is accompanied by increase production of domestic waste. Abu Dhabi produces an estimated 1,532 tones of municipal waste daily, which is higher than the rate in OECD countries (EAD 2008,57). Estimates for UAE assume average per capita waste production at 547 to 766 kg per year, making UAE one of the world's highest waste producing countries (EAD 2007, 31). While the major urban areas of Abu Dhabi and Al Ain have some disposal facilities, smaller settlements lack removal and treatment options. This concern is further reflected by current trends of large-scale construction which produces significant quantities of hazardous substances such as asbestos, paints and glues/solvents. The continued growth of the construction industry requires adequate landfills and disposal facilities and improved monitoring of impacts.

THE EAD POLICY REVIEW PROCESS: PRIOR STATEMENTS, TARGETS AND STRATEGIC DIRECTIONS

The primary policy objectives have focused on creating a regulatory framework with specific codes of practice and regulations for all sectors of waste management. The objective remains the protection of human health and the environment against the damaging effects of improper waste management, including the collection, transportation, treatment, storage, or leaking of waste. Recent targets help reach this overarching objective, including approving a new waste management strategy, setting codes of practice and regulation, establishing insurance law, and issuing regulatory framework. In 2005, Law no. 21 clarified roles and responsibilities of private sector and government agencies for waste management. To further facilitate this law, a Waste Management Higher Committee was established with EAD as the chair.

The EAD five year Strategic Plan sets several clear goals and accompanying targets detailed below:

Table 2.5 EAD Strategic Priorities and Targets for Waste Management

EAD Priority	Target	Indicator	Target Results 2013
Set Waste Management Policy and Regulations	Approve Waste Management Policy and Strategy by 2009	Completion of Waste Management Policy	100% Compliance
		Completion of Waste Management Strategy (Master Plan)	100% Compliance

	Set Codes of Practice and Regulations for Waste Management by 2013	Issuance of Law Establishing of Waste Management Center	100% Compliance
		Develop and Approve Executive Order of Law No. 21/2005	100% Compliance
		Approve COP for Waste Management	100% Compliance
Protect Society and Environment from Hazardous Materials	Establish Integrated System for Hazmat by 2010	Database System	100% Compliance by 2010
		COPs and Guidelines	100% Compliance by 2010
		System at Federal Level	100% Compliance
		Installation of Radiation Detection Gates	100% Compliance by 2010
		Completion of Recruitment of Human Resources	100% Compliance by 2011
		Completion of COPs and guidelines	100% Compliance by 2011

The following targets and key performance indicators identified by EAD in their KPI reports are considered when constructing EPI indicators.

Table 2.6 EAD Waste Management Key Performance Indicators (KPIs)

EAD Priority	Key Performance Indicator	Target: End of 2010
Waste Reduction: Household Wastes	Waste to Landfill	25% Reduction
	Recycling	25% Increase
Waste Reduction: Commercial and Non-Hazardous Industrial Waste	Waste to Landfill	20% Reduction
	Recycling	30% Increase

Construction and Demolition Waste	Waste to Landfill	30% Reduction
	Recycling	20%of C&D recycled
Hazardous Waste	Precise Data on Hazardous Waste	All Generators and their wastes
	Secure Chain of Custody	Fully Operational Tracking Hazardous Waste System
	Safe Treatment and Disposal System	Best Practice Treatment or Storage Facilities established.
	Strong Incentives to Minimize	Expert Advice and Polluter Pay's Tariff System

INTERNATIONAL PRACTICE IN HOW TO MEASURE PROGRESS IN THE POLICY AREA

The Basel Convention on the Control of Transboundary Movements of Hazardous Waste of 1989 set a three-step strategy for creating guidelines and regulations on the movement and treatment of hazardous wastes. The convention set strict standards for transboundary movement of wastes and also created a set of guidelines to help governments produce incentives for different sectors to reduce waste generation and create systems for safe disposal (OECD, 2004). Some of the action items include strict control of storage, transport, treatment, reuse, recycling, recovery, and final disposal of waste. They also provided technical guidelines for environmentally sound management of organic solvents, waste oils, persistent organic pollutants, household wastes, clinical wastes, and other hazardous materials. Subsequent conference of the parties have elaborated on numerous subsets of these guidelines and protocols (UNEP, 2002).

The 2006 International Conference on Chemical Management adopted the Strategic Approach to International Chemicals Management (SAICM) policy framework to guide safe management and use of potentially dangerous chemicals. The agreement sets out the scope, needs, objectives, and approaches to implementation under five themes: risk reduction, knowledge and information, governance, capacity-building and technical cooperation, and illegal international traffic (UNEP, 2008)

The United States Environment Protection Agency developed a system to identify specific substances known to be hazardous. The EPA regulations provide guidelines to determine what characteristics define solid waste and what is considered hazardous waste regulations (EPA RCRA, 2008). They have classified a list of 31 priority chemicals that pose significant threats to human and environmental health. Through the US National Waste Minimization Program, these substances are targeted to be reduced or eliminated from production and use. A longer compilation of chemicals is registered through the CAS Registry, run by the American Chemical Society (CAS 2008).

The 1990 Kuwait Regional Convention for Protection of the Marine Environment Against Pollution from Land-Based Sources called for stricter regulations for waste discharge in Article VI. Other countries also provide examples of guidelines and technical standards. The EPA Resource Conservation and Recovery Act (RCRA) provides guidelines and definitions for waste management of both solid and hazardous materials (EPA, 2008).

The European Environmental Agency provides examples of a range of waste indicators. Although they have limited country data even within Europe, they calculate indicators around the main waste treatment framework of the "cradle to grave" lifecycle (EEA, 2008). The European Union's approach to waste management is based on three principles: Waste prevention, recycling and reuse, and improving final disposal and monitoring (EEA, 2005).

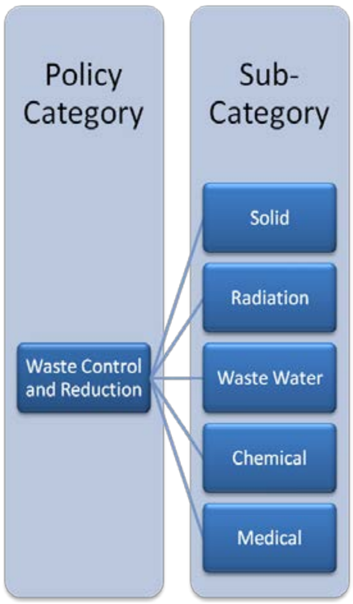
Global EPI Targets

This policy area was not included in the Global EPI targets owing to the absence of internationally comparable data on waste disposal.

AD-EPI INDICATORS AND INTERPRETATION

Solid Waste

Municipal solid waste consists of everyday items generated from daily behaviors and actions. They can include packaging from products, food scraps, bottles, newspapers, paint, batteries, etc. Reduction programs, recycling, and composting are all methods that can reduce the quantity of waste to be disposed of in landfills or incinerated.



Waste Water

Untreated waste water from point sources (such as pipes, sanitary sewers) can cause significant harm to ecosystems. This is a growing concern for urban areas that are expanding rapidly. Careful urban planning requires adequate treatment plants, preferably with tertiary treatment capacity.

Hazardous Waste

The characteristics defining hazardous waste include ignitability, corrosivity, reactivity, and toxicity. Some of the primary health concerns from hazardous waste are the release of the following:

- Arsenic is a highly toxic and carcinogenic substance that is used as an alloy in lead shot and electrical circuits
- Asbestos which can cause cancer and mesothelioma when inhaled.

- Cadmium which can damage the lungs, kidneys, and digestive track, chromium is used as a rust-resistant coating on metals and used in wood preservatives and liquids for tanning hides

Medical Waste

Wastes from hospitals require sites to dispose syringes, medication bottles, and other materials that can be infectious and spread pathogens and harmful micro-organisms.

Chemical Waste

Similar to hazardous waste, chemical wastes can be highly toxic and dangerous substances for both human and environmental health. They are considered persistent, bioaccumulative, and highly toxic and require special disposal and storage policies. Laboratories and industries that handle chemicals are responsible for proper disposal.

INDICATORS FOR MEASURING POLICY PERFORMANCE AND RESULTS FOR DECISION-MAKING:

Table 2.7 Initial Suggestions for Waste Management Indicators

Recommended Indicators	EPI Policy Goal and Description
Waste Generation	This composite indicator measures the total waste production by sector and tracks the growth or reduction annually. This reflects a range of potential issues, from inefficient production processes to unsustainable consumption patterns. The overall goal is to prevent the increase of waste generated, noting that current levels are already unsustainable. The large per capita waste production in Abu Dhabi remains a key concern within the EAD assessments. This links to education initiatives and raising awareness and changing behavior. This indicator could be calculated by measuring each sectors waste production to determine an aggregate level of waste production. Sector analysis would be crucial for policy goals while the overall indicator measures Emirate wide progress on the target.
Municipal Waste Generation Per Capita	Reducing the quantity of municipal waste is currently a strategic goal of the Abu Dhabi Waste Management Center. This indicator would measure the value and annual change in production at a municipal level. This indicator would be a subset of the broader waste management but sets the target of 300kg/capita, a level that reflects best practices set forth by the European Environment Agency (EEA, 2008). It could also be set to waste/GDP (EEA, 2008).
Relative Recycling	To support waste reduction, recycling is also critical to sustainable use of resources. This indicator would measure the total waste recycled as a percentage of total waste produced. The target, still under discussion, would be set around 25% according to EEA targets (EEA, 2008).

Waste Treatment	This indicator is the second key stage of waste management: providing safe disposal sites for all forms of waste generated. Preventing illegal and unregulated dumping of waste is crucial for human and ecosystem health. This indictor therefore measures the ratio of total waste generated to total waste treatment per year. It includes all types of waste generation and all sectors including municipal, construction, industrial, agricultural, and medical. Waste treatment calculates all forms of waste designated waste management. The target would be a ratio of 1:1. This indicator is derived from OECD's measures (OECD 2001; 2004).
Illegal Marine Dumping	The goal is to prevent all illegal dumping of waste into the marine ecosystem. This indicator measures total violations per year. The target is zero violations. This indicator is derived from the EEA (EEA, 2008).

DISCUSSIONS AND CONCLUSIONS

Waste management requires efforts for both the reduction in the quantity of waste generated as well as concerted efforts for waste disposal procedures and safe treatment centers. EAD has indentified and responded to concerns over the amount of waste generated per capita and the need to increase treatment capacity.

Performance in these indicators is connected to the quality of human health. See the human health section for more details about environmental health indicators. While waste indicators are not included in the human health category, improper disposal of any type of waste can lead to a wide range of health concerns, from respiratory illness to poisoning and diarrhea.

Therefore, the EPI should support these identified goals by measuring progress toward waste reduction. There are a variety of potential indicators to be discussed. A clear target should be introduced for each indicator. Data would be needed for these indicators. Creating effective waste management indicators will provide guidance for future Global EPI although data at the global level is not currently available.

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CULTURE ASSETS AND AESTHETIC VALUES

General overview

Knowledge of the natural world and traditional practices utilizing its resources reflect skills and values linking human communities to natural ecosystems. These relationships are often expressed through language, oral traditions, or attachment to places. The complex interactions are also closely related to community's spiritual traditions.

Rapid urbanization and changing life styles have shifted the traditional role of the environment in daily lives. Urban life styles caused attachments and relationships of the individual to the natural environment to deteriorate. Livelihoods also adapt to new markets and modes of production shifting the dependence from traditional sources of income derived from close relationships to nature to often more abstract ones.

The link between individuals, the community, and the natural world is crucial for maintaining mutual respect and preserving sustainable development.

CULTURE POLICY REVIEW

OVERVIEW OF THE CULTURE CATEGORY IN ABU DHABI EMIRATE

Before the major urbanization and development in Abu Dhabi, the unique ecosystems and hyper arid climate conditions required specific knowledge and skills for human survival. The culture in Abu Dhabi is highly responsive to several key ecosystems. The oasis in the desert provided crucial water for survival. Palm groves and date trees provided food for both settlements and nomadic tribes. The Liwa Arc is the largest oasis in Abu Dhabi and archaeology reveals structures and efforts to protect this area from desert encroachment, such as gates to prevent sand movement. The extensive range of Arabic vocabulary that describes environmental conditions in the deserts reflects the significance natural conditions while also emphasizing cultural traditions.

Three long slim peninsulas which extend northwards into the Gulf and are important sites preserving artifacts from previous human settlements along the coast. Archaeological finds have given insights into the history of the Emirate and provide information on possible changes in the natural environment. The sites on these peninsulas reflect past abundance of marine species.

Another important traditional livelihood centers on pearl diving. Many of the traditional sources of livelihood are centered on coastal activity, including fishing from the traditional dhow boats. While these have diminished in economic importance, there is a need to preserve marine species

Two terrestrial species have particular cultural importance in Abu Dhabi; camels and falcons. Camels maintain their cultural significance, providing meat and milk as well as an important economic activity in the desert. Arab Falconers are used for recreation and sports. The tradition emerged from the wintering of the houbra bustard in the Emirate.

There are also several natural geological formations that are linked to aesthetic and cultural values, including the Baynuah Formation, a distinct series of rocks deposited on the Shuweihat Island.

THE EAD POLICY REVIEW PROCESS: PRIOR STATEMENTS, TARGETS AND STRATEGIC DIRECTIONS

This category is closely linked with other policy areas in the EAD strategic plan. Conservation of land areas is often tied with cultural or historical importance placed on specific locations. Designation of protected species is often a reflection of cultural values around multiple species. While no policies are directly formed under this category heading, the goals are reflected in the education sector by measuring the level of environmental awareness as well as general prevention of environmental degradation from sources like air pollution or uncontrolled dumping of waste.

Abu Dhabi's archaeological heritage is not supported by strong policies or regulation of historical sites. The EAD archaeology sector paper calls for increased monitoring, organization, and management of paleontological and archaeological resources. The sector paper also notes a clear absence of trained local archaeologists (EAD, 2007).

With tourism growing rapidly, estimates of over 10% growth in 2003-2004 alone, protecting natural resources and attractions are a key priority (EAD, 2008). The Abu Dhabi Tourism Authority has recorded increasing number of annual visitors and identified cultural heritage as a key attraction (EAD, 2008). This includes a growing eco-tourism sector, highlighting the fragile ecosystems and wildlife species (Neto, 2003).

The Abu Dhabi Authority for Culture and Heritage is primarily responsible for education and awareness of cultural heritage and historical preservation.

This category is not directly included in the strategic plan but is reflected in priorities and several areas including conservation, preservation of biodiversity, and productive natural resources associated with traditional livelihoods.

INTERNATIONAL PRACTICE IN HOW TO MEASURE PROGRESS IN THE POLICY AREA

The 1972 Convention on World Cultural and Natural Heritage created international definitions of the intersections of the environment and socio-cultural heritage. The convention defines natural heritage as physical and biological formations which maintain outstanding universal value from both the scientific and aesthetic point of view. It also includes geological and physiographical formations which constitute the habitat of threatened species of animals and plants. UNESCO also designates global heritage sites to be preserved for future generations. By recognizing a site as a global heritage site, UNESCO encourages governments to protect these locations and help preserve them for the future generations (UNESCO, 1972).

The 2003 Convention for the Safeguarding of the Intangible Cultural Heritage is an international effort to preserve the oral traditions, social practices, performing arts, knowledge and practices concerning nature and the universe, and traditional craftsmanship (UNESCO, 2003).

Global EPI Targets:

There were no global EPI indictors or targets for this category. This category requires further discussions and consultations before developing.

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ENVIRONMENTAL EDUCATION

General overview

Environmental education is a crucial component for achieving sustainable development goals and an essential tool for informed decision-making and constructive community engagement. Comprehensive education programs are key to transform environmental goals into realities.

Education programs reach across all of the categories and themes of EAD strategic goals. The programs span topics from personal use of natural resources to the potential impact of global climate change. The goals of the programs vary and encompass raising awareness to changing personal behavior. These programs can take the form of general media broadcasts, school curriculum development, to major awareness-building and behavior change campaigns.

ENVIRONMENTAL EDUCATION POLICY REVIEW

OVERVIEW OF THE EDUCATION CATEGORY IN ABU DHABI EMIRATE

Raising awareness and changing behavior are key tools for environmental protection in Abu Dhabi. The rapid rate of development and urbanization was accompanied by major increases in patterns of personal consumption and use of natural resources. Sector papers and education surveys have identified levels of per capita water consumption surpassing most other industrialized countries. Similar high rates are found in per capita waste production. These patterns are encouraged by the consumer sectors. For example, the population is now approximately 80% urban. This is matched by per capita waste production averages between 547kg and 766kg per year (EAD 2008, 31). Even though many products are imported, given the Emirate's limited natural resources, and given the desire to reduce greenhouse gas emissions, conservation and moderation will be key to sustainable development.

Environmental awareness projects and civil society efforts started developing in the 1980s. The Emirates Natural History Group (ENHG) made the first efforts to develop environmental awareness and education in the Emirates, beginning in 1977. ENHG's primary audience was a largely western group of expatriates with interest in natural history. Their efforts provided data on wildlife and natural history of the Emirate. Over the years it has attracted more diverse cultural groups to join in as members.

The Abu Dhabi Environment Group (ADEG) was formed in 1991 as the first community group in Abu Dhabi. This was the first effort to build environmental awareness for students and the general public through their educational programs and campaigns. They developed educational resources and materials for teachers, conducted campaigns, gave green awards and held workshops. The Emirates Environment Group, a similar group to ADEG and based in Dubai, expanded their effort and reached out to Abu Dhabi audience to fill the gap of ADEG. The Environmental Friends Society with its environmental activities targeted at schools, students and the public was the primary non-governmental organization operating from Abu Dhabi during the 1990s. Currently, however there are many more community and civil society organizations notably the Emirates Wildlife society (WWF- UAE) along with others who are contributing to the effort to raise awareness.

In addition to private group efforts, multiple government agencies within the Abu Dhabi contribute to environmental education objectives. The municipal governments of major urban areas can have an active role in supporting the public's behavioral changes. For example the Ministry of Agriculture and Fisheries increase their constituent awareness through projects such as clean up campaigns, regular meetings, and other information exhibitions and festivals. At the federal level in 1993, the UAE formed the Federal Environment Agency and placed environmental education as one of their key stated objectives. A committee was then formed with the objective of generating a national strategy for environmental awareness. Later in 2006, the Ministry of Environment and Water was constituted which is now addressing environmental awareness from a federal perspective.

A systematic and a sustained approach to environment education within the school system began in 1998 when the Communication and Education Department of EAD began its outreach to school students on biodiversity issues. After becoming an official agency and gaining additional responsibility in 2000 the agency expanded its educational programs to include all relevant environmental issues applicable to student-age populations. By 2001, a draft Environmental Strategy for the Emirate of Abu Dhabi was framed by the Environment Agency in which environmental education and awareness was placed as one of the key strategic objectives. The plan identified specific constituent/interest groups and created an action plan to be pursued with each of the group. This strategy was revised later in 2003, during which the strategic actions 2003-2007 were designated and pursued. Both formal and non-formal approaches to environment education were pursued by the Agency in its outreach efforts. Formal programs targeted students both schools and the higher education establishments through interactive classroom sessions workshops, field trips, training of training, hosting environmental forum for teachers. Other motivational and participatory programs included campaigns for the general public, awareness efforts through the media, incentive-based programs for students, establishing environmental clubs, commemorating all environmental occasion with relevant activities, exhibitions, seminars for professionals, and presentations for the corporate sectors. As the main international coordinator for the UNESCO's water education program for the Arab World, EAD introduced modules on solar power to school students and teachers in addition to producing a variety of resource materials for awareness and education.

The State of the Environment (SoE) website is an example of using new media technology to reach wider audiences. The website provides critical information about the current state, impact, pressure and specific responses. While readership is limited this site provides a tool to reach new constituent groups and share important information and data.

In 2005 EAD was restructured to be the main environmental authority in Abu Dhabi allocating responsibility for the environmental sustainability in the Emirate to the Agency. In addition to this institutional emphasis, the decade of 2005-2015 being declared as the decade for Education for sustainable development placed awareness as one of its top priority among other priority issues for the Emirate such as waste, water, biodiversity, air quality, climate change etc. The Education strategy for 2008-2012 is based on the environmental priorities for the Agency and the emirate, with thrust on resource development, capacity building, increasing outreach through networking and partnerships, learning and sharing with best practices locally, regionally and internationally.

THE EAD POLICY REVIEW PROCESS: PRIOR STATEMENTS, TARGETS AND STRATEGIC DIRECTIONS

The 2001-2004 Abu Dhabi Environment Strategy outlined a target audience for direct implementation of education efforts to increasing environmental awareness. The policy objective now is to establish and support programs throughout a variety of actors and educational levels (EAD Education Policy Paper). The Environmental Education Initiatives targets five specific areas: waste, water, biodiversity, global issues and pollution. Target audiences include women, fishermen, farmers, and industrial employees, corporate sector and government and non-government agencies and the general public. There is now a move to engage wider stakeholder participation and a more inclusive approach to include civil society in the whole of the educational and awareness initiatives and process. For example a multi-stakeholder dialogue with 10 distinct groups gathered and drafted individual action plans for education and awareness programs targeted at members of their group around issues of climate change. EAD education initiatives and programs are structured around principle and guidelines of the Tbilisi Framework and in pursuit of the goals of the UNESCO Education for Sustainable Development. There is a focused effort to engage all constituent groups and stakeholders using a bottom-up approach.

The Ministry of Education is a potential implementing partner around efforts to reach out to schools and to support environmental curriculum training of educators. Students remain a crucial target group for EAD programs for both long-term potential impact and the growing proportion of youth to total population. In addition EAD has been a leader in efforts to green the curriculum in schools, looking into gaps and providing information, direction, and developing relevant resources.

Recent collaborative efforts have focused specifically on engaging the broad community interest and awareness around climate change, reducing water consumption, enhancing awareness on waste and biodiversity and helping establish a sustainable school education initiative.

Previous monitoring programs recorded the number of students reached and programs implemented. In 2008, environmental education monitoring efforts focused on measuring the impact and change in awareness levels and linked behavior. A 2008 Environment Awareness and Behavior Survey were conducted to identify key areas and concerns. The survey identifies specific focal areas and subjects but also analyzes indicators based on nationality, location, gender, age, education level, and profession. The 2008 survey identified awareness levels around average with practice trailing behind. The survey and EAD programs focus on educational awareness in the following categories targeted as specific audiences:

Table 2.8 EAD Environmental Education Program Areas and Target Audiences

EAD Education Sector	Audience	Programs
Waste	Commercial Establishments, Construction industry, Educational Institutions, Medical Centres, Agricultural Waste, Domestic Waste	Targeted Awareness Programs, Clean-Up Campaigns, Recycling Programs
Water	Domestic consumers , farmers and the agricultural community	Interactive, presentations, workshops, Educational and awareness resource materials, training, World Water Day Activities, Municipal level efforts. Water efficiency.
Biodiversity	Students, educators, developers, corporate sector, industries, fishermen, boat owners, island managers, media, decision makers.	Field trips and activities , interactive presentations, lectures, development of resource material for awareness dissemination and events organized to raise awareness – By EAD, Emirates Heritage Club, EWS etc
Pollution	Targeted audiences: Indoor Air Pollution to Women groups, industries , corporate sectors, students and educators	Awareness Programs in schools and ministries, marine cleanup programs, presentations and workshops.
Global Issues (Climate Change)	General Public	General Awareness and Information Programs, issue awareness days, Climate Change impacts and reduction in carbon emissions.

The agency will support the development and dissemination of educational material and training programs and ensure that the material is integrated into all school curricula. The program will coordinate with other agencies, institutions, and non-governmental organizations to avoid duplication. It will also set aside small funding opportunities for local groups designing, managing, or disseminating education and training (EAD, 2008).

The current EAD five year Strategic Plan sets several clear goals and accompanying targets detailed below:

Table 2.9 EAD Strategic Plan for Environmental Education

EAD Priority	Target	Indicator	Target Results by 2013
Create a Society with Increased Environmental Awareness and Action	Enhance Level of Awareness and behaviour in EAD's priority issues by effectively targeting population through increased outreach	Number of Population Reached	2 million
		Level of Public Awareness	65%
		Level of Behaviour Change on EAD's priority Issues	57%

INTERNATIONAL PRACTICE IN HOW TO MEASURE PROGRESS IN THE POLICY AREA

There have been numerous international agreements and strategic statements emphasizing the crucial role of environmental education. Public awareness and early education have been built into the sustainable development agenda as a key factor to pursuing the longevity and success of these programs. This link was established under several major international agreements and is currently being emphasized with the decade of "Education for Sustainable Development." The 1992 Earth Summit stated in Principle 21, "the creativity, ideals, and courage of the youth of the world should mobilize to forge global partnerships in order to achieve sustainable development and a better future for all." Agenda 21 also contains a chapter focused on children and youth in sustainable development programs. UNEP and UNESCO in 1975 founded the International Environmental Education Programme (IEEP) in Belgrade, creating a variety of educational modules to help guide and structure education programs (ICEE, 1983). Another initiative came from the Rio Declaration, Principle 10 and the Aarhus Convention stating that everyone has the right to environmental information, decision-making, and justice.

In 2002, the United Nations adopted a resolution creating the Decade of Education for Sustainable Development (DESD). This program places education and learning at the center of sustainable development. The environment is set as one of the key thematic areas. The program seeks to empower societies, communities, and individuals by integrating the principles, values, and practices of sustainable development into education systems (UNECE, 2005). Guidance papers provide recommendations on setting up national committees and their assigned roles (UNESCO,YEAR).

Specific national environmental education programs exist and demonstrate a variety of programs and responses to specific needs. The United States Environmental Protection Agency support a variety of incentive-based programs providing awards and recognition for projects and successful programs, to training programs and general curriculum building targets. Their primary target remains early education and integration into schools and communities.

In India, the Center for Environment Education (CEE) was created as a partnership between the government and non-governmental organizations. Their mandate is to raise awareness of environmental issues to promote conservation and sustainable use of natural resources. The center supports education programs, distribution of teaching material, and synergies between different actors and organizations (CEE, 2007). CEE is supporting EAD's efforts to develop and adapt educational resources.

Global EPI Targets

Education has not been incorporated into the global EPI process due to a lack of globally comparable data. Therefore all indicators in this category are proposed and still in the development phase. Should global data become available, it will be assessed and integrated into the global EPI measurements.

AD-EPI INDICATORS AND INTERPRETATION

The following are initial suggestions for potential indicators. They are being recommended based on education survey completed in 2008. The publication of the survey techniques and results will provide a basis for construction of these indicators and refinements in the future.

Table 2.10 AD-EPI Indicators for Environmental Education Category

Category	Indicators	EPI Policy Goal and Description
Environmental Education	Environmental Awareness	There are a variety of educational programs in use and proposed to raise the general public's awareness of environmental issues. The target is a 100% awareness based on a 5-point average on the rating scale of 1-5. These ratings can be measured through different layers to reflect policy needs. These layers of analysis increase the policy strength when understanding dynamics between age groups, professions or gender.
	Behavior and Individual Action	Understanding or recognizing a problem must be converted into personal action. This indicator measures the environmentally significant behavioral patterns (e.g., miles driven per year, recycling) of individuals in Abu Dhabi. This indicator measures the average % of behavior based on 5-point rating on the scale of 1-5. The target is 100%

RESULTS

Target: Percent Awareness and percent Behavior change about Important Environmental

The results of the survey show an overall awareness of 48.9% or 2.94 on a rating scale of 6, and an overall behavior of 43.8% or 2.63 on a rating scale of 6.

The issues where the respondents are least aware, and also lack in exercising behavior is water (42.8% awareness and 40.6% behavior). The highest level of awareness is less than 62% for each of the main issues of concern; the respondents seem to know more about energy concerns, and it looks as they are willing to make positive steps by being environmentaly friendly in area of pollution.

Since the poor performance benchmark is 0 and the best score is 100, the proximity to target is the same as the score for this indicator.

DISCUSSIONS AND CONCLUSIONS

EAD strategy has identified strategic goals to reduce personal consumption levels in several key categories, including water resources and waste management. EAD has recorded low level of community and individual awareness of the consequences of individual actions related to daily routines. This lack of awareness should be linked to efforts to shift personal behavior. Therefore, tracking various actors' knowledge and behavioral choices generates information to guide the development of new learning tools and constructive education programs. This also informs other policy options such as providing incentive or disincentive based programs aimed at changing behavior. These educational indicators therefore track shifts in the awareness and behavior using 2008 as baseline data with the end goal of total community awareness.

CIESIN recommends careful attention to behavioral studies. Concerns about data reliability of surveys for behavior remain high. Pairing behavioral studies with other direct indicators like water consumption in the water resources section or waste management indicators on recycling are secondary measures to the environmental education targets.

While the EPI calculates an aggregate overall score for awareness, combining each focal, policy makers should consider disaggregated analysis to target programs on specific interest groups or themes. The survey data per issue area is an important policy tool to help measure other sector policy goals. The EAD strategic plan are reduce per capita water consumption as well as waste production is critically linked to education programs. Therefore the survey results can be triangulated with measures of consumption rates. A reduction in personal consumption of water should match increased awareness and behavior in educational surveys.

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ECOSYSTEM VITALITY

AIR QUALITY (EFFECTS ON NATURE)

General overview

High levels of air pollution directly damage ecosystem health and vitality. High concentrations of ozone (O3), benzene (C6H6), sulfur dioxide (SO2), particulate matter, nitrogen oxides (NOx) and volatile organic compounds (VOC) threaten forests, natural vegetation, crop yields, ecosystems, and historic or cultural monuments. The increase in soil and water acidification due to air pollution also threatens fish species, biological diversity, and agriculture productivity.

Since they diffuse freely through the atmosphere and frequently react with other atmospheric chemicals, air pollutants are difficult to track and measure. SO2 and NOx are primary chemical compounds that react in the atmosphere to create acid rain or ozone (in the case of NOx). The impacts are not limited to national borders and can make policy options difficult to identify.

AIR QUALITY POLICY REVIEW

OVERVIEW OF THE AIR QUALITY CATEGORY IN ABU DHABI EMIRATE

Atmospheric data is currently being collected by EAD through a monitoring network of ten ambient air quality stations and two mobile air quality stations. The stations collect readings on concentrations of SO2, NOx, O3, H2S, PM10, BTEX, NMHC, noise, wind speed, wind direction, and ambient temperature from urban, roadside, industrial, and regional station locations. Data from the EAD ambient air quality network can be used to track trends and provide direction to decision-makers on emissions controls. However, elevated ambient particulate concentrations, mainly due to soil erosion and strong wind patterns, are expected as the climate is generally hot and humid combined with regions of dry deserts and strong winds (EAD, 2007).

THE EAD POLICY REVIEW PROCESS: PRIOR STATEMENTS, TARGETS AND STRATEGIC DIRECTIONS

EAD is currently in the implementation phase of an emirate wide air quality monitoring and management project where they have collected baseline data, analyzed emissions and dispersion patterns, determined the optimal number and locations of monitoring stations, and established monitoring network (Gartner Lee Limited, 2008).

With regards to ozone depleting substances, Abu Dhabi is in process of phasing out the consumption, import, and export of CFCs and Halon. These substances will be banned by 2010 (EAD, 2007), which will help to protect the stratospheric ozone layer.

The EAD five year Strategic Plan sets several clear goals and accompanying targets. EAD currently follows the 2006 air quality guidelines listed by the Council of Ministers and compliant with the federal standards. However, there are currently no standards in place regarding the ecosystem ozone.

EAD Priority	Target	Indicator	Target Results by 2013
Improve Air Quality	Ensure 70% compliance with air quality standards listed in Council of Ministers Decree No 12/2006 by the year 2013	PM_{10}	70% compliance by 2013
		SO_2, O_3, NO_2, CO	100% compliance by 2013

INTERNATIONAL PRACTICE IN HOW TO MEASURE PROGRESS IN THE POLICY AREA

In 1979 as an effort to address these concerns, European countries became signatories to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) which serves as a mechanism to share clean technology, conduct joint monitoring, and promote education and training programs (UNECE, 1979). This program also has organized a task force to examine the impact on human health as well specific components of the environment and ecosystem. Other international programs monitor air pollution on regional and global scales. The European Environment Agency also sets standards and environmental targets for air quality. The European International Cooperative Programmes (ICP) organizes research and monitoring efforts for air pollution effects on forests, on acidification of rivers and lakes, effects on historic and cultural monuments, effects on natural vegetation and crops, on ecosystems, on mapping critical loads and risks, trends. This program provides assessments of potential ecosystem damage and studies the cause-effect relationship of air pollution to different ecosystems. The United Nations Environment Programme GEO reports tracks data related to the impacts of air pollution: premature deaths due to outdoor urban PM10, energy trends, passenger cars by region, industrial output as well as sulfur dioxide and nitrogen oxides levels by region (UNEP 2007, 52).

International agreements have set clear reduction strategies for ozone depleting pollutants through the Vienna Convention and Montreal Protocol. The Montreal Protocol regulates 96 chemicals with specific targets to phase out for halons by 1994, CFC's by 2005, HCFC's by 2020 (UNEP, 2000). Yet the international community has not set binding objectives or reduction targets for other air quality standards, instead creating non-binding guidelines for countries and establishing regional agreements.

Other examples of national targets include the United States Clean Air Act which requires the US Environmental Protection Agency to set National Ambient Air Quality Standards (NAAQS) (EPA 2006; EPA 2008). As a result, the EPA guidelines target six pollutants: Carbon monoxide, lead, nitrogen dioxide, particulate matter, and sulfur dioxide. Specifically for ozone, the EPA has set two scenarios; a 1-hour ozone level is at 0.12ppm and an 8-hour ozone level is not to exceed 0.08ppm (EPA, 2008).

The global EPI target for Ozone is based on the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops analysis of the maximum level of Ozone above which would cause damage. The target and data for the SO2 indicator are based on estimates of emissions compiled by the Netherlands Environment Assessment Agency's Emission Database for Global Atmospheric Research (EDGAR).

Global EPI Targets

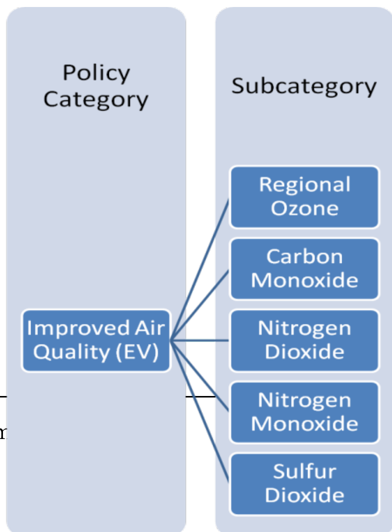
Table 2.11 Global EPI Targets for Air Quality

Parameter	Target	Details
Ecosystem Ozone	0 Exceedance above 3,000ppb hours over three-month summer period (sum of ppb accumulated exceedances over 40ppb/day)	The focus is ozone concentrations during the summer growing season, and the indicator was calculated using results from the MOZART-2 model.
SO2 Emissions	Zero Emissions (recognizing variation in ecosystem thresholds)	The target varies between locations and can be influenced by transboundary as well as local sources. The US EPA sets the target at 0.03ppm annual and 0.14ppm in a 24-hour period.

AD-EPI INDICATORS AND INTERPRETATION

Ozone

Ground-level ozone can reduce the ability of plants to photosynthesize, thereby reducing crop productivity and potential lowering of agricultural yields (Mutters 1998, 17). It is also considered a significant greenhouse gas.



Sulfur dioxide and NOx

When SO2 and NOx gases react in the atmosphere with water, oxygen, and other chemicals, they form various acidic compounds that can then fall back to the ground as acid rain that can diminish fish stocks, degrade forests and soils, and diminish agricultural productivity. It can lead to loss of trees, crops, formation of ozone, and deterioration of monuments and buildings.

INDICATORS FOR MEASURING POLICY PERFORMANCE AND RESULTS FOR DECISION-MAKING

Table 2.12 AD-EPI Air Quality Indicators

Category	Indicators	EPI Policy Goal/Relevance
Air Quality (Effects on Nature)	Ecosystem Ozone (O_3)	Measures the vulnerability to ecosystem of high levels of ozone. Taking into consideration natural levels of ozone in Abu Dhabi, this indicator monitors for ozone levels exceeding 40 parts per billion, ppb (μg/m^3). In order to create an emirate-wide score that represents the diffuse nature of ozone particles, the exceedance sums are overlaid with vegetation areas (using irrigation areas as a proxy). However, the months of June, July and August are excluded because high temperatures naturally cause exceedances during this period. This provides a comprehensive measure to indicate the scale of compliance and impact on vegetation. The target is 80μg/m^3 or 0 cumulative annual exceedance above 18,000 μg/m^3 for cropland and 30,000μg/m^3 for forests during non-summer months.
	SO_2 Emissions per Vegetated Areas	High concentrations of sulfur dioxide have been shown to damage plants and animal respiratory systems when exceeding designated levels. Therefore this indicator measures hourly SO2 levels in exceedance of background SO2 levels of 5μg/m3. The background values are based on the passive sampler study by NILU.
	NO_2 Emissions Per Vegetated Area	NO2, generated primarily through the combustion process is a key component of ground ozone. The goal is to measure levels throughout the Emirate to capture both urban area levels but also industrial emissions and impacts on ecosystems. The indicator measures hourly NO2 levels in exceedance of background NO2 levels of 3μg/m3. The background values are based on the passive sampler study by NILU.

RESULTS

Ecosystem Ozone

Target: No cumulative annual exceedance above 18,000 μg/m^3 for crop areas and 30,000μg/m^3 for forest areas. This is based on hourly measurements of exceedance above 80μg/m^3 during non summer months.

This indicator represents the cumulative hourly exceedance above 80μg/m^3, during non summer months.

Table 2.14 Hourly ozone in exceedance for crops cultivated areas and forest plantations

	Number of day-light hours	Hourly exceedance of Ozone concentrations > 80ug/m^3	Crops exposure to Ozone concentrations >80ug/m^3	Forest exposure to Ozone concentrations > 80ug/m^3	Grid cell days with Ozone exceedance > 80μg/m^3	Mean hourly exceedance > 80μg/m^3
May-07	14	3,178,691,358	79,298,153	250,579,180	25,822,379	90.75
Sep-07	14	1,076,171,862	44,534,526	136,604,526	11,874,830	88.21
Oct-07	13	799,224,281	47,072,177	115,949,754	9,096,476	85.38
Nov-07	13	929,016,825	58,435,046	111,011,996	10,277,618	86.99
Dec-07	12	750,612,298	39,176,078	73,553,926	8,498,179	85.34
Jan-08	12	1,019,637,701	38,493,756	68,327,412	11,667,222	85.29
Feb-08	12	1,754,533,000	47,586,657	95,364,916	19,694,604	86.84
Mar-08	13	2,218,943,278	56,575,121	135,719,632	23,695,141	90.80
Apr-08	13	6,918,338,827	137,208,029	446,492,562	10,485,629	87.92
Year total		**13,089,817,664.00**	**443,509,264.00**	**1,042,611,054.00**		

The 9 month sum exceedance above the threshold is 50,942 for crops and 32,064 for forest. The accumulated exceedance is nearly three times the value of the threshold for crops (about 86.49 % of the crop cultivated area) and more than the value of the threshold for forest (covering about 70% of the area).

If ground-level ozone were available throughout the Gulf region, we could have alternatively calculated a poor-performance benchmark equal to the highest ozone concentrations in the region. In the absence of such data we simply used the current values within Abu Dhabi as this benchmark.

DISCUSSIONS AND CONCLUSION

The three indicators were selected based upon available data and significance for environmental impacts. Ozone levels have clear targets while SO2 and NOx are based on best practices and scientific literature while also recognizing the specific regional conditions.

SO2 and NOx pollutants require additional discussions and adaptations of existing EPI indicators to accurately reflect air quality policy priorities and appropriate reduction strategies. The FEA has set clear air quality standards for the UAE. The EPI air quality performance is based on international best practices and findings of healthy levels for natural ecosystems, some of which are lower than FEA levels.

The guidelines set by EAD are constructed from protecting human health and are not based on environmental vitality. Therefore future efforts should identify appropriate targets and standards to measure performance as it relates to ecosystem vitality. The overall objective remains reducing the levels of these pollutants to the lowest level possible and limiting domestic production of these pollutants.

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SUSTAINABLE WATER RESOURCE MANAGEMENT (EFFECTS ON NATURE)

General overview

Protection of water systems and the provision of adequate quantities of water for various types of water uses are critical for sustainable development. Clear and effective policies are crucial to protect water resources from the impacts of growing urban populations, the increase in agricultural runoff and pollution, and growing contamination from industrial wastes. The interrelationship between protecting the natural environment, water resource management and economic development has been emphasized by various UN programs and activities such as the integrated water resource management program IWRM (IRWM, 2000). As many organizations have reported, there are crucial links between protecting the natural environment, water resource management and economic development.

WATER RESOURCE POLICY REVIEW

OVERVIEW OF THE WATER SITUATION IN ABU DHABI EMIRATE

The past three decades of development coupled with a sharp increase in population growth, has increased the demands on limited water supplies. In the past 30 years the per capita freshwater consumption rate has tripled (Brook undated, 87). Water use is currently 26 times larger than the total annual renewable water resource supply. While the water demand is growing rapidly, the average annual precipitation is at its lowest level in 10 years, reducing recharge of groundwater aquifers (Dawoud 2008, 87). This has led to an increasing reliance on desalination plants. Other conventional water supply measures include recharge dams, storage dams, recharge wells, interception of groundwater losses, re-use of wastewater and water transfers.

Desalinated water is currently the primary source of potable water in Abu Dhabi (Brook undated). It also constitutes a significant proportion of water used for agriculture, forestry and industrial purposes (Figure 1). Large-scale desalination plants constructed in the coastal region of Abu Dhabi have strong impacts on the environment. The coastal region is an overpopulated region with extremely high population growth rates. The construction of both the desalination plants and all required infrastructure in coastal areas affects the local environment.

Deterioration in water quality and quantity has a negative impact on socioeconomic development. Rapid development and uncontrolled drilling of wells has led to groundwater depletion and exposure to higher contamination risks. Past mismanagement of water resources has contributed to a deteriorating quality of water resources and has affected ecosystem vitality.

THE EAD POLICY REVIEW PROCESS: PRIOR STATEMENTS, TARGETS AND STRATEGIC DIRECTIONS

The region's water use and needs are increasingly creating pressures on the currently available water supplies. The Water Sector Paper generated projections of predicted future demands of water supplies for domestic consumption, agricultural production, and forestry needs. EAD has clearly identified policy priorities and potential problems relating to protecting the water supplies and preventing damage to the natural ecosystem through a systematic strategic plan.

Water policies are shifting from supply management to demand management with a focus on conservation and reuse of existing water supplies. With domestic water consumption on a per capita basis double that of many nations in Europe, EAD with other stakeholders have set new target to minimize water wastage by using new water saving technology as well as developing a plumbing code. In forestry and agriculture sectors there are efforts to increase the use of reclaimed wastewater, to reduce consumption, to improve the control the unplanned groundwater wells and to prevent deterioration of groundwater quality (Dawoud 2008, 94). Officials have identified a specific policy focus on reducing water use in the agricultural sector, focusing on improving efficiency before expanding land under production. No policies have been identified currently to address pricing and other market based incentives for water conservation.

Another important challenge is centralizing data collection for water resources within the Emirate. EAD has compiled an initial database for the eastern region which has been identified as a model to be expanded for the rest of the Emirate (Dawoud 2008, 129). The EAD was recently given complete responsibility for groundwater management (Brook undated, 99) The Groundwater Resource Management Strategy specifies three components of the EAD policy: (1) development of a comprehensive water information (database) network, (2) establishing and enforcing groundwater regulations, and (3) developing and sustaining a nationwide monitoring system (Dawoud 2008, 203). Other agencies will maintain the responsibility for data collection in other areas of water management and use. EAD has prioritized groundwater monitoring through GIS databases to store, analyze, and produce graphical output and statistics on water exploration, quality monitoring, water use, water supply, well permitting, well registration, company registration, assessment, modeling, meteorology, and mapping of resources.

The EAD five year Strategic Plan sets several clear goals and identifies accompanying targets presented in table 2.14.

Table 2.13 EAD Strategic Plan for Air Quality

EAD Priority Area	Target	Indicator	Target Results by 2013
Improve quality and quantity of water resources in the Emirate of Abu Dhabi	To reduce 50% of the present water resource stress by 2013 towards achieving a sustainable level	Water Stress Index	Reduce 250% of water consumption as percentage of available supply
		Water Consumption per Capita per Day	Reduce water consumption to 350 litters/person/day
		Water Consumption per Hectare in Agricultural sector	Reduce water consumption to 18,000 m3/ha
		Water Consumption per Hectare in Forestry sector	Reduce water consumption to 2500 m3/ha
		Water Salinity and Nitrogen Levels	Nitrogen: 5-45ppm
			Salinity: 300-70,000 ppm
		Groundwater reserves/availability	Increase freshwater, brackish, and saline

INTERNATIONAL PRACTICE ON MEASURING PROGRESS IN POLICY AREAS

Water has been prioritized as a crucial resource in the efforts to protect biodiversity, prevent desertification, and promote sustainable development. Based on the 1992 Rio Declaration on the Environment and Development, 178 governments adopted a comprehensive plan of action to achieve sustainable development (UNEP, 1992). Furthermore, the Dublin Principles recommended a process of periodic assessments to monitor progress by countries. Shortly after the Rio Declaration, the United Nations Convention to Combat Desertification identified water management as a key factor required to mitigate the adverse effects of drought and protect land use vulnerable to human practices (Esty, 2008; UN, 1994).

In 2002, the United Nations General Assembly adopted the Millennium Development Goals which set a target to half the population without access to sustainable safe drinking water and sustainable improved sanitation by 2015. Despite this significant attention and policy importance given to water resources there are no equivalent globally recognized targets for controlling pollution concentrations in water supplies or, on the quantity side, definitions of sustainable water use.

Water Stress Measurements	
Available annual fresh water (Cubic Meters per capita per year)	**Level of Water Stress**
>1700	Occasional Water Stress
1000-1700	Regular Water Stress
500-1000	Chronic Water Scarcity
<500	Absolute Water Scarcity

Recent studies have elaborated on the relationship of population size to water supply by defining water stress indicators (see table). Studies by Falkenmark (1990, 2005) define water crowding and water scarcity indices to demonstrate sustainable water use taking into consideration household water demands, food security, industrial use, and energy production. Levy (2008, 46) and Falkenmark (1990) defined water supply of 1,700m3/person/years as the level above which water shortages are rare and localized. At levels below 1,000m3/person/year, water supply begins to hamper health, economic development, and well-being, Finally, a supply of less than 500 m3/person/year will constrain life (Falkenmark, 1989). This measure, however, does not take into account water use which is a key factor for Abu Dhabi context.

The World Health Organization has developed specific water quality guidelines (WHO, 2004). Water quality is evaluated in relation to the type of use with individual measurement parameters: human consumption versus food production versus sustainability of natural ecosystems. Globally, the United Nations Environment Programme maintains the most comprehensive global water quality data and information database, Global Environment Monitoring System (GEMS)/Water. The goal of the program is to improve water quality monitoring and assessment programs activities in participating countries and to determine trends in global and water quality deterioration (UNEP, 2007).

Although the global community has not agreed to clear goals, there are numerous guidelines and training manuals available for national planning and management agencies. Specific examples of data coordination systems relate to the European Union's directives such as the Water Information System for Europe (WISE). This program streamlines and facilitates reporting and sharing of information between member states, the European Environment Agency, EUROSTAT, and the Joint Research Center. Within WISE the Common Implementation Strategy for a Water Framework Directive (WFD) created a technical working group on groundwater with the goal of exchanging information and experiences (characterization, risk assessment, monitoring, chemical status and trends, programs of measures) (EEA, 2000). This directive monitors and creates a policy basis for water quality standards set by the European Union.

The global EPI identifies five water quality parameters with target levels for the index calculation (Esty, 2008). These broad criteria are used at the global scale and are limited by available data at the national scale (see Table 2.15).

Table 2.14 Global EPI Water Quality Targets for Freshwater as Included in the WATQI indicator

Parameter	Target	Details
Dissolved Oxygen	6 mg L^{-1}	DO must not be less than target when average water temperatures are > 20 °C
	9.5 mg L^{-1}	DO must not be less than target when average water temperatures are ≤ 20 °C
pH	6.5 – 9	pH must fall within target range
Conductivity	500 µS cm^{-1}	Conductivity must not exceed target
Total Nitrogen	0.5 mg L^{-1}	Total Nitrogen must not exceed target
Total Phosphorus	0.05 mg L^{-1}	Total Phosphorus must not exceed target

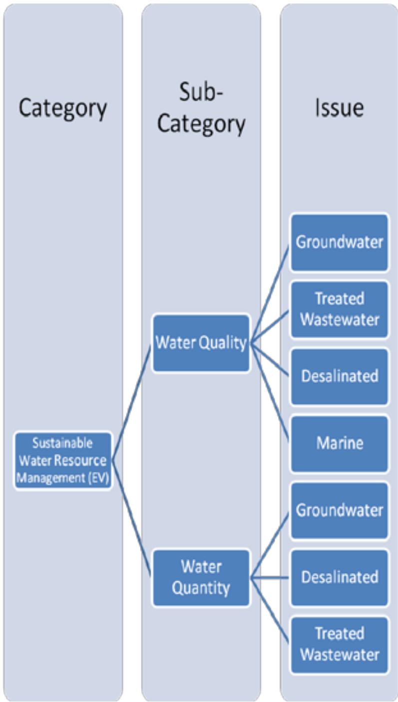
As for water quantity indicators, the EPI uses as a measure of the percentage of a nation's territory that is affected by oversubscription of water resources.

Table 2.15 Global EPI Water Quantity Targets

Parameter	Target	Details
Water Stress	No areas affected by water stress	Although some oversubscription can be accommodated with alternative water sources, the end goal in the global EPI is to have no areas in the territory affected by water stress, which is defined as consumption of more than 40% of local availability.

AD-EPI INDICATORS AND INTERPRETATION

Groundwater



Groundwater quality and quantity is a central focus for management and future policies. Rapid development accompanied by uncontrolled drilling of wells has led to unsustainable extraction rates and increased saline intrusion and higher levels of pollutants. The use of chemicals and fertilizers in agriculture has also led to deteriorated water quality.

Desalinated water

Brine and several chemical products used in the desalination process are returned to the sea. The effluent of this heavily concentrated brine water has an impact of the marine ecosystems. The discharged brine water has the potential to raise the temperature and turbidity of coastal water near the outlet. Also, one of the major indirect environmental impacts is the use of the energy required by desalination plants, particularly when electricity is produced by fossil fuels. This relates to the air quality and climate components of the AD-EPI.

Treated wastewater

Monitoring for increased reuse of treated wastewater in landscaping, green areas, foresters, road verges, and rehabilitation of natural vegetation cover. If used for irrigation there are concerns about the method used for wastewater treatment, the impact on soil deterioration, the types of plantations and the health risk.

Marine

Marine water quality is important to marine ecosystems. Currently brine discharges from desalination plants and nutrient loading from coastal settlements is having an adverse impact on marine systems. The current sample of stations is too small for an accurate assessment of performance, so we used a proxy measure of change in Chlorophyll-A concentration using remote sensing data. In the future, the index needs a representative number of stations for Abu Dhabi coastal waters.

INDICATORS FOR MEASURING POLICY PERFORMANCE AND RESULTS FOR DECISION-MAKING

Table 2.16 AD-EPI Air Quality Indicators

Policy Category	Sub-Category	Issue	Indors	EPI Policy Goal and Description
Sustainable Water Resource Management (Effects on Nature)	Water Quality	Marine Water	Coastal Chloro-phyll-a Concen-tration	Chlorophyll-a concentrations are an important measure of coastal eutrophication. Excessive eutrophication can lead to oxygen depletion that kills off benthic organisms and results in declines in fish stocks. The target is to reduce average Chl-A levels in ADE's exclusive economic zone (EEZ) to match the low levels recorded in 1999, the lowest level recorded since consistent SeaWiFS satellite observations began.
			Marine Water Quality Index	Maintaining a thriving and diverse marine ecosystem requires a high water quality level and specific characteristics. This indicator monitors several parameters critical to sustaining habitats and diversity of marine species. The index includes Ammonia, DO, pH, total Nitrate, and total Phosphate. The target needs to be established.
		Groun dwater	Groundwater Salinity	The extensive demand and use of groundwater can induce salt-water intrusion while high evaporation can increase salinity in shallow aquifers. This indicator detects changes and can alert policy makers to threats of deteriorating quality. It measures the total area where an increment of concentration in EC was detected. The target is no further increase of saline, brackish and brine water. It is possible to identify the anthropogenic source contamination of water from agricultural activity by closely analyzing the change in the electrical conductivity of groundwater within areas cover by irrigation.
	Water Quantity	Groun dwater	Water Stress Index	In a hyper arid climate, water use is usually higher than the total water supply. By measuring the ratio of the two, policy-makers can identify unsustainable tracks and isolate concerning use patterns or diminishing supply. This indicator calculates the percentage of Abu Dhabi's water use that comes from renewable water resources (including desalinated water), with a target of 100%.
			Water Consumption	A priority for Abu Dhabi remains reducing water consumption per capita in order to increase productivity of limited and expensive water supplies. Therefore this indicator measures the annual reduction of daily per capita water consumption rate towards the target of 350litres/person/day.
			Groundwater Level	Preventing over extraction of limited groundwater resources is crucial for long term vulnerability reduction and protecting the quality of groundwater sources. With minimum to zero annual recharge, this indictor sets a target of zero decline or positive recharge. Measurements come from abstraction centers and are calculated by subtracting water levels of a specific

				year from records of previous year's levels. Target is 0% of the territory of Abu Dhabi with more than 0.2m decline in the water table. Groundwater exploitation leads to permanent groundwater decline if the water is used unsustainably; for example, excessive water decline may cause a flow of brackish water from a greater depth of the aquifer (Mot, 2002). Areas covered by vegetation have to be carefully monitored and evaluated to identify areas where the water may be used unsustainably; therefore we are particularly analyzing the water reduction within these areas (using irrigated areas as proxy).

RESULTS

1) Water Quality

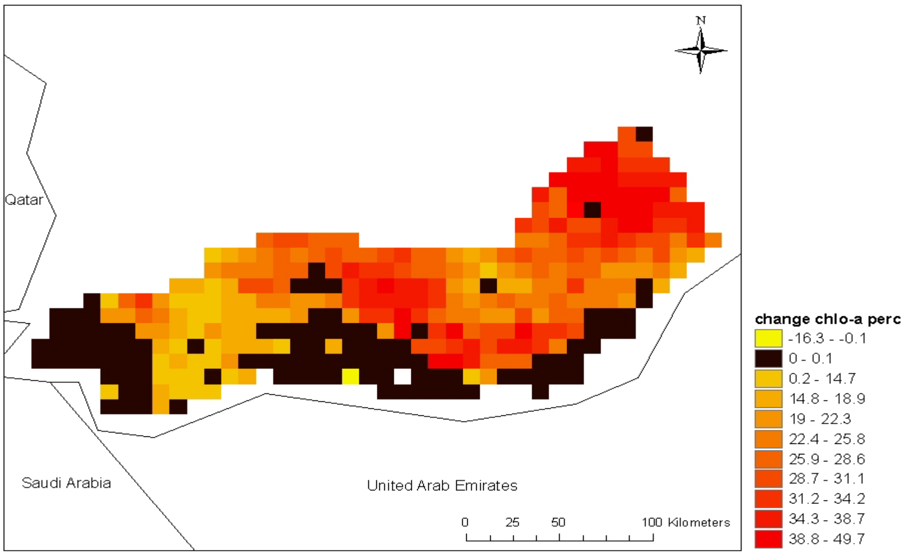
a) Coastal Chlorophyll-a Concentration

Target: 1.29 μg/liter

Given the particularities of different marine environments, determining an "acceptable" or target level of chlorophyll-a (Chl-A) concentrations, an important indicator of eutrophication which is also associated with harmful algae blooms, is not really possible. In this indicator we measure the change in concentration in the Abu Dhabi coastal zone from 10km to 100km from the coast line using SeaWiFS data from 1998-2007. Although problems with using SeaWiFS for Chl-A monitoring in the coastal zone of UAE have been identified, the trend data circumvent this problem by focusing on secular change rather than absolute values. We exclude those portions of the coastal zone that are part of the territorial waters of Qatar or Dubai. The average increase over the entire Abu Dhabi coastal zone during this period was 23 percent. A recommended target is to return to the chlorophyll-a concentrations of 1998, the year of lowest concentration, during which average concentrations were at 1.29 micrograms per liter (μg/l).

The average concentration in 2007, at 1.58 μg/l, is the highest concentration experienced to date. Translating this to a proximity-to-target score can be accomplished if we assign the year with the highest concentration in the time-series from 1998-2007 the low score of 0. Thus, in this most recent year the Emirate received a proximity-to-target score of 0 for this indicator.

Figure 5 Percent Change in Chlorophyll-a Concentration Abu Dhabi, UAE, 1998-2007 (black means no significant change)

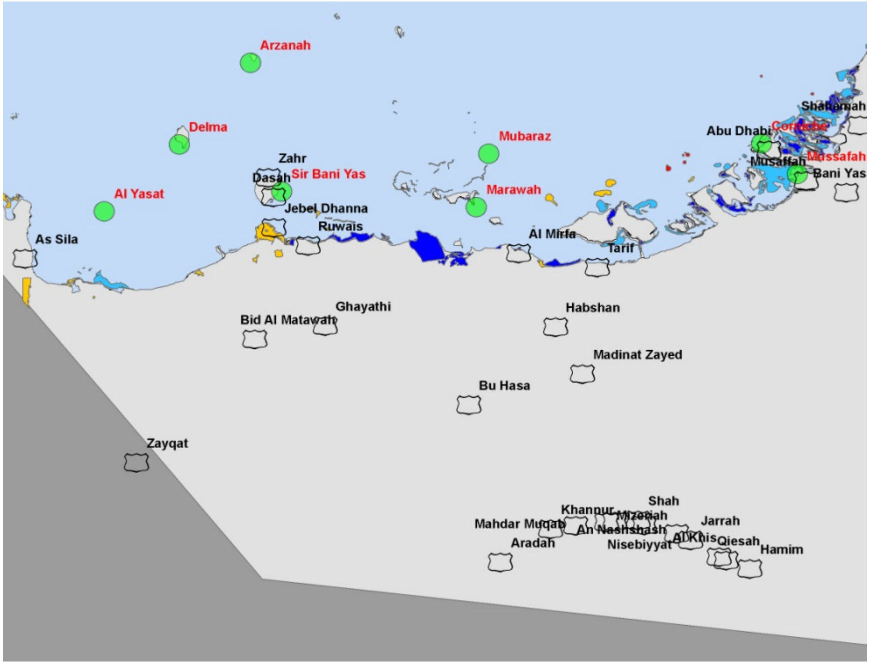


EAD has implemented marine water quality monitoring stations along the coast, and the Chl-A concentrations are consistently lower than those measured by SeaWiFS, as described below. Examining the above figure, however, we would expect the observed data to be lower in the near-shore areas. The advantage of the satellite data is that they estimate values for the entire surface of Abu Dhabi waters, which cannot be achieved without a large sample of station data.

The ground level data for this indicator range between 0.02 and 1.79 µg/l in 2004, with highest (exceeding the target) levels observed at Cornish (urban) and Mussafah (industrial) stations located in Abu Dhabi coastal area, represented with green bullets in the map below. A closer look to this area, including Cornish, Mussafah and the public beach show increasing high chlorophyll a value in the industrial station, with high values of 2 and 3ppb in 2006 and 2007, respectively.

Further studies are needed to better assess the correlation between the satellite and ground observation data for chlorophyll-a. We believe that this will only be possible through an expansion of the station network to include areas that are not currently observed. In the meantime, we propose using the model data for calculating the indicator, and advise recalibration of the SeaWiFS data if characteristics of the Abu Dhabi waters may bias the results.

Figure 6 Marine quality monitoring stations where green circles stations for AD Emirate



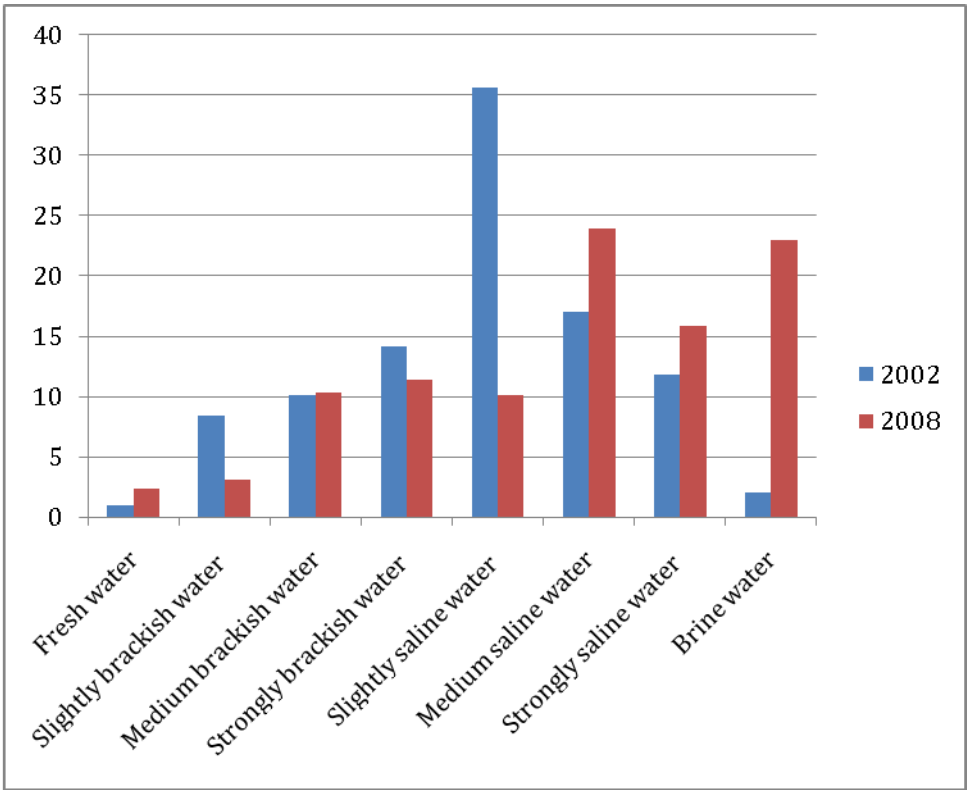
b) Groundwater Salinity

Target: No areas experiencing an increase in salinity levels (no increase in salinity levels on a grid-cell by grid-cell basis)

More than 70% of the total area of Abu Dhabi Emirate has groundwater with salinity higher than 10,000mg/l total dissolved solids (TDS), of which 23% is brine according to the 2008 Water Salinity campaign. Brine areas are mostly used for forest plantations, though close to 3% of the small farms are located in areas that are high in salinity or brine.

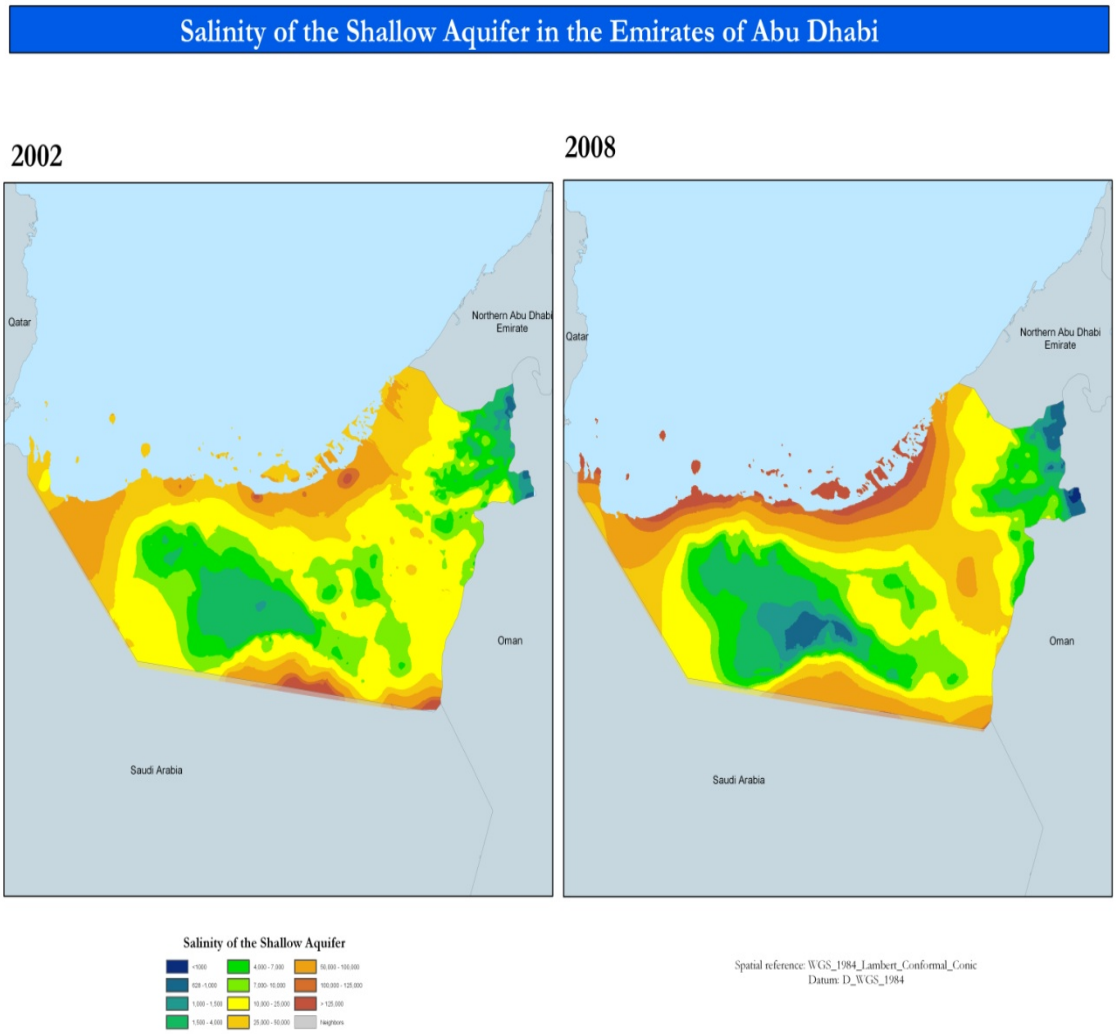
As seen in the chart below, several categories of brackish and saline water areas are increasing in extent, especially medium saline water, strongly saline water, and brine water, which expanded from 2% in 2002 to 23% of the territory in 2008. The total area of the Emirate that experienced an increase in salinity is 55%, and hence the proximity to target score is 45%.

Figure 7 Percentage Area of ADE Territory by Salinity Level from 2002-2008



Salinity levels are as follows: Fresh water (TDS <1,500ppm), Slightly brackish water (1,500<=TDS <4,000), Medium brackish water (4,000<=TDS <7,000), Strongly brackish water (7,000<=TDS <10,000), Slightly saline water (10,000<=TDS <25,000), Medium saline water (25,000<=TDS <50,000), Strongly saline water (50,000<=TDS <100,000), and Brine water (TDS >=100,000)

Figure 8 Salinity of Shallow Aquifer in Abu Dhabi Emirates



2) Water Quantity

a) Groundwater level

Target: No areas experiencing a decrease in ground water levels of more than 0.2m

This indicator represents the annual area with decreased groundwater levels, with a strong focus on major abstraction centers. The changes in groundwater levels are calculated by subtracting the water levels of a specific year from records acquired the previous year available.

The percent of area with more than 0.2m decrease in groundwater level is 67.3%. The distance to target is therefore 32.7.

Table 2.17 Water Decline Levels

Water level decline, 03 – 07	Percent area by water decline levels AD Emirate
Steady state (less than 0.2m decline)	32.71
Gentle and medium decline (0.2 – 1.0m)	33.11
Strong and very strong decline (> 1m)	34.18
of which (1.5 - 5m)	19.14
(5 - 10m)	12.73
(10- 20m)	2.31

Approximately 63% of the areas that currently experience decline correspond with areas of irrigated farms, forests, and urban greening.

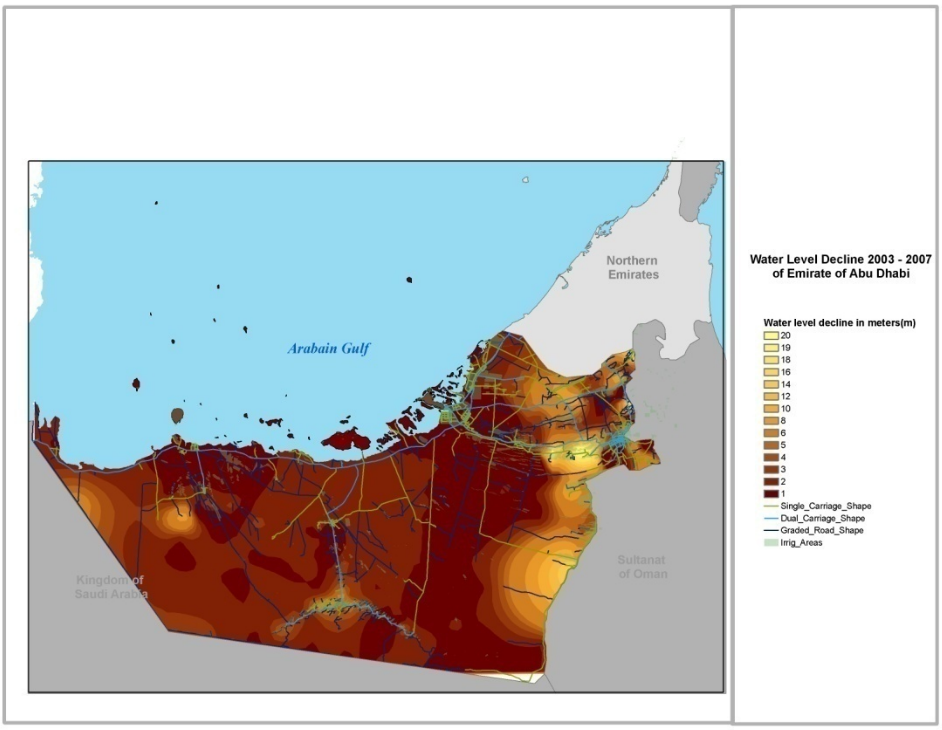
Table 2.18 Water Decline in Irrigated Areas

Water level decline, 03 - 07	Percent area by water decline levels AD Emirate	Irrigated areas	Irrigated areas, 2002						
			forest	small farms	large farms	urban park	urban greening	urban dates	hay
Stable	32.71	37.1	19.5	3.9	0.7	0.2	12.8	0.00	0.1
Gentle and medium decline (0.2 – 1.0m)	33.11	21.9	10.3	4.9	0.2	0.1	6.4	0.06	0.1
Strong and very strong decline (> 1m)	34.18	40.8	9.7	25.1	1.1	0	4.5	0.04	0.3

of which (1.5 - 5m)	19.14
(5 - 10m)	12.73
(10- 20m)	2.31

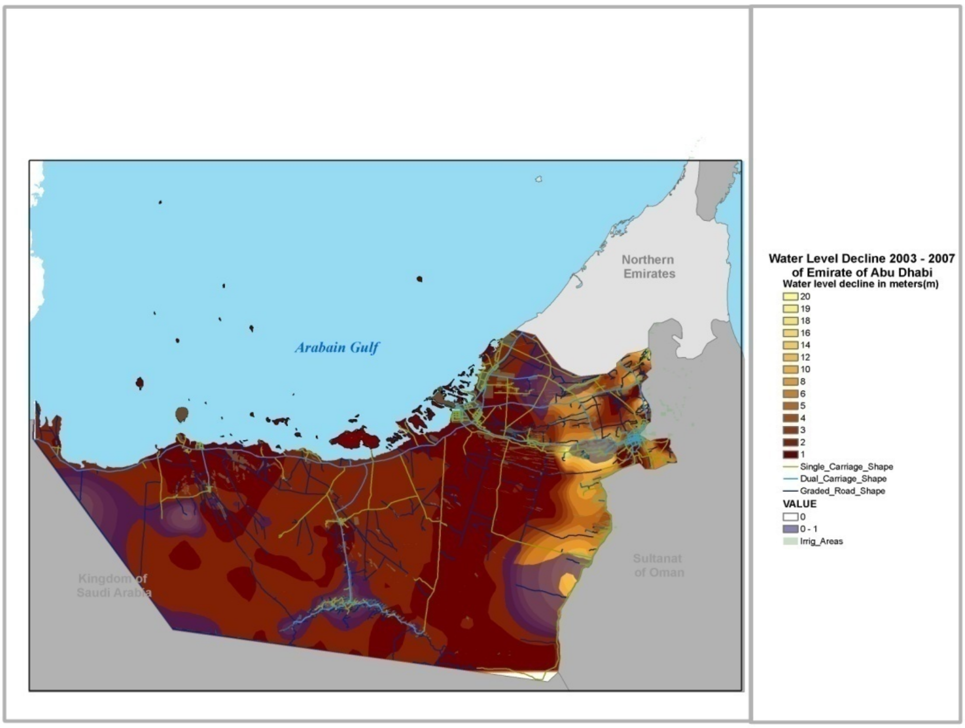
Below is the spatial distribution of water level decline:

Figure 9 Water level decline, 2003-2007



The map below is produced based on wells with depths no greater than 100m. The area in the vicinity of municipality of Al Ain, Remah, and Al Qua'a from the eastern Abu Dhabi Emirate had declines of 10 to 20 meters.

Figure 10 Water level decline representing areas with strong and very strong decline 2003-2007



b) Water Consumption in Domestic Sector (liters/person/day)

Target: 350litres/person/day

Between 2001 and 2006, per capita domestic water consumption has increased from 385.3 to 697.6 daily liters per capita, an 81% increase from the baseline. Emirate residents are increasing their use at a very rapid pace despite rapidly depleting water resources.

Table 2.19 Domestic Water Consumption Per Capita 2001-2003, 2006

Indicator	2001	2002	2003	2006
Daily water consumption for domestic use per capita (cubic meters)	140.65	172.57	218.67	254.64
Daily water consumption for domestic use per capita (liters)	385.33	472.79	599.11	697.63
Daily water consumption for domestic use per capita (gallons)	101.79	124.90	158.27	184.29

Because of the arid habitat and scarce water resources, the main source of water for domestic needs is desalinated water.

Table 2.20 Percent of Water Consumed that is from Desalination, 2001-2003, 2006

	2001	2002	2003	2006
Total Emirate	95.00	95.30	95.60	98.60
Eastern region	22.85	19.74	21.78	14.09
Central and Western	72.14	75.53	73.78	84.48

The water consumption per capita is twice the Abu Dhabi Emirate goal for year 2013, which is 350litres/person/day. A high mean annual population growth rate of 5% from 2001 to 2006 has resulted in a mean increase in the daily per capita water consumption by 22% over this period.

Table 2.21 Total Population by Region and Annual Population Growth 2001-2003, 2006

	2001	2002	2003	2006
Total Population	1,125,365	1,215,218	1,258,352	1,292,119
Western Region		804,474	847,032	858,650
Eastern Region		410,744	411,320	422,340
Islands				11,129
Annual Population Growth Rate	3.92%	7.90%	3.70%	3.70%

The daily water consumption per capita in Abu Dhabi Emirate is one of the highest in the world. The distance to target is 0 for this indicator.

c) Water stress index

Target: Maximum of 100% of water used from renewable sources (including desalination)

Based on ADWEA water publication, we have the following data on the above mentioned formula components:

Table 2.24 Renewable water supply (millions of cubic meters)

	2002	2003	2006
Total	818.2	884.74	1192.3
Rainfall	0.00	0.00	0.00
Groundwater*	300.00	300.00	300.00
Desalination	377.41	554.24	742.41
Treated wastewater	140.79	130.85	149.89

*This amount is considered the maximum sustainable yield for ground water

The following data relate to water use are available from ADWEA.

Table 2.25 Water Use by Type (millions of cubic meters)

Water use	2002	2003	2006
Total	3,221.22	3,439.68	3,123.30
Domestic - from wells	20.84	25.78	10.28
Domestic and agriculture desalination	419.70	554.20	708.31
Agriculture - wells	1,963.90	1,949.36	1,741.39
Forestry	512.00	607.30	362.38
Amenities	255.98	245.04	233.20
Industry	48.80	58.00	67.74

Using the formula of calculation for water stress index, we get the following scores:

	2002	2003	2006
Total	393.70	388.78	261.96

The proximity to target is 44.86 of 100.

DISCUSSION AND CONCLUSIONS

Water resource assessments are critical to sustain resource development and security in arid climates. Therefore policy targets for sustainable use must balance raising demands and limited if not shrinking supply. There is widespread awareness that water use is beyond the renewable supply. The primary use of these indicators will be to help identify sectoral consumption that is beyond the capacity of ADE's limited water supply and to make necessary adjustments. The spatial information can also help to identify areas that are particularly prone to over-abstraction of groundwater resources, leading to salinization of aquifers. Monitoring these indicators will allow EAD to target policies to address both reduction in water consumption and prevent further deterioration in water quality (EAD, 2008).

EAD should start monitoring some of the groundwater indicators surveyed by international organizations:

1. Renewable water resources per capita (UNESCO, FAO, National Committees of IHP, IGRAC)

Groundwater renewable sources include also artificial recharge, which currently exist in Abu Dhabi Emirate. This indicator measure availability of groundwater resources necessary for social and economic development.

The formula is:

$$\text{Groundwater renewable resources}[m^3/\text{year}]*100/\text{Inhabitants}$$

2. Total groundwater abstraction/Groundwater recharge(regional water authorities)

Groundwater abstraction as part of groundwater recharge at the catchment scale, including natural and induced recharge, is one important indicator. A few EAD publications report that groundwater recharge rate was less than 4% in 2006 in Abu Dhabi Emirate. However, spatial data on groundwater recharge (regional, or emirate maps) are not available. Groundwater abstraction represent the total withdrawal of water by means of wells, boreholes or other ways for domestic, agriculture, industrial or other use.

This indicator attempts to evaluate sustainability of abstraction of groundwater resources.

The formula is:

$$\text{Total groundwater abstraction}[m^3]*100/\text{Groundwater recharge}[m^3]$$

3. Groundwater abstraction as part of exploitable groundwater resources(UNESCO, IAEA, National Committees of IHP, WWAP,IGRAC, IAH)

Exploitable water resources represent the amount of water that can be annually abstracted, considering socio economic conditions, as well as political and ecological factors. This indicator also helps to evaluate sustainability of abstraction of groundwater resources.

The formula is:

Total groundwater abstraction[m^3]*100/Exploitable groundwater resources[m^3]

Indicators 2 and 3 can be used together to identify possible aquifer depletion problem.

4. Groundwater depletion (UNESCO, IAEA, National Committees of IHP, WWAP,IGRAC, IAH, regional water regulators)

This indicator reveals the excessive groundwater exploitation, and helps evaluate the groundwater resource management. The depletion problems can be identified in areas with high density of production wells (frequent in Abu Dhabi Emirate), areas with change in groundwater characteristics (decrease in water quality), or land subsistence

The formula is:

Σ Area with groundwater depletion problem * 100/ Σ areas of studied aquifer

5. Exploitable non renewable groundwater resources/annual abstraction of non renewable groundwater resources (UNESCO, IAEA,UNECE, WWAP, IGRAC, IAH)

The annual abstraction is calculated as average over a significant range of years. This indicator estimates lifetime of non renewable groundwater resources, with very low or no recharge. This is an important indicator for shared aquifer management. This indicator measures the importance of groundwater resource for population in rural areas.

The formula is:

Total exploitable non renewable groundwater resources[m^3]* 100/Annual abstraction of non renewable groundwater resources[m^3/year]

6. Dependence of agricultural population on groundwater

The formula is:

Number of agriculture farmers and livestock farmers using groundwater*100/Inhabitants

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CONSERVATION/PROTECTION OF ECOSYSTEM AND NATURAL LIVING RESOURCES (BIOTIC)

General overview

Biological diversity, essential for human well-being, is vulnerable to the impacts of human activities. A rich diversity of species and healthy ecosystems provide essential ecological functions as well as services that are critical to human activities. Biodiversity is also central to recreation and tourism. Strong policy instruments are required to reduce the rate of loss and address major threats to biodiversity such as climate change, pollution, and habitat change and maintain ecosystem integrity.

Pressures on natural ecosystems emerge from rapid population growth, urbanization, land exploitation, habitat degradation, multiple forms of pollution, invasive species, and climate change. In response to these multiple pressures, the global community agreed to the Convention on Biological Diversity (CBD), a landmark international law that catalyzed efforts to maintain sustainable use of biological diversity and pursue important conservation efforts.

CONSERVATION POLICY REVIEW

OVERVIEW OF THE CONSERVATION CATEGORY IN ABU DHABI EMIRATE

The emergence of an oil-based economy in the 1960's brought parallel development and changes to the region's infrastructure and population demands. The significant increase in population and standards of living has increased pressures on natural resources. As outlined in other indicators, deteriorating water quality, increased air pollution, unsustainable agriculture practices, and poorly managed waste disposal have direct impacts on natural ecosystems and species health. The majority of the population is clustered along the coastal regions, creating pressure on fragile marine habitats (EAD 2008). Coastal development has lead to habitat loss, fragmentation, and degradation. Industrial development is primarily located along the coast, utilizing seawater for desalination and cooling, increasing risks to marine environments and threatening existing mangroves.

Abu Dhabi is placing high priority on developing and implementing integrated approaches to conserve biological diversity and to ensure its sustainability (EAD 2008, 76). Approximately 4% of the UAE's total area is currently set aside as protected areas. Yet implementation of conservation laws remains weak and further information is needed to fully understand the dynamics and areas of concern.

THE EAD POLICY REVIEW PROCESS: PRIOR STATEMENTS, TARGETS AND STRATEGIC DIRECTIONS

EAD is shifting away from a species approach to a system-wide approach. The general strategy focuses on developing sound science for conserving biological resources through research, baseline data, and monitoring of ecosystems (EAD 2008, 80). The recent five-year strategy identifies several key targets with associated performance indicators to improve conservation of the region's biological diversity. A significant constraint for policy formation remains the lack of data on threatened species and resources for implementing the strategy (EAD 2008, 78).

EAD has already implemented the following programs in their policy and regulatory frameworks. Under current system marine regulatory system, EAD provides licenses and permits for commercial fishing, recreational fishing, traditional fishing, fishing gear, fisherman trainees, recreation diving institutions, and fishing rights in traditional seas (EAD Law No. 23, 1999). The EAD is monitoring bird migration to support National Avian Influenza Action Plan. They also have a program to collect and classify different groups of taxa of invertebrates. The Al Wathba Reserve was established in 1998 to conserve bird species and their habitats and now protects more than 240 species. Following this there are currently proposals to create the Jebel Hafit National Park and the Arabian Oryx Protected Area. There are three marine protected areas – Marawah, Al Yasat, and Bul Syayeef – and comprehensive fisheries data, including monitoring of fishing and marine resources by UAE since 2001.

The EAD five year Strategic Plan sets several clear goals and accompanying targets detailed below:

Table 2.22 EAD Strategic Plan for Conservation of Biological Diversity

EAD Priority	Target	Indicator	Time Frame for Achieving Results
Conserve Biological Diversity	Increase Protected Areas as percent of total areas to 12%	Protected area as a percent of total area	Increase to 12% by 2012
	Maintain the Percentage of Area Under Forest Plantations in Abu Dhabi at 1.84%	Percentage of area under forest plantation in Abu Dhabi	Maintain current level of 1.84% through 2012
	Increase the Number of Species in Ex-Situ Programs to 25 Species	Number of Species in Ex-Situ Programs	Increase number of species from 18 to 25 by 2013
	Increase the Fisheries Resources Status to 20 Key Species	Fisheries Resource Status	Increase from 5 species to 20 species by 2013
	Increase level of Compliance of Marine Ecosystems and Habitats to 8	Key Marine Ecosystems and Habitats: Composite Weighted Index	Increase from 1 habitat to 8 by 2013
	Increase Status of Key Marine Endangered groups to 3	Key Marine Endangered Species: Composite Weighted Index.	Increase from 1 to 3 species by 2013

	Conserve at least 90% of coastal and marine habitats	Percentage Loss of Coastal and Marine Habitats	Reduce percentage loss to 10% by 2013

INTERNATIONAL PRACTICE IN HOW TO MEASURE PROGRESS IN THE POLICY AREA

The anthropogenic pressures on natural resources and services derived from ecosystems have increased significantly over the past 30 years. The traditional approach to measuring conservation efforts have focused on specific resources. During the past few years, governments have reinforced the technique of a sectoral approach to measuring and monitoring natural resources (EPI, 2008). Instead the framework has been adopted considering a comprehensive ecosystem approaches.

The Convention on Biological Diversity has set specific goals, targets and timetables for global implementation of conservation efforts to preserve biodiversity (UNEP, 2000). For instance the CBD identified the Marine Tropic Index (MTI) as a key measure, where a declining slope of the trend reflects a greater risk of fisheries collapse. The agreement, first signed in 1992, has developed into a robust cooperation between nations with the 2010 targets and financing mechanisms to support efforts (UNEP 2000, 89) .This includes setting national priorities, reporting to the Secretariat on progress and key indicators, and support.

Other key international agreements include the 1971 RAMSAR convention on the Conservation of Wetlands. UAE has listed one site as protected under RA List of important wetlands and has agreed to include conservation of wetlands in the national land use planning. The Convention to Combat Desertification also has targets related to protecting land resources preventing degradation of ecosystems in drylands. Yet these major international agreements have not set specific compliance mechanisms, therefore only having limited effectiveness.

The Nature Conservancy defines effective conservation as areas where biodiversity is protected with expectations to continue as a result of conservation policies and actions. The TNC framework measures

The global EPI emphasizes the importance of monitoring data and consolidating information as a foundation of future policy measures. The EPI uses three indicators to assess biodiversity protection and as listed in the table.

Global EPI Targets

Table 2.23 Global EPI Targets for Biodiversity, Habitat Protection, and Marine Productive Natural Resources

Category	Parameter	Target	Details
Biodiversity and Habitat Protection	Conservation Risk Index	Global average ratio is 2:1 (converted: protected)	Measures the ratio of converted to protected land by biome or ecosystem type.
	Effective Conservation	CBD Target is 10% by biome within a country.	Measures the percentage habitat that has been effectively conserved within each biome by country; in this measure human impacted portions of protected areas are considered to be unprotected.
	Critical Habitat Protection	100% protection of critical habitats	Measures the percent area of critical habitats (coral reefs, mangroves, sea grass, and salt marsh) that are protected.
Productive Natural Resources /Fisheries	Trawling Intensity	0%	Measures the percentage of shelf area that is fished by trawlers. This is calculated with data from fish landings and the gear used to catch these fish.
	Marine Trophic Index	No Decline- Slope of trend line is positive or zero.	The indicator averages trophic levels for the overall catch (from fish catch data) after assigning a number based on the species location on the food chain.
	Marine Protected Areas	10% of EEZ waters.	Measures the fraction of the countries exclusive economic zone that are protected.
Productive Naturale Resources/Forestry	Change in Growing Stock	No decline	Measures the ratio of standing tree volume of the forest resources.
Productive Natural Resources/Agriculture	Irrigation Stress	0%	Measures the percentage of irrigated areas located in water stress areas.
	Agricultural subsidies	100	Measures the agricultural subsidies represented by the Nominal Rates of Assistance (NRA) by country. The NRA is defined as the price of a product in the domestic market less its price at a country's border, adjusted for transport costs and quality differences.

	Intensive Cropland	0%	Measures the percentage of cropland that is in agriculture dominated landscapes. The 2008 EPI sets a target of 40% uncultivated land in areas of crop production, although this figure includes grazing land and settlements, so is quite conservative.
	Pesticide Regulation	22 points as 0 represent the lowest score and 22 the highest	Examines the legislative status of countries on two landmark agreements on pesticide usage, the Rotterdam and Stockholm conventions, and also rates the degree to which these countries have followed through on the objectives of the conventions by limiting or outlawing the use of certain toxic chemicals.
	Burned Areas	0%	Measures the percentage of country area burned

AD-EPI INDICATORS AND INTERPRETATION

Habitat Protection and Effective Conservation

The first subcategory measures the status of terrestrial and marine conservation. The EPI uses the percentage of protected area to total area is a key indicator. More specifically, conservation of habitat must be accompanied with adequate implementation authority, conducting inspections and preventing incursions. For marine protection, similar analysis must be conducted of zoning and protected areas and enforcement capabilities.

Species Protection and Conservation (Flora and Fauna)

There is a need to identify vulnerable species both listed as protected and others in vulnerable ecosystems, threatened by the wide array of hazards. This indicator identifies conservation programs, number of species under protected status to indicate the current efforts to protect vulnerable species.

Productive Natural Resources

The protection of forests, fisheries, and productive agricultural land are central for natural resource management in the Emirate. This requires information on current land cover patterns, percentage of land being irrigated for forestry or agriculture, and the state of the fisheries.

Table 2.24 AD-EPI Indicators for Conservation and Natural Living Resources

Category	Sub- Category	Indicators	EPI Policy Goal and Description
		Habitat Protection	The indicator provides a measure of the proportion of the Emirate's natural habitats that are actively protected. The percent of national territory that is protected has long been recognized as an important conservation indicator. This indicator measures the percentage natural habitat that has been effectively protected. Only those protected areas that are known to have well developed management goals and plan in place are included, effectively removing from consideration those areas that are protected "on paper" but not in reality. The target is 12% of each of the Emirate's marine and terrestrial habits.
Ecosystem Restoration	Ecosystem Restoration	Habitat rehabilitation and restoration	This indicator measures the change in extent of habitats that have been restored. The annual area of habitats rehabilitated or restored can be tracked, and the goal should be to increase the area restored from year-to-year.
Species Protection and Conservation (Flora and Fauna)	Terrestrial and Marine	Terrestrial Species Abundance	Tracking changes in species abundance will help the Emirate to put into place conservation mechanisms before species reach a critical state of endangerment. This indicator measures the ratio between the current abundance and the previous recorded abundance for endangered birds, mammals and amphibians using consistent population estimation techniques over time. If the highest recorded abundance is in that year, the score is 100% and the target for future years is reset (assumes standard transects and methods).
		Marine Species Abundance	Tracking changes in species abundance will help the Emirate to put into place conservation mechanisms before species reach a critical state of endangerment. This indicator measures the ratio between the current abundance and the previous recorded abundance for Dugongs and Sea Turtles across the five zones; if the highest recorded abundance is in that year, the score is 100% and the target for future years is reset (assumes standard transects and methods). The goal is to find an equal or upward sloping trend.
Productive Natural Resources	Fisheries	Marine Trophic Index (MTI)	The MTI expresses the abundance of fish with high trophic levels in a marine ecosystem. It measures the mean trophic level of fish catch from landings fisheries in exclusive economic zones. Fish species are given a MTI value from 1 to 5 based

			on position in the food chain. This creates a time series to show the trend of increase or decreasing trophic levels. The target is to have a sustainable fishery meaning a zero or positive slope trend. The Fishing in Balance (FiB) measures the balance between quantity of fish harvested and trophic levels, and is a meaningful indicator to follow when the MTI shows a negative trend. FiB indicates two trends: it identifies if the decrease in MTI is related to the increase in fish catches or to another phenomenon (for example the result of a voluntary down fisheries policy). The FiB also indicates when fisheries have expanded geographically. Given an estimate of the energy transfer efficiency between trophic levels, the FiB is designed to maintain a value of zero when a decrease in trophic level is matched by an appropriate catch increase. The target is to have a positive trend.
		Fish Resource Status (FRS)	Relative spawner biomass per recruit is a proxy for the adult stock size used to evaluate the status of fisheries resources. It is routinely calculated on an annual basis for the three most important commercially exploited species in the demersal fishery of Abu Dhabi; Epinephelus coioides (Hamour), Lethrinus nebulosus (Shaari), and Diagramma pictum (Farsh). The indicator is derived from a population model with input parameters that relate to population dynamics (e.g., growth rate and the age at maturity) and fishery characteristics (e.g., the age at first capture and fishing mortality rate). Meta analyses of the relationships between stock sizes and recruitment (Mace 1994) have produced biological reference points against which the SBR is compared in order to infer the status of the population (if it is over-exploited or not). The target reference point is a SBR of 40% and the limit reference point is a SBR of 30% which management should avoid in order to prevent stock declines.
	Agriculture	Farm areas expansion	Tracks the change of land used for farming. The farming land area is defined by the following land uses arable land, crop land, and pasture land. Given a time series data on the farming land area, this indicator will measure the agriculture rate expansion. The target is zero expansion.
		Forest area expansion	Tracks the change of land covered by forest plantations. Using time series data on the forest plantations areas, this indicator will measure the forest rate expansion. The target is zero expansion.

		Percent area with pesticide residue	The immense expansion in the agriculture sector over the past 20 years led to groundwater pollution from agriculture activities from extensive use of fertilizers, pesticides and/or form the agriculture landfills. About 406 pesticides are used in agriculture in the UAE, as shown in (EAD, 2008). List of pesticides used in farming in the UAE (MAF, 2004)

No.	Classification	Number	Use
1	Insecticides	83	Allowed
2	Soil Insecticides/Nematocides	13	Allowed
3	Acaricides	4	Allowed
4	Fungicides	61	Allowed
5	Natural and Bio-Pesticides	24	Allowed
6	Insect Growth Regulators	9	Allowed
7	Herbicides (Restricted)	18	Restricted
8	Chemosterilizers (Restricted)	6	Restricted
9	Pheromones	14	Allowed
10	Deodorizers	5	Allowed
11	Adjuvants	6	Allowed
12	Restricted pesticides	34	Restricted
13	Miscellaneous	6	Allowed
14	Public health (General)	87	Allowed
15	Public Health (Restricted)	31	Restricted
16	Public Health (Miscellaneous)	5	Allowed
	TOTAL	406	

		Annual agriculture and forestry subsidies	Agriculture and forest plantations are heavily subsidies in Abu Dhabi emirate. This indicator measures the annual change in bad subsidies, i.e. those subsidies that do not encourage water saving, which is of critical concern in the emirate.

RESULTS

Results are presented here for only those indicators in the above table for which data were available. It is expected that in future years the ADEPI will include additional indicators as data become available.

1) Habitat Protection and Effective Conservation

a) Habitat Protection (HABPROT)

Target: 12% of each habitat in protected areas

The following table shows the proportion of the Emirate's terrestrial and marine habitats that are effectively protected. Effectively Protected Areas are those protected areas with well-developed management plans. The effectively protected area by habitat is capped at 12% (so that it is not possible to compensate for under protection in one habitat type by exceeding the target in another habitat).

Table 2.25 Description of Habitat Types and Characteristics

	A	B	C	D
Critical Habitats	**Habitat Area (ha)**	**Area Protected in Each Habitat**	**Percentage of Habitat Protected**	**Habitat Protection Score Capped at 12%**
Coastal	542,381	37,879	6.984	6.984
Coral Reef - Deep	1,132	0	0.000	0.00
Coral Reef - Shall	29,850	3,055	10.235	10.235
Ghaf Zone	1,294,751	0	0.000	0.00
Gravel Plain	92,062	0	0.00	0.00
Liwa Dunes	1,314,031	0	0.000	0.00

Mangrove	53,466	18,178	34.00	12.00
Sabkha	239,102	0	0.00	0.00
Seagrass Deep	21	0	0.00	0.00
Seagrass Shallow	44,911	12,007	26.74	12.00
Western Desert	4,558,335	629	0.01	0.01
Total Habitat Protection(HABPROT) Score (sum of weighted contributions):				3.75%

The Emirate average of the percentage of protected habitat is 3.75%, which is a nearly one third of the way towards the target. This yields an HABPROT indicator proximity-to-target score of 31.25 out of 100. The results show that only shallow seagrass and mangroves reach or exceed the threshold of 12% effective protection. However, the tiny size of these two habitats constitute less than 1% of Emirate's territory, and their relative ecological importance may in fact demand higher levels of protection.

In the future we recommend that this indicator measure ecosystem protection.

2) Species Protection and Conservation

a) Status of threatened marine species

Target: no decline in the population trend of dugongs and sea turtles

The following table shows the evolution of dugongs and sea turtles population of the the Abu Dhabi waters in 2001 and 2004. Dugongs (Dugong dugon) and sea turtles (hawksbill turtles (Eretmochelys imbricata) and green turtles (Chelonia mydas)) are two of the most endangered marine species in the Abu Dhabi waters. These sea turtles are listed in the IUCN Red List (2000) as critically endangered and endangered, respectively. The results are based on aerial surveys during the summers and winters of 2001 and 2004, conducted in five zones including the Marawah marine protected area, along transects (36 for the dugongs, 79 for the sea turtles).

Table XX :Estimated Population of Dugongs, February 2001 and February 2004

Zone	No of transect	Area covered Km2	Estimated population		Density		Ratio	Ratio, capped at 1
			2001	2004	2001	2004		
1	7	2,100	1,096	1,050	0.52	0.5	0.96	0.96
2	7	850	358	650	0.42	0.76	1.81	1.00
3	7	1,068	372	300	0.34	0.28	0.82	0.82
4	7	1,140	124	50	0.1	0.04	0.40	0.40
5	10 (8)	1,539 (1,296)	235	875	0.15	0.67	4.47	1.00
	38 (36)	**6,697 (6,454)**	**2,185**	**2,925**	**0.326**	**0.453**	**1.39**	**0.84**

Table XX :Estimated Population of Sea Turtles, February 2001 and February 2004

Zone	No of transect	Area covered Km2	Estimated population		Density		Ratio	Ratio, capped at 1
			2001	2004	2001	2004		
1	7	2,100	2,070	2,400	0.99	1.14	1.15	1.00
2	7	850	690	570	0.81	0.67	0.83	0.83
3	7	1,068	870	420	0.81	0.39	0.48	0.48
4	7	1,140	630	60	0.55	0.05	0.09	0.09
5	10 (8)	1,539 (1,296)	1440	2,100	0.93	1.62	1.74	1.00
	38 (36)	**6,697 (6,454)**	**5,700**	**5,550**	**0.851**	**0.859**	**1.01**	**0.68**

Given the area of surveys, the density of species has been calculated (number of species per Km2). From this information, a ratio representing the change in density from 2001 to 2004 has been derived. The results show that the population of dugongs and sea turtles are relatively stable. However, the population is unequally distributed within the different zones of study. Dugong populations experienced a significant decline in zone 4 during the period of the study (ratio = 0.4), and to a lesser extent in zones 1 and 3 (ratio = 0.96 and 0.82). Conversely, zone 5 has a population of dugongs that is four times larger in 2004 when compared to 2001 (ratio = 4.47).

A similar situation is observed regarding the status of the population of sea turtles. Almost all species have been depleted in zone 4 (ratio = 0.09), and the population reduced with more than half in zone 3. Generally speaking, even if the overall measurements of the population of dugongs and sea turtles are stable, policy strategies should focus more on these zones identified as experiencing a critical decline of the marine species population trend. Therefore, special attention should be given to the regions of Al-Yasat, Umm Al Hatab and Al-Sila. The decline in population of endangered marine species may reflect an important degradation of their marine habitat in these areas. This will impact on the reduction of marine biodiversity in the Abu Dhabi waters.

The table below summarizes the proximity to target of the conservation of endangered marine species in the Abu Dhabi waters. The results show that generally speaking, Abu Dhabi Emirate attained the target to maintain the population of dugongs and sea turtles in the marine studied zones as stable. However, zone 4 is only has proximity to target scores of 40 and 9, for dugongs and sea turtles respectively, zone 3 scores just above zone 4, at 82 and 48 for dugongs and sea turtles respectively.

Species	Proximity to target in the zones of surveys from 2001 to 2004					
	zone 1	zone 2	zone 3	zone 4	zone 5	All zones
Dugongs	96	100	82	40	100	84
Sea turtles	100	83	48	9	100	68

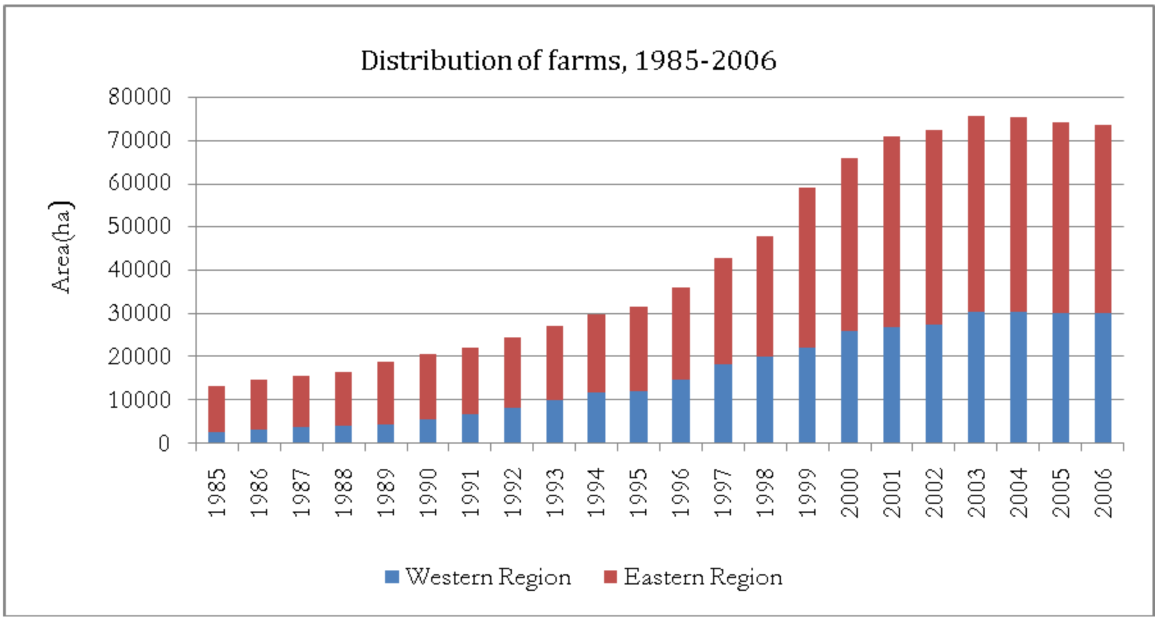
3) Productive Natural Resources

a) Farm areas expansion

Target: No expansion in the area of citizen farms

This indicator is represents the expansion in citizen farms in Abu Dhabi Emirate. The graph below represents the distribution of citizen farms between 1985 and 2006. The rate of increase in citizen farm areas averages at 14.4% for the western region and 8.6% for the eastern region between 1985 and 2002. The average rate of increase of the emirate is 10.52%. The maximum rate of increase for Abu Dhabi Emirate was recorded in 1998, with 23.54% increase compared with the previous year.

Figure 11 Distribution of Farms 1985-2006



The expansion is currently restricted, and some farms are closed due to exhaustion of ground-water supplies. The proximity to target is 100%.

b) Marine Trophic Index (MTI)

Target: Positive trend of >= 0

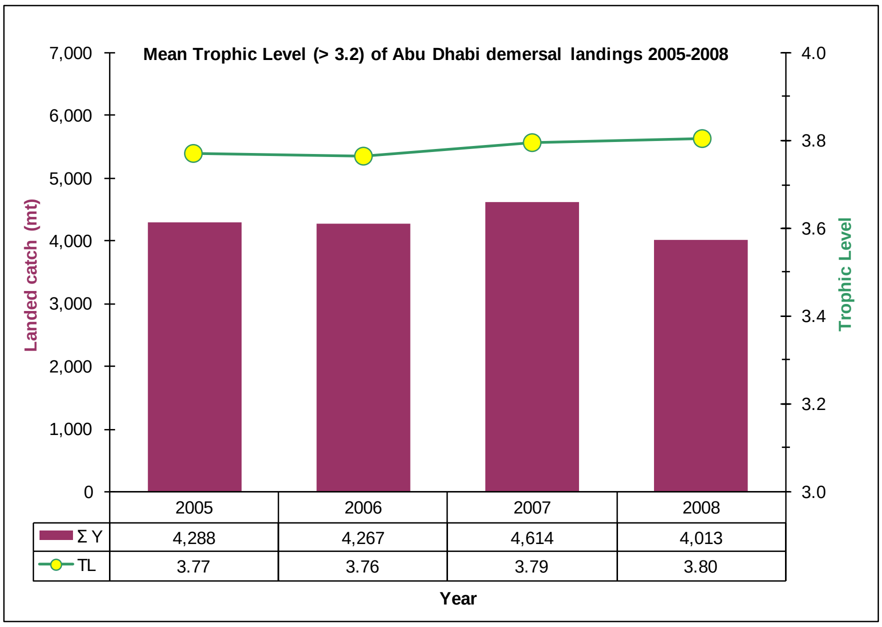
Marine Trophic Index is the name given by the United Nations Convention on Biological Diversity (CBD) for the mean trophic level of fishery landings, originally conceived by Pauly (Pauly et al, 1998). The marine trophic level ranges from 1 in plants to 4 or 5 in larger predators. It expresses the relative position of fish and other animals in the hierarchical food chain that nourish them. These low trophic level animals or plants provide food for small fish which have a trophic level of about 3, and the small fish are eaten by slightly larger fish that have a trophic level of 4, which, in turn, are what large predators such as sharks and marine mammal and humans typically eat (Pauly, 2003). If the average catch level at which a country is catching fish declines over time, it means that the overall trophic structure of the marine ecosystem is becoming depleted of larger fish higher up the food chain, and is resorting to smaller fish, this is called the "fishing down" effect.

Given the short time series recorded for the Emirate's fisheries, we are cautious in our interpretation of the results for this indicator. The mean trophic level has been calculated from 74 species present in ADE waters. Pauly et al. advise basing the calculations on species for which trophic level is above 3.25 in order to eliminate the bottom-up bias, which results in a decrease of mean trophic level due to the increase in the numbers of small pelagic fishes.

The figure below represents the MTI trend from 2005 to 2008, based on the landing statistics of demersal fish species by the commercial fisheries in ADE waters. Generally speaking, the MTI shows a positive trend over the years 2005 – 2008, indicating that the phenomena of "fishing down" the food chain is not apparent in Abu Dhabi Emirate waters.

The absolute amount of demersal landings from 2005 to 2008 indicates that more than 99% of catches are fishes with a trophic level higher than 3.25, supporting the results of the MTI indicator.

Figure 12 Mean Tropic Level of Abu Dhabi Demersal Landings



The table below represents the corresponding FiB of each MTI value in Abu Dhabi from 2005 to 2008.

Table 2.26 Fishing in Balance and MTI Values

Year	Sum of Landed Catch	Mean Trophic Level	FiB
2005	4.288	3.77	0.00
2006	4,267	3.76	-0.01
2007	4,614	3.79	0.06
2008	4,013	3.80	0.00

The MTI index shows a small dip in 2006, by 0.01 related to the MTI level in 2005, followed by positive values in 2007 and 2008. Given the rather short history of only four years, the recommendation is to continue the time series of good quality landing statistics.

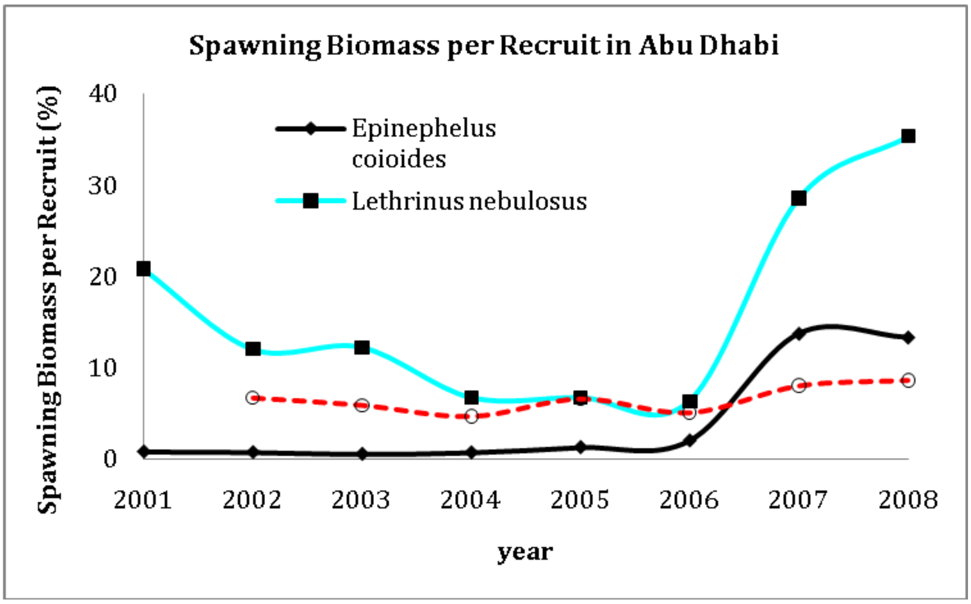
c) Fish Resource Status (FRS)

Target: 40% of the Spawning Biomass per Recruit

The Fish Resource Status (FRS) is a stock assessment indicator based on the Relative Spawning Biomass per Recruit (SBR). The spawning stock biomass per recruit estimates the expected lifetime reproductive potential of an average recruit, which is an important correlate of population growth potential (Goodyear 1993).

The common target used in international convention fishery is 40% of the unexploited level. Figure below shows the Spawning Biomass per Recruit (SBR) of the three key demersal of ADE from 2001 to 2008.

Figure 13 Spawing Biomass per Recruit



Fisheries are considered as sustainable when the current SBR is above the 40% of unexploited level. In other words, leaving a minimum of 40% of spawner population will insure rebuilding of the stock. If the biomass of spawner is below this target point, there is oversfishing. The FRS has been calculated based on the three most endangered species in the Abu Dhabi Emirate waters: the Epinephelus coioides (Hamoor), the Lethrinus nebulosus (Shaari), and the Diagramma pictum (Farsh).

Since a target score of 40% of the SBR has been settled for ADE fishery, we decided to use a proximity-to-target approach for calculating this indicator. In other words, we evaluate how far Abu Dhabi is from the SBR target score, in terms of sustainable fishery management.

The performance is measured between 0 and 100, with 100 corresponding to the target, which is an SBR of 40%. The following table shows the perfomance of Abu Dhabi equivalent to the calculated SBR from 2001 to 2008 (values are in percentage).

Table 2.27 Annual SBR from 2001-2008

Year	Epinephelus coioides	Lethrinus nebulosus	Diagramma pictum
2001	1.93	52.00	No data
2002	1.78	30.00	16.75
2003	1.28	30.50	14.75
2004	1.70	16.75	11.75
2005	3.13	16.75	16.50
2006	4.97	15.75	12.75
2007	34.25	71.25	20.00
2008	33.23	88.25	21.50

The results show that despite an increasing efforts in managing sustainably fisheries in Abu Dhabi, the three key species are still over-exploited. To measure the performance of Abu Dhabi toward the SBR target of 40% : 0 is the lowest value, which means the farthest point from the target and 100 is the highest value, which means achieving the target. If the epinephelis coioides were only at 2%-3% of the target from 2001 to 2005, results show that they are at 33%-34% these last years. Since 2007, there is a positive change in the status of these species showing more than 30-40% improvement. Even if the lethrinus nebulosus experienced a depletion from 2002 to 2006, 2007 marks a big positive shift in their status approaching the target at 71% and 88% in 2008. Finally, the diagramma pictum species are making little progress and the stock assessment shows that Abu Dhabi is still far from the reference point target: at only 21% on 2008 for these species.

DISCUSSION & CONCLUSION

The habitat protection indicator indicates that the Emirate could be doing more to protect habitats, especially the most vulnerable coastal habitats. The Emirate is about one-third of the way towards its own target for protected areas coverage of 12%. Conservation of important marine species is fairing slightly better with proximity to target scores of 84 and 68 respectively for dugongs and sea turtles, meaning populations are at least not declining rapidly. .

In terms of fisheries, there appears to be a slight positive trend in marine trophic level which is to be encouraged and developed. However, the fish resource status indicator based on the SBR indicates that the three most endangered commercial species in Abu Dhabi remain over-fished despite an improvement in fisheries. The Emirate did not reach the half way towards the target regarding the Hamoor and Farsh species (respectively the Epinephelus coioides and Diagramma pictum), even if the Shaari (lethrinus nebulosus) species is very close to the spawning biomass target.

Discussion of potential additional policy goals/priorities

There are several areas that require additional information, data, and research. The habitat protectio measure would be improved it were based on a more refined map of ecosystems. One measure that is currently under development is the vulnerability index of coastal zone management. A clear goal for EAD experts is to finalize the designation of marine protection zones and identification of critical marine habitats. This is part of the strategic plan and would allow further indicator construction.

Data on agricultural subsidies and economic incentive programs were limited and are important components of different policy tools. These subsidies are key data for the global EPI analysis of agricultural land. The agricultural sector is highly related to the water management area, therefore, improvement in the water use data collection (wells functionality, salinity, irrigation system, groundwater level) is critical for an efficient agricultural management.

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SUSTAINABLE LAND RESOURCES USE AND LAND COVER (ABIOTIC)

General overview

Land use is the term that is used to describe how humans "use" or define the purpose of certain landscape types, and is related to (but distinct from) land cover, which refers to the actual biogeo-physical surface conditions or cover types that characterize specific areas of the earth's surface. For example, grasslands are a type of land cover that is characterized by dominance, biologically and ecologically, of grasses, and which can be further sub-divided into ecological characteristics depending on whether they are more or less "natural" or "human-modified". Furthermore, there can be sub-types that vary with latitude, climate, landforms, as well as extent of human modification. Some examples of grassland land cover types include largely natural ecosystems such as prairies, steppes, and savannahs, and human modified types such as pastures, lawns, or golf courses. On the other hand, a land use category refers to how certain areas are defined in terms of human use or utility, e.g. for agriculture (pastures), recreation (golf course) or urban landscaping (lawns). Furthermore, a specific land use category may include multiple cover types just as golf courses may include both forest as well as grassland cover types whose purpose or "use" is recreation as compared to agriculture or urban landscaping.

It is important to note that "forest" or "grassland" as land cover types refer to their structure and morphology and not to their use. Both a natural forest and an African Oil Palm plantation are in the same land cover class, whereas their "land use" categories are quite different. One may be a natural reserve or park and the other is for agriculture. In terms of "grassland" both a cornfield and mountain meadow may be classified into the same land cover category, but their land use is radically different. Furthermore, there will be major differences in terms of biodiversity between the natural forest versus the tree-crop plantation or cornfield versus the mountain meadow. Therefore, knowing precisely the distribution of land use as well as land cover within specific regions down to fairly detailed level, is a crucial ingredient for any land resource management or planning process.

Land resource types can also be characterized by their associated soil (pedological) and land form (geomorphological) characteristics into broad landscape types that have specific ecological, biological, geological, cultural or even aesthetic attributes important to specific places and peoples. In Abu Dhabi certain desert dune areas (e.g. the Liwa) or coastal salt-flats (Sabkhas) have very unique soil chemical, physical, geological and biological characteristics that have important cultural and historical significance that is reminiscent of past livelihood patterns or other hazards typical of the hyper-arid coastal zone in the UAE.

Soils in particular, are of critical importance for land management in that they are the key interface zone at the earth's surface where terrestrial, atmospheric, aquatic, and biotic systems merge together to produce the conditions for the location of most human activities from agriculture to recreation or urban/settlement expansion. Protecting soil quality is vital to agriculture, forestry, wildlife, and many cultural uses. Therefore monitoring changes in soil conditions—i.e. evaluating the level of physical, chemical, or biological degradation is crucial to all types of land use and land cover planning, policy-making, or land resource management.

LAND USE POLICY REVIEW

OVERVIEW OF LAND DEGRADATION IN ABU DHABI EMIRATE

Abu Dhabi's natural environment is characterized by hyper arid conditions with sparse vegetation cover combined with increasing anthropogenic pressures leading to accelerated soil degradation. A primary concern from the perspective of land and soil resource management is the effect of wind erosion and increasing soil salinity. Erosion removes surface layers thus degrading the quality and quantity of topsoil which may impact its use for agriculture or pastoralism. Aeolian deposits are predominant in the Emirate desert environment. (EAD 2008,, 9). Naturally occurring high temperatures and low rainfall continually present challenges to improving or maintaining soil quality. These natural conditions place significant constraints on the land uses possible from the human perspective.

Human activities also threaten the vitality of naturally occurring ecosystems and soils. As identified in other policy categories, over-extraction of groundwater can lead to increased salinity. A heavy use of groundwater for irrigation can result in excessive soil salinization because of the high saline content of groundwater or surface water runoff as compared to that found in rainwater. Farm subsidies and agricultural policies support farmers continued expansion of livestock and overuse of rangelands. This may lead to overgrazing on what are already fragile grassland and desert ecosystems and soils. Land and soil degradation is also accelerated by the un-managed and excessive use of off-road vehicles for recreational purposes.

Another major concern for land use management is the extensive excavation of sands and gravel for construction material. The rapid rate of urbanization has a disproportionate impact on land resources both to provide the venue or space for settlement growth and associated recreational activities, as well as the source for raw materials such as gravel, sand, water, or agricultural products, e.g. fiber, timber, etc.

THE EAD POLICY REVIEW PROCESS: PRIOR STATEMENTS, TARGETS AND STRATEGIC DIRECTIONS

The primary concern for this category remains the lack of an Emirate wide comprehensive soil survey. EAD recently initiated a four-year Emirate (2006-2009) wide soil survey with emphasis on evaluating soil and soil mapping units for their potential uses (Shahid, 2004). This project, in partnership with the International Center for Biosaline Agriculture (ICBA) will produce a digital soil information database to support broad land use planning and agricultural expansion (EAD 2005). This project will use The results are not yet available. The previous soil map is very general and does not provide recent or focused data. The coastline has been identified as a priority area and was studied closely in an UAE wide soil survey in 2004 (EAD, 2004).

Other cross-cutting areas of concern are water and education. Increased soil salinity is linked with new water projects. Heavy irrigation using desalinated water does not provide the soil nutrients that normally come from surface or groundwater, while irrigation with saline water has increased soil salinity levels as well. Groundwater aquifer replenishing projects, specifically with saline water, can also dramatically change soil salinity levels.

Many aforestation projects are currently under way to prevent encroachment of the desert. The greenbelt efforts reduce movement of wind-blown sand and thus have helped expand the potential for agriculture or other landscaping. Abu Dhabi has set a strategic target in the Strategic Goals 2009-2013 of maintaining the current level of total forest cover, which represents 1.84% of the Emirate's land area. The potential trade-off for increased forest cover is additional stress on limited water resources. This concern is reflected in the water resources section

Similar to issues identified above, increased population growth and urban development is a significant driver impacting land use and land cover change. The continued construction boom requires raw materials for development.

The Strategic Goal 2009-2013 identifies several areas of land use change within their policy categories but not as one of the 13 key priority areas. Although these EAD priority areas are discussed in greater detail in other policy categories, they are briefly listed here with specific and relevant initiatives.

Table 2.28 EAD Strategic Goals for Land Use and Land Cover

EAD Priority	Target	Indicator/Initiative
Improve the Quality and Quantity of Water Resources	Reduce Water Stress Index	Reduce Salinity level
		Soil Survey
		Salinity Mapping and Monitoring
Conserve Abu Dhabi's Biological Diversity	Maintain Percentage of Area under Forest Plantation	Establish a Plant Conservation and Rehabilitation Program
Education	Increase Awareness	Formulate Emirate-Wide Environment Education and awareness policy and act
	Change Behavior	

INTERNATIONAL PRACTICE IN HOW TO MEASURE PROGRESS IN THE POLICY AREA

Policy Performance goals and objectives

The international community agreed to the terms of the United Nations Convention to Combat Desertification (UNCCD, 1994). The global recognition that desertification (or "drylands degradation") can cause major economic, social and environmental problems has galvanized efforts in desert regions like the UAE. The Greening the Desert program, led by the United Arab Emirates, is not only to combat desertification, but to increase vegetation cover in this otherwise hyper-arid setting partly to reduce the impacts of wind erosion. The program started in the 1980s but has been controversial due to the unsustainable use of groundwater for these human-managed forest plantation systems. The current strategic goal in Abu Dhabi is to maintain the current level of forest cover but to not to expand further afforestation efforts.

There is an absence of global data on the state of soil and land resource quality or quantity. The Global Assessment of Human Induced Soil Degradation (GLASOD) is one of the few comprehensive and uniform global assessment tools available but it has not been kept up-to-date (OECD, 2003). Recent efforts to update this information have focused on improving and recording methodologies used to collect data. The FAO's Land Degradation Assessment in Dryands (LADA) focuses on changes in net primary productivity (greenness) as reflected in satellite images, but this approach does not provide information on soil degradation per se which would need to include water management parameters, e.g. groundwater extraction as well as other measures of ecological health appropriate to the local environmental context. For instance, "greenness" per se may not be the most appropriate measure for what is naturally a desert environment. The 2006 EPI reported that a global organization would need to provide the impetus to improve global measurement of soil degradation if this type of assessment was going to be done seriously.

Recent efforts to use remote sensing data have improved the availability of global information on land cover. FAO and UNEP launched the Global Land Cover Network (GLCN) to help generate essential data needed for sustainable development and environmental protection programs. The Africover project successfully established a digital geo-referenced database on land cover for the whole of Africa. The initiative has also brought training and support to build individual countries capacity (FAO, 2005).

The European Environment Agency measures the soil erosion risk for semi-arid regions. They also collect data on soil type and soil contamination. The agency produces a soil erosion hotspot map, indentifying critical regions and providing objective comparisons which support policy decisions (EEA, 2003). The United States Department of Agriculture also sets criteria for measuring vitality of soil resources, focusing on physical, biological, and chemical indicators (USDA, 1996). The United States Geological Survey developed a national land use and land cover classification system in the 1970's consolidating data collection in order to support policy design. This effort was a response to concerns of loss of prime agricultural lands, uncontrolled development, deteriorating environmental quality, and loss of habitats (Anderson, 1976).

The global EPI measures the decline in subsistence crop yields instead of focusing on changing soil salinity levels. There were no specific indicators for surface or sub-surface land or soils resources in the last global EPI. And there are no direct measures of sub-surface (non-soil) resources that provide minerals, petroleum, gravel, sand, and other raw materials.

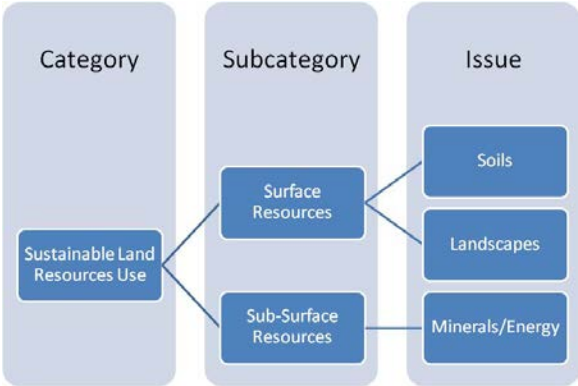
Global EPI Targets

There are no global EPI indicators for this category.

AD-EPI INDICATORS AND INTERPRETATION

Surface Resources

A number of economic activities can cause soil pollution as well and land/soil degradation. Urban development, over extraction of groundwater sources, and waste disposal are potential threats to the quality of surface and sub-surface land and water resources. And there is the potential for loss of critical archeological records or earth history remains and artifacts which portray past approaches to subsistence and survival in this harsh environment.



Sub-Surface Resources

Extraction or modification of sub-surface geological resources such as gravel or sand mining, petroleum or gas exploration, and other industrial activities impact the environment in several ways. They can cause damage to natural ecosystems and change land use and land cover patterns which in turn affect biodiversity, soil/land quality, and even aesthetic or cultural values associated with certain landscapes. There is also the potential for dangerous contamination from the byproducts (residue) left behind in the extraction process of modern extractive or industrial processing activities, e.g. heavy metals.

INDICATORS FOR MEASURING POLICY PERFORMANCE AND RESULTS FOR DECISION-MAKING:

These indicators will be developed at a future date in collaboration with soil experts. Examples of types of indicators that would be recommended include area affected by soil erosion, soil salinity, loss of soil biodiversity, waterlogging (for irrigated areas), compaction, and landfilling or mining activities.

DISCUSSIONS AND CONCLUSIONS

While this category has not been used in the Global EPI, it provides new opportunities for measuring the health and vitality of land resources. The relevance for this category is to measure areas of soil degradation in a time series to measure changes in the condition and management of soil erosion, salinization, or soil pollution and mineral extraction. Large scale cultivation of the soils for agriculture (afforestation) is limited by natural constraints. Therefore the policy target should be to prevent increased desertification (drylands degradation) a as well as reduce contamination resulting from mineral extraction activities. There should also be some consideration for preservation of key landscapes that have inherent aesthetic, recreational, or cultural values associated with specific "livelihoods" now rapidly disappearing, e.g. the desert dune environment or coastal sabkha which are reminders to the modern urban population of bygone livelihood patterns such as coastal fishing, pearl diving, desert nomadism and pastoralism, as well as hunting and gathering including falconry—the sport of kings.

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CLIMATE VULNERABILITY, ADAPTATION AND MITIGATION

General overview

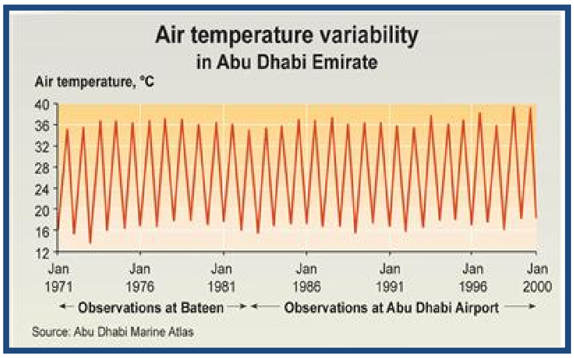
The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) finds that there is a high confidence that changing climatic conditions due to anthropogenic emissions of greenhouse gases will strongly affect terrestrial and marine biological and physical systems. This has led to interest in mitigation strategies to reduce their contribution to global greenhouse gas emissions, as well as adaptation strategies that can decrease vulnerability to current and projected future climate change.

Recent climate change models predict shifts in average temperatures and weather patterns with a range of potential impacts. Arid zones ecosystems are particularly sensitive to these environmental changes. The AR4 predicts a 1ºC or 2 º C increases in average temperatures for the Arabian Peninsula within the years 2030-2050. This could be accompanied by a decrease in already low precipitation levels, though precipitation is more difficult to model. The rise in temperature will bring increased evapotranspiration rates and greater vulnerability in this already arid region. With these predicted changes, a range of new vulnerabilities emerge impacting the water supply, agricultural productivity, fisheries, livestock, marine ecosystems, and soil quality.

CLIMATE POLICY REVIEW

OVERVIEW OF THE CLIMATE CATEGORY IN ABU DHABI EMIRATE

Air Temperature Variability



The risks posed by climate change reach across many sectors and issues areas. Many of the concerns already articulated in the water resources and biodiversity policy areas will be compounded by changing climate conditions. A possible rise in sea level of 0.5-0.8m in this century, as projected by the AR4, could cause further salt-water intrusion to coastal aquifers, while rising temperatures would damage dry ecosystems (UNFCC 2006, 11) The already extensive cultivation of land, estimated to be well beyond the level of naturally arable land, makes the Emirate more vulnerable to small climate shifts (FAO 2008, 13). The potential rise in sea level is also a serious threat to the region's development patterns as 85% of the population and 95% of infrastructure is built in low lying coastal regions.

Coral bleaching in the coastal areas of Abu Dhabi was first observed in 1996. These events are believed to be linked with rising sea surface temperatures (UNEP-GRID, 13).

The first comprehensive inventory study of greenhouse gases occurred in 1994. The data identified domestic and industrial energy use as the main cause of carbon dioxide emissions. The energy sector emitted roughly 95% of the total greenhouse gases (CO2, methane, nitrous oxide). Waste management, agriculture, and industrial processes are the remaining significant contributors according to this study (EAD, 2006; EAD 2008, 46).

The UAE submitted its first national communication to the Conference of Parties through the UNFCCC Secretariat in 2006. The report found that the UAE has among the highest per capita commercial energy consumption in the world at 33.6 metric tons of CO2 emitted per person per year. The 2002 figure dropped to 25.1 tons per capital per year, making the UAE the fourth highest emitter in the world (EAD 2008, 16).

THE EAD POLICY REVIEW PROCESS: PRIOR STATEMENTS, TARGETS AND STRATEGIC DIRECTIONS

As this report was being written, experts from EAD were drafting a new framework of action for climate policies in Abu Dhabi. This comprehensive policy review will provide opportunities for future indicator construction. EAD has taken an initial approach that outlines key strategies to effectively addressing climate change adaptation and mitigation goals. The emerging policy framework will focus on four key objectives: 1) build observation networks in costal zones, track GHG emission, and regional climate modeling; 2) mitigate greenhouse gas emissions with a focus on energy supply, transportation, residential, and waste management; 3) support adaptation measures in costal zones, water resources, and dryland ecosystems, and 4) build national capacity and awareness.

The UAE is signatory to the Kyoto protocol as a non-annex I country under the terms of the UN Framework Convention on Climate Change (UNFCC). The objective is to reduce emissions of key greenhouse gases by at least 5% from 1990-levels during the period of 2008-2012 (EAD 2008, 16).

In order to facilitate the implementation of projects within the Clean Development Mechanisms, in 2005 the UAE Cabinet of Ministers Decree Number 11 created a National Higher Permanent Committee for Clean Development Mechanisms. The committee's main role is to ensure that any activity within the framework of CDM will help achieve sustainable development in UAE. The committee is responsible for reviewing initial CDM project proposals prior to submission to the higher committee (Qawasmeh 2008, 32). EAD's current strategy has set a target of developing a climate change framework by 2013 with targets to continue building inventory data (EAD2008, 48).

Total GHG emissions in the UAE, 1994 (Gg)

Sector	CO_2-equivalent	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2
Energy	70,879	60,246	396	5	162	836	95	18,310
Industrial processes	3,455	3,443	1	0	1	138	6	5
Waste management	2,552	0	108	0	0	0	0	0
Agriculture	1,777	0	48	2	0	0	0	0
Land use change & forestry	-4,227	-4,227	0	0	0	0	0	0
Total	74,438	58,462	553	7	163	974	101	18,315

MASDAR, the Abu Dhabi Future Energy Company, established by Local Law No. (22) of 2007 has the mandate to develop a CDM implementation strategy and set the sustainable development criteria(Qawasmeh 2008, 32).

The EAD five-year Strategic Plan sets several clear goals and accompanying targets detailed below:

Table 2.29 EAD Strategic Priorities for Climate Change

EAD Priority	Target	Indicator	Target Results by 2013
Climate Change Framework	Develop and Implement Climate Change Framework	Policy Formation	100% Compliance by 2013
		Track CDM Project	100% Compliance by 2013
		UAE 2nd National Communication to UNFCC	Work with Ministry of Energy to complete by 2010
		Build Capability to Greenhouse Gas Emission Inventory	100% Compliance by 2013

INTERNATIONAL PRACTICE IN HOW TO MEASURE PROGRESS IN THE POLICY AREA

International standards are still being negotiated but were initially codified in the Kyoto Protocol, setting carbon emission limits reductions on certain Annex I countries by a 5% 1990 levels over the fiver year span of 2008-2012, creating markets for trading, and setting up technology transfers to less-developed countries. According to the UNFCCC "Emission reductions on the order of 60-80 per cent of 1990-level emissions would be necessary to stabilize concentrations of carbon dioxide in the atmosphere" (UNFCCC, 2006).

Below are the indicators and targets set by the global Environmental Performance Indicators. Some of these goals are recognized to be the theoretically idea target.

Table 2.30 Global EPI Targets for Climate

Parameter	Target	Details
Emissions Per Capita	50% below 1990 levels by 2050.	GHG Emissions/Total Population (Median Global Population Projection by 2050)
Industrial Carbon Intensity	0.85 Metric tons carbon dioxide equivalent per $1,000 USD	This measures the extent to which GHG's are being managed within a countries industrial economy. This is calculated through Industrial GHG Emission (Metric tones carbon dioxide)/ Industrial GDP
Emissions Per Electricity Generation	Zero emissions per unit of output.	This is intended to measure emission reductions within one of the sectors responsible for most of the emissions. The measurement used is GHG/Electricity and Heat Output (kWh)

AD-EPI INDICATORS AND INTERPRETATION

Greenhouse Gas Emission

Carbon dioxide, methane, and nitrogen dioxide are primary drivers of human-made climate change. Measuring the amount of emissions

Increased Energy Efficiency

Energy production is generates the largest percentage of emissions. Increasing energy efficiency through clean technology

Climate Adaptation

The impacts of climate change vary significantly between regions and threaten human safety and ecosystems. The potential for higher average annual temperatures could result with rising sea levels or prolonged heat waves. This requires preparation to reduce vulnerability.

Climate Policy Engagement

National governments generate new policies such as CDMs or carbon sequestration programs in order to reduce their carbon footprints.

INDICATORS FOR MEASURING POLICY PERFORMANCE AND USING THE RESULTS FOR DECISION-MAKING:

There are no current indicators due to lack of available data. Climate data has been at an Emirate level and has been limited so ability to calculate specific Abu Dhabi indicators is not currently possible. The recent efforts and emerging new strategic direction are positive signs for future inclusion of indicators.

DISCUSSIONS AND CONCLUSIONS

Monitoring greenhouse gas emissions is critical for targeting effective climate change policy. This requires information for the public sector as well as the private sector. With oil and gas production a major driving factor for the economy, careful monitoring of all sectors is required. Emission levels are currently calculated primary at the UAE Federal level, limiting the ability to create Emirate level analysis. With major shifts occurring in EAD policy, future plans should include specific emission monitoring programs and data generation along with the new objectives. Once the new objectives are finalized, indicator construction can proceed.

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ANNEX 1. AD-EPI INDICATOR PROFILES AND TARGETS

ENVIRONMENTAL HEALTH

INDICATOR: UNDER 5 MORTALITY RATE

Policy / Subcategory: Human Health Well-Being, and Safety

Code: U5MR

Full name: Under-five mortality rate (deaths per 1000 live births) .

Description: Children's health in the first 5-years is closely linked to environmental variables. While not all deaths are environmentally caused, child mortality provides a key indicator for impact of several environmental indicators. Pearce and Warford (1993) argue that the most important and immediate consequence of environmental degradation in the developing world takes the form of damage to human health. Rainham and Mc Dowell (2005) found that child survivals are clearly linked to the environment, even if it is difficult to depict in empirical analysis.

Policy relevance: Correlation between post-natal mortality and environment has been well demonstrated in scientific literature. Therefore a decrease in mortality rates should correspond to improved environmental quality.

Target: The target is to reduce child mortality rates from the baseline year until it reaches 3. This is the lowest rate registered globally in year 2006.

Target rational: Since child mortality is one of the best indicators of human well-being, a lower mortality rate should correspond to improved environmental quality. .

Target source: CIESIN

SOURCE(S)

Variable:	Annual births
Source:	Preventive Medicine Departments ADE – Ministry of Health UAE
Source Definition:	n/a
Years Available:	2007
Data assessment	CIESIN encourages EAD to take into account the historical data and to include a time series to demonstrate changes over time.
Variable:	Annual deaths between 0 and exact age 5

Source:	Preventive Medicine Departments ADE – Ministry of Health UAE
Source Definition:	n/a
Years Available:	2007
Data assessment	CIESIN encourages EAD to take into account data time series for assessing the performance of this indicator.

Indicator methodology: The indicator is calculated as the number of deaths divided by the number of population under five years of age, an age group considered particularly vulnerable to environmental health impacts.

Recommended actions: CIESIN encourages the collection of under 5 mortality rate as an indicator correlated to the state of the environmental health.

INDICATOR: PARTICULATE MATTER

Policy / Subcategory: Air quality – effects on health

Code: PM10

Full name: Particulate matter concentrations

Description: The indicator represents population-weighted accumulated concentrations of PM10. It measures the exceedance of a threshold of 150µg/m3 for 24-hour mean. This indicator utilizes hourly station by station measurements of PM10 concentrations between May 2007 and April 2008.

Summary of Fixed Air Quality Monitoring Stations considered for PM10 analysis

Type of AQMS	Stations
Urban background/Residential (4)	Al Ain Islamic Institute, Khalifa School, Bida Zayed, Baniyas School
Down town (2)	Kadejah School, Gayathi School
Road Side (2)	Hamdan Street, Al Ain Street
Industrial (1)	Mussafah
Regional background (1)	Liwa Oasis

Policy relevance: Particles suspended in outdoor air contribute to acute lower respiratory infections and many other non-communicable diseases, such as cancer. Lung cancer contributes more to the global disease burden for all cancers than any other Research as shown that an estimated 5% of the lung cancer disease burden is attributable to outdoor air pollution (EAD, 2008). Urban particulates measures the concentration of small particles, between 2.5 and 10 micrometers (PM 2.5 to PM10) in diameter, suspended in air. These particles are dangerous to human health because they are small enough to be inhaled and become lodged deep in lung tissue.

Target: No people exposed to 150µg/m^3 or higher 24-hour mean PM10 concentrations

Target rational: The target represents 0 population exposure to 24 hour average PM10 of more than 150µg/m^3. Studies suggest that health risks associated with short-term exposures to PM10 are likely to be similar in cities in developed and developing countries, producing an increase in mortality of around 0.5% for each 10µg/m^3 increment in the daily concentration. Therefore, PM10 concentrations of 150µg/m3 for 24 hour mean (FEA guideline) would be expected to translate into roughly a 5% increase in daily mortality, an impact that would be of significant concern (WHO, 2008).

Target source: The critical value of 150µg/m3 for 24 hour mean is based on FEA regulation concerning protection of air from pollution. It is 3 times higher than the established 2005 WHO Air quality guidelines (AQGs) are designed to offer global guidance on reducing the health impacts of air pollution. The new (2005) guidelines, as opposed to the previous 1987 and 1997 versions, apply worldwide and are based on expert evaluation of current scientific evidence.

Sources:

Variable:	Particulate matter (PM10)
Source:	EAD Ambient Quality Monitoring Network
Source Definition:	The concentration of total suspended particulate matter (TSP) measures of the particles in the atmosphere that are too small to settle out quickly (less than 44 µm), but remain suspended for significant periods of time. TSP is produced by mechanical processes, such as the abrasion of vehicle tires on unpaved roads, and by combustion processes, which is either mineral ash or hydrocarbons. Higher health risks have been associated with smaller particles, these with 10 µm in diameter (PM10) and those that are smaller still, PM2.5. The larger aerodynamic particles (PM10) are trapped by the upper airways, and do not enter the lungs.
Years Available:	May 2007 – April 2008
Variable:	Inhabitants
Source:	EAD/2005 census
Source Definition:	The total number of persons inhabiting in Abu Dhabi Emirate according to the latest geocensus.
Years Available:	2005
Data assessment	Limited time span. The last 12 hours of observed data are currently missing for February to April, 2008. Therefore, to insure meaningful calculation of daily means, we removed the data from the analysis.

Indicator methodology: The population-weighted concentrations of PM10 with a threshold of 150µg/m3 per 24 hour mean are calculated as following:

- Use IDW approach to generate hourly PM10 surfaces
- Calculate the 24 hour average concentrations per grid
- Calculate the difference between the 24 hour concentration, and the guideline 150 µg/m3. Calculate the mean 24 hours concentration over the threshold.

- Overlay the PM10 exceedance surface with the population areas and calculate exceedance values multiplied by population
- Sum the exceedance-person and divide by total population.

PM10 measurement:

"The PM10 is measured using the beta gauge which utilizes beta transmissivity for sampling of PM concentrations. The beta gauge uses a heated sampling probe to obtain an isokinetic sample. The sample is collected on a filter, which, at the end of the sampling period, is moved, using a continuous filter tape mechanism, to a measurement location between a carbon-14 beta particle source and a detector. The beta gauge uses the carbon-14 radioactive source and measures the attenuation of radiation through the filter containing the sample. The beta transmission through each blank filter is determined before sampling begins. The sampling duration is programmable and determines the mass concentration detection limit" (EAD, 2008).

The source of this information is the Ambient Air Quality Monitoring Network: 2007 Annual Report

Recommended actions: Smaller diameter particles (PM2.5) can make their way deep into the lungs, and may become lodged there. Abu Dhabi Emirate network will expand to include PM2.5, and data will be available within the next year and a half. Once data is available, we recommend replicating the calculation of this indicator using particles concentration data.

CIESIN also recommends setting both short-term targets for PM levels as well as long-term maximum exposure. Human health is impacted differently based on length of exposure.

Reference:

EAD (2007). *Ambient Air Quality Monitoring Network: 2007 Annual Report*, JW Project No. 1008345

INDICATOR: HEALTH OZONE

Policy / Subcategory: Air quality – effects on health

Code: OZONE_H

Full name: Ozone concentrations with effects on humans

Description: This indicator represents the population-weighted accumulated hourly concentrations of ozone exceeding target daily threshold of 200µg/m^3. This indicator relies on hourly station by station measurements of ozone between May 2007 and April 2008.

Summary of Fixed Air Quality Monitoring Stations considered for health ozone indicator

Type of AQMS	Stations
Urban background/Residential (4)	Al Ain Islamic Institute, Khalifa School, Bida Zayed, Baniyas School
Down town (2)	Kadejah School, Gayathi School
Industrial (1)	Mussafah
Regional background (1)	Liwa Oasis

Policy relevance: Ground-level ozone causes significant health impacts, including increased mortality and respiratory distress. According to EPA, exposure to ozone (O3), a toxic component of photochemical smog, results in significant respiratory inflammation, discomfort, and pulmonary function impairment. The main target of ozone exposure is the respiratory system. Fatigue, and headache may persist for several months after ozone has been eliminated from breathing stream. Mild to moderate exposure to ozone produces upper respiratory tract symptoms and eye irritation, like lacrimation, burning of the eyes and throat, nonproductive cough, headache, chest soreness and bronchial irritation. Therefore a reduction in levels of outdoor ozone should correspond with improved human health (EAD, 2008).

Target: No exceedance above 200µg/m3

Target rational: The target is based on the expert judgement – Regulation concerning protection of air from pollution

Target source: FEA

Sources:

Variable:	Ozone (O3)
Source:	EAD Ambient Quality Monitoring Network
Source Definition:	Ozone, unlike many other major air pollutants, is not emitted directly into the air, instead it is mainly formed through a photochemical process from emission of other componds, such as nitrogen oxides (NOx) and volatile organic compounds (VOC).
Years Available:	May 2007 – April 2008
Variable:	Inhabitants
Source:	EAD/2005 census
Source Definition:	The total number of persons inhabiting in Abu Dhabi Emirate according to the latest geocensus.
Years Available:	2005
Data assessment	Limited time span. The last 12 hours of observed data are currently missing for February to April, 2008.

Indicator methodology: The population-weighted accumulated hourly concentrations of high level ozone with a threshold of 200µg/m^3 are calculated as following:

- Use IDW approach to generate hourly ozone surfaces
- Calculate difference between the ozone concentrations (daily) and the critical level 200µg/m^3. This will represent the surface of concentrations in exceedance.
- Overlay the ozone exceedance surface with the population areas and calculate exceedance values multiplied by population
- Sum the exceedance-person-days and divide by total population.

Ozone measurement:

Ozone detection is based on the principle that ozone (O3) molecules absorb UV light at a wavelength of 254 nm. The degree to which the UV light is absorbed is directly related to the ozone concentration as described by the Beer-Lambert Law:

$$\frac{I}{I_o} = e^{-KLC}$$

where:

K = molecular absorption coefficient, 308 cm-1 (at 0-C and 1 atmosphere);

L = length of cell, 38 cm;

C = ozone concentration in parts per million (ppm);

I = UV light intensity of sample with ozone (sample gas); and

Io = UV light intensity of sample without ozone (reference gas).

The sample is analyzed through the sample bulkhead and is split into two gas streams. One gas stream flows through an ozone scrubber to become the reference gas (Io). The reference gas then flows to the reference solenoid valve. The sample gas (I) flows directly to the sample solenoid valve. The solenoid valves alternate the reference and sample gas streams between the cells every 10 seconds. When one cell contains reference gas, the other contains sample gas and vice versa.

The UV light intensities of each cell are measured by detectors in each cell. When the solenoid valves switch the reference and sample gas streams to opposite cells, the light intensities are ignored for several seconds to allow the cells to be flushed. The analyzer calculates the ozone concentration for each cell and outputs the average concentration to both the front panel display and the analog outputs.

The source of this information is the Ambient Air Quality Monitoring Network: 2007 Annual Report

Recommended actions: The Abu Dhabi Emirate Ozone concentration surface is based on data from 8 stations only (the 2 near road stations were removed to insure representativeness). We recommend expending the network of stations to cover a larger surface area of the emirate

Reference:

EAD (2007). *Ambient Air Quality Monitoring Network: 2007 Annual Report*, JW Project No. 1008345

INDICATOR: ENVIRONMENTAL EDUCATION

Policy / Subcategory: Education Behavior and Awareness

Code: EDUC

Full name: Percent awareness and percent behavior change about environmental concerns

Description:

Policy relevance: Raising awareness and changing behavior are key tools for environmental protection in Abu Dhabi. The rapid rate of development and urbanization was accompanied by major increases in patterns of personal consumption and use of natural resources. For example, the population is now approximately 80% urban. This is matched by per capita waste production averages between 547kg and 766kg per year (EAD 2008, 31). This is also reflected in the very high per capita water consumption, higher than European countries. Conservation could quickly reduce pressures on limited natural resources and improve environmental performance in other categories.

Target: 100%

Target rational: Environmental awareness is highly correlated with behavior. The goal is to achieve a close ratio of awareness to behavior. The target is to achieve 100% awareness among the population of Abu Dhabi Emirate. Although the ecosystem friendly behavior usually lags behind the awareness, it is imperative to achieve bring the level of behavior to a corresponding 100%.

Target source: CIESIN

SOURCE(S) EAD Educational Survey

Variable:	Environmental awareness
Source:	Environmental education department of EAD
Source Definition:	Knowledge regarding the main issues of concern in Abu Dhabi environment, such as water, waste/energy waste, biodiversity, pollution, as well as general and global issues. For example, fuel consumption, freshwater use, desalination impact, pollution rate, flora, fauna knowledge, AC usage, tap water flow, etc.
Years Available:	2008
Data assessment	There no continues measurement of environmental awareness at Abu Dhabi emirate level. The survey should continue as planned for yearly assessments in order to capture positive or negative changes in awareness levels.
Variable:	Environmental behavior
Source:	Environmental education department of EAD

Source Definition:	Behavior vis-a-vis the issues of environmental concern, such as water, waste/energy waste, biodiversity, pollution, as well as general and global issues. For example, switching off electricity, closing taps, shower/bath usage, food wasting, etc.
Years Available:	2008
Data assessment	CIESIN recommends careful attention to behavioral studies. EAD is adjusting for behavioral bias in the survey, however, concerns about data reliability of surveys for behavior remain high. Pairing behavioral studies with other direct indicators like water consumption in the water resources section or waste management indicators on recycling are secondary measures to the environmental education targets.

Indicator methodology: The indicator relies on survey data, which was completed in 2008. A total of 18 target groups and 2263 sample from a balanced statistically representative population were interviewed face to face, for about 30 to 45 minutes each, on issues such as water, waste/energy waste, biodiversity, pollution, as well as general and global issues. The sample was stratified by public(students and adults), functional groups (fisherman, farmers, falconers, hotels, hospitals, retail chains, corporate industries) and influencer sample (media, teachers and preachers).

The responses to each questions are collated and rated as per the following Awareness and Behavior Scales/levels –indicating what proportion of respondents are falling under each level.

Ratings	5	4	3	2	1	0	0
Awareness Level	Excellent	Good	Average	Fair	Poor	No Answer	Not Sure/Don't Know
Behavior Level	Always	Most of the time	Sometime	Rarely/ Occasionally	Not Sure/Don't Know	Never	No Answer

Recommended actions: CIESIN recommends careful attention to behavioral studies. Concerns about data reliability of surveys for behavior remain high. Pairing behavioral studies with other direct indicators like water consumption in the water resources section or waste management indicators on recycling are secondary measures to the environmental education targets.

ECOSYSTEM VITALITY
INDICATOR: ECOSYSTEM OZONE

Policy / Subcategory: Air Quality/Air quality – effects on nature

Code: OZONE_E

Full name: Ozone concentrations with effects on ecosystems

Description: This indicator tracks the annual cumulative exposure of hourly ozone concentrations above the threshold of 80µg/m3 during daylight time, excluding the summer months. This indicator relies on hourly station by station measurements of ozone between May 2007 and April 2008.

Summary of Fixed Air Quality Monitoring Stations considered for Ecosystem Ozone analysis

Type of AQMS	Stations
Urban background/Residential (4)	Al Ain Islamic Institute, Khalifa School, Bida Zayed, Baniyas School
Down town (2)	Kadejah School, Gayathi School
Industrial (1)	Mussafah
Regional background (1)	Liwa Oasis

Policy relevance: Critical levels of ozone have been defined for the protection of vegetation, primarily agricultural crops and forests (Werner and Spranger, 1996; Kärenlampi and Skärby, 1996). A decrease in exceedences reflects improved regulation and effective protection efforts.

Target: No cumulative annual exceedance above 18,000 µg/m^3 for crop areas and 30,000µg/m^3 for forest areas. This is based on hourly measurements of exceedance above 80µg/m^3 during non summer months..

Target rational: The critical level is therefore expressed as a cumulative dose over a threshold of 40 ppb(80µg/m3) generally referred to as AOT40 (Accumulated exposure Over a Threshold of 40 ppb/80µg/m3). The AOT40 is calculated as the sum of the differences between the hourly concentration (in ppb) and 40 ppb(80 µg/m3) for each hour when the concentration exceeds 40 ppb(80 µg/m3). Only daylight hours are included in the exposure evaluation, since vegetation is most susceptible to damage during daylight. The critical level for crops and (semi-) natural vegetation is set at 3000 ppbh during a three-month period from May-July, when the vegetation is assumed to be most sensitive to O3 (Werner and Spranger, 1996). For forests it is more difficult to demonstrate linear relationships between yield-decline and cumulative exposure. The critical level is set at 10000 ppbh during a six-month period from April-September, (Werner and Spranger, 1996, Kärenlampi and Skärby, 1996).

The growing season extends throughout the year in Abu Dhabi Emirate. Because of the high background level of ozone characteristic to the summer season, the data for the month of June, July and August are removed from the analysis. For the non summer months, we consider a 18000 µg/m3(9000ppbh) as critical level for crops, calculated by multiplying the three month critical cumulative level by 3). For forest, the critical level for the year is 30000 µg/m3(15000ppbh) , calculated as 1.5 times the six month period value.

Target source: Expert judgment

Sources:

Variable:	Ozone (O3)
Source:	EAD Ambient Quality Monitoring Network
Source Definition:	Unlike many other major air pollutants O3 is not emitted directly into the air, but mainly formed photochemically from emission of precursors, such as nitrogen oxides (NOx) and volatile organic compounds (VOC).
Years Available:	May 2007 – April 2008
Variable:	Irrigated areas
Source:	EAD
Source Definition:	Spatial data on irrigated areas include farms, forest, urban greens and urban parks.
Years Available:	2004
Data assessment	Limited time span Irrigated areas are used as a proxy for surfaces covered with vegetation, which are currently unavailable. A complete vegetation surface will add to a better evaluation of the pollution impacts.

Indicator methodology: The accumulated exposure concentration over a threshold in daylight time is calculated as follows:

- Use IDW approach to generate hourly ozone surfaces. Only select daylights hours of ozone concentrations
- Calculate exceedance above the 80µg/m3.
- Calculate the 9 month cumulative exceedance

- Overlay the ozone exceedance surface with the vegetation areas (using irrigated areas as proxy), and calculate the vegetation areas with ozone in exceedance.

- Divide by total irrigated areas type: crops and forest.

Ozone measurement:

Ozone detection is based on the principle that ozone (O3) molecules absorb UV light at a wavelength of 254 nm. The degree to which the UV light is absorbed is directly related to the ozone concentration as described by the Beer-Lambert Law:

$$\frac{I}{I_o} = e^{-KLC}$$

where:

K = molecular absorption coefficient, 308 cm-1 (at 0-C and 1 atmosphere);

L = length of cell, 38 cm;

C = ozone concentration in parts per million (ppm);

I = UV light intensity of sample with ozone (sample gas); and

Io = UV light intensity of sample without ozone (reference gas).

The sample is drawn into the analyzer through the sample bulkhead and is split into two gas streams. One gas stream flows through an ozone scrubber to become the reference gas (Io). The reference gas then flows to the reference solenoid valve. The sample gas (I) flows directly to the sample solenoid valve. The solenoid valves alternate the reference and sample gas streams between the cells every 10 seconds. When one cell contains reference gas, the other contains sample gas and vice versa.

The UV light intensities of each cell are measured by detectors in each cell. When the solenoid valves switch the reference and sample gas streams to opposite cells, the light intensities are ignored for several seconds to allow the cells to be flushed. The analyzer calculates the ozone concentration for each cell and outputs the average concentration to both the front panel display and the analog outputs.

The source of this information is the Ambient Air Quality Monitoring Network: 2007 Annual Report

Recommended actions: The Abu Dhabi Emirate Ozone concentration surface is based on 8 station data only (the 2 near road stations were removed to insure representativeness). We recommend expending the network of stations to include a more representative sample

Reference:

EAD (2007). *Ambient Air Quality Monitoring Network: 2007 Annual Report*, JW Project No. 1008345

INDICATOR: WATER CONSUMPTION PER CAPITA

Policy / Subcategory: Sustainable water resource management / Water quantity (effects on nature)

Code: WPC

Full name: Water Consumption in Domestic Sector (liters/person/day)

Description: Domestic consumption of water per capita defined as the amount of water consumed per person for the purposes of ingestion, hygiene, cooking, washing of utensils and other household purposes including garden uses. Where it is customary for domestic animals to be kept at or in the living environment, their needs are also included in the assessment. The indicator assesses the quantity of water needed and/or available to individuals in particular communities for their basic needs.

Policy relevance: Adequate quantities of water for meeting basic human needs are a prerequisite for existence, health, and development. Exceedence of the target level reflects over consumption of water supplies and identifies opportunities for conservation of resources.

Target: 350 liters/person/day.

Target rational: Expert Judgment and World Wide Best Practices

Target source: EAD/ADWEA

Sources:

Variable:	Water Consumption
Source:	EAD/ ADWEA
Source Definition:	This indicator measures the per capita water usage, the total amount of water consumed in the domestic sector from the main distribution network divided by population. In Abu Dhabi as an arid region, all of the residential, commercial, institutional, greening and industrial water which could not be accounted is included in the total amount of water consumed. Therefore, per capita water use includes the water use at home, at work and play, plus the process water used by industries, water used in schools and other public facilities, and leakage in the delivery system. So that water consumption per capita in Abu Dhabi calculated in this report is high compared with other countries. Per capita water use shows water usage over time, taking into account the population increase, which helps determine progress toward water conservation goals. So, water conservation in Abu Dhabi is an essential element of the water policy to ensure a sustainable water supply. Low flow toilets, water saver showers, low water use washing machines and dishwashers, and hot water recirculation systems along with consumer practices to conserve water, reduce indoor water use.

Years Available:	2001 – 2003, 2005
Variable:	Inhabitants
Source:	EAD/2005 census
Source Definition:	The total number of persons inhabiting in Abu Dhabi Emirate according to the latest census.
Years Available:	2005

Indicator methodology: The following steps used in calculations:

- sum up domestic water consumption from wells and desalination based on ADWEA water consumption publications; the results represent million meter cubes of water per year
- divide by total population(millions); the results represent yearly meter cubes per capita
- divide by 365, to generate domestic water consumption per capita per day, measured in meter cubes
- multiply by 1000, to generate domestic water consumption per capita per day, measured in liters

Recommended actions: Satisfactory indicator; the measurement does not capture the quality of the water consumed, therefore needs to be complemented with indicators of water quality from wells, desalination or imports. According to EAD Water Sector Paper, "Nitrate and Chromium occur naturally in the groundwater at levels that exceed drinking water standards. Nitrate from inorganic fertilizers is also the main pollutant of fresh groundwater. Nitrate levels exceed drinking water guidelines for a bulk of the groundwater. Exposure to high levels of nitrate represents a health risk". (

The monitoring of water quantity for domestic use should also include indicators followed by international organizations, such as access to drinking water and access to sanitation.

The WHO defines an improved drinking water source as piped water into dwelling, plot or yard; public tap/standpipe; tubewell/borehole; protected dug well; protected spring; and rainwater collection (WHO 2007). As arid region, Abu Dhabi Emirate should include "desalinated water" in their indicator calculation.

INDICATOR: WATER STRESS INDEX

Policy / Subcategory: Sustainable water resource management/Water quantity (effects on nature)

Code: WSI

Full name: Water Stress Index

Description: The water stress index is the ratio between the total water use in the Abu Dhabi Emirate to the available renewable water resources (including desalinated water).

Policy relevance: Increasing demands to supply water for domestic, agricultural, and/or industrial use to a growing population has extensively modified inland waters, leading to habitat and biodiversity loss, pollution, the introduction of invasive species, and the construction of dams (UNEP GEMS/Water, 2006). Public policy should monitor the balance of demand to supply of critical water resources to protect populations from both short and long term needs.

Target: Maximum of 100% of water used from renewable sources (including desalination and treated wastewater)

Target rational: Water use is considered sustainable if this ratio is equal to or less than 100%. In Abu Dhabi emirate, as in other arid regions, the demand of water exceeds the available renewable water resources. Therefore, the water from unconventional sources as desalinated water and treated waster are included in the calculation of water stress index.

Target source: Expert opinion

Sources:

Variable:	Renewable water resources
Source:	EAD/Natural Resources Policies Department
Source Definition:	Renewable water supply includes rainfall, renewable groundwater, desalination and treated wastewater. Including the desalination and reuse of treated wastewater as part from the available renewable water sources especially in arid regions is still a big debate and discussion in the water resources community and not included in the global indicators.
Years Available:	2001 – 2003, 2006

Variable: **Source:** **Source Definition:** **Years Available:**	Total water use EAD/ Natural Resources Policies Department Water use includes water used for domestic, agriculture, forestry, commercial, industrial and touristic purposes. 2001 – 2003, 2006
Data assessment	The data source is unclear. EAD experts need to provide detailed description of data and calculations.

Indicator methodology: The two approaches to define water stress index and scarcity are: heuristic proportionality and empirical methods, and appropriations and calculations based on human and economic needs through food intake calculations and industrial use estimate. The critical ranges and definition of stress index are still actively discussed in the water resources community. To establish the validity and usefulness of these indices one needs to find a correlation with other indices that measure the degree of development or general economic well being of a country. The most likely indicator is the Gross Domestic Product (GDP). Intuitively a positive correlation between GDP and WSI should exist, similarly to the well known per capita relation between energy consumption and GDP.

The formula used for calculation of water stress index is:

$$WSI = (\text{Total water use} / \text{Renewable water supply}) \times 100\ (\%)$$

Where:

Renewable water supply = rainfall + renewable groundwater + desalination + reuse of treated wastewater

Water use = domestic + agriculture + forestry + commercial + industrial + tourism

Recommended actions: The data source is unclear. The information on renewable groundwater resources was not found in any of the published water reports provided by EAD. The figure currently used to calculate the water stress index was provided by Dr. Dawoud in our direct conversations. We use the same figure of 300 million cubic meters as renewable groundwater estimate for all years where calculations were made: 2001-2003, and 2006.

INDICATOR: GROUNDWATER LEVEL

Policy / Subcategory: Sustainable water resource management/ Water quantity (effects on nature)

Code: GWL

Full name: Annual percent area with decrease in groundwater level of 0.2 m or more.

Description: This indicator represents the annual area with increased groundwater levels, with a strong focus on major abstraction centers. The changes in groundwater levels are calculated by subtracting the water levels of a specific year from records acquired the previous year available.

Policy relevance: The level of groundwater is an essential parameter in areas of groundwater use. Groundwater is replenished from precipitation and from surface water, but the rate of abstraction (withdrawal by humans) may exceed the rate of natural recharge, leading to reduction of the resource. Some aquifers, especially in arid regions, contain paleowaters (fossil groundwater) stored from earlier periods of wetter climate, and the reduction of these reserves can be permanent. Measurement on a regular basis of water levels (the "water table") in wells and boreholes provides the simplest indicator of changes in groundwater resources.

Declining water levels are classified as follows:

Class	Annual Change
Steady state	<0.2 m
gentle and medium decline	0.2 – 1.0 m
strong and very strong decline	> 1.5 m

For rising groundwater levels, classes of the same values are applied. Steady-state conditions are considered for annual changes less than 0.2 m.

Target: No areas experiencing a decrease in ground water levels of more than 0.2m

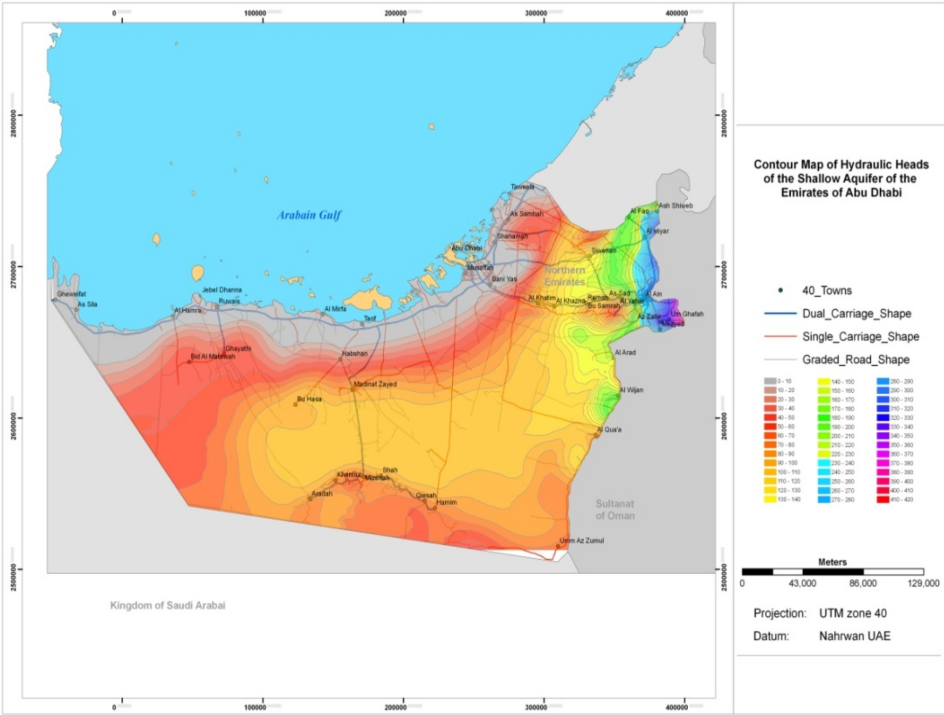
Target rational: A comparison of the change in groundwater table and the sustainable yield or availability of the groundwater resource provides a way to measure the pressure of extraction on the resource. The extraction of groundwater for human use without knowing the limits on the resource could place significant pressure on this resource.

Target source: Expert judgment

Variable:	Water level

<table>
<tr><td>Source:</td><td>EAD/Water Department</td></tr>
<tr><td>Source Definition:</td><td>Water level values (WL) is the difference between the altitude of the water level measuring point (zWL_MP) and the water table above mean sea level.

Water level contour for year 2005.


</td></tr>
<tr><td>Years Available:</td><td>2003 and 2007</td></tr>
<tr><td>Data assessment</td><td>The most recent summary of water level decline was developed in 2008 based on water levels campaigns from 2005 and 2008. However, this analysis also used a long term study (water level decline map from 2003 to 2007), for a long term reflection of the areas that were overexploited.</td></tr>
</table>

Indicator methodology:

Water Level Measuring Campaigns

In performing the water level campaigns, the main approach was to integrate a representative number of wells covering the area of interest. In addition to the regular measurements during the Continuous and Periodical Monitoring Programme, wells have been integrated to get an ideal spatial resolution to interpolate the hydraulic heads.

Until 2001, several water level measuring campaigns were carried out (Table 0.1 and Table 0.2) covering the Eastern Region and the Liwa Area, which was continuously extended. The campaign covers the area as a whole. Water levels were measured in 617 wells showing precise elevations as determined by differential GPS (Table 0.3).

Water Level Campaigns in the Eastern Region

Water Level Campaign	Total Number of Wells	Period of Measurements
July 2001	373	20.05.01 - 01.09.01
January 2002	369	02.01.01 - 02.02.02
January 2003	357	02.11.02 - 27.11.02
January 2004	346	16.11.03 - 22.12.03

Water Level Campaigns in the Liwa

Water Level Campaign	Total Number of Wells	Period of Measurements
January 2001	101	09.01.01 - 31.03.01
July 2001	103	15.05.01 - 02.02.01
January 2002	129	13.01.02 - 11.02.02
January 2003	178	20.10.02 - 27.11.02
January 2004	253	02.09.03 - 29.12.03

Water Level Campaign in the Abu Dhabi Emirate

Water Level Campaign	Total Number of Wells	Period of Measurements
January 2005	617	06.12.04 - 09.01.05

The creation of the groundwater table surface is carried out using the Kriging approach.

Recommended actions: Other important groundwater resource sustainability indicators are:

CIESIN recommends continued monitoring of the current water table levels and maintain the same points. Potential expansion of the monitoring network to include more private wells, especially for farming areas, would increase the surface measured.

INDICATOR: GROUNDWATER SALINITY

Policy / Subcategory: Sustainable water resource management/ Water quality (effects on nature)

Code: GWS

Full name: No areas experiencing an increase in salinity levels (no increase in salinity levels on a grid-cell by grid-cell basis)

Policy relevance: Groundwater provides is a globally important source for human water consumption, and changes in quality can have serious consequences. The chemical composition of groundwater is a measure of its suitability as a source of water for human and animal consumption, irrigation, and for industrial and other purposes. It also influences ecosystem health and function, so that it is important to detect change and early warnings of change both in natural systems and resulting from pollution. Fresh groundwater may be limited laterally by its interface with sea water and adjacent rock types, or vertically by underlying formation waters. Saline water intrusion into coastal aquifers can result from over pumping of fresh groundwater, or when stream flow decreases (e.g. due to dams or diversions) lead to reduced recharge of aquifers in alluvial plains. Strong evaporation in areas with shallow water tables may also lead to salinization. Changes in levels of salinity may occur due to natural climate change (prolonged droughts) or due to excessive pumping and irrigation practices that stimulate precipitation of dissolved solids as salts on agricultural lands. It is important to monitor overall changes in salinity.

Increasing levels are classified as follows:

Source	Total Dissolved Solids Range (mg/l)	Classification
(ERWDA, 2003)	0-1500 1,500-8,000 8,000-15,000 15,000-35,000 >35,000	Fresh Low Brackish High Brackish Saline Hypersaline
GTZ et al (2005) – German Standards	0-1,500 1,500-4,000 4,000-7,000 7,000-10,000 10,000-25,000 25,000-50,000 50,000-100,000 >100,000	Fresh Slightly Brackish Medium Brackish Strongly Brackish Slightly saline Medium Saline Strongly Saline Brine
USGS (USGS/NDC,1996)	0-1,500 1,500 – 15,000 >15,000	Fresh Brackish Saline

Forestry Dept Abu Dhabi Municipality & Agriculture	0-1,500 1,500-10,000 10,000-20,000 >20,000	Fresh Brackish Saline Hypersaline
Al Ain Municipality & Agriculture -Agriculture Extension Service (2001)	0-1,000 1,000-2,000 2,000-4,000 4,000-6,000 6,000-8,000 >8,000	Class 1 very Fresh Class 2 Fresh Class 3 low brackish Class4.medium brackish Class 5 high brackish Class 6 saline

In addition, there is a measure based on electrical conductivity, adopted by the Abu Dhabi Municipality and Agriculture Extension Service

Abu Dhabi Municipality and Agriculture Extension Service	0-4,000µS/cm 4,000-8,000µS/cm 8,000-12,000µS/cm >12,000µS/cm	Class I Fresh Class II low brackish Class III high brackish Class IV saline

Target: 0% increase in salinity above the 1500mg/l TDS threshold

Target rational: We distinguish changes between salinity of freshwater and different levels of groundwater, in order to identify and monitor the areas experiencing increased salinity levels as well as areas with previously high measurements.

Target source: EAD

Variable:	Electrical conductivity levels
Source:	EAD/Water Department
Source Definition:	Electrical conductivity is the measure of total concentration of dissolved salts in water. When salts dissolve in water, they give off electrically charged ions that conduct electricity. The higher levels ions in the water, the greater the electrical conductivity it has.
Years Available:	2002 and 2008 Campaigns

Data assessment	One major campaign in 2008, but previous emirate area level measurement done in 2002. Yearly salinity measurements are needed to allow comparison. The study of water salinity should be complemented with information on land use, particularly irrigated areas. Yearly maps of irrigated areas are also needed for a thorough analysis.

Indicator methodology: In 2008, an effort was undertaken to measure groundwater abstraction centers and the adjacent 3-km zone. In the remaining remote areas, the salinity of the shallow aquifer is expected to be rather constant due to the lack of groundwater abstraction activities. Ten EAD wells drilled after the termination of the GWAP are located in the south-eastern part of the Abu Dhabi Emirate. Salinity data of these wells representative for the shallow aquifer were provided by EAD and incorporated into the database. The final selections of "GWA-GOW wells" (561 records), and of EAD wells (10 records) were merged. GWP wells with a distance greater than 3km to wells of the merged data were selected. The resulting 118 GWP wells were merged with the results above.

The combined dataset comprises 1,027 salinity measurements of the shallow aquifer. Artificial points located in the Arabian Gulf were also merged. The final input data were investigated by exploratory geostatistical analysis.

The data set was divided into several regional sub-sets each comprising less than 300 records. Each sub-set was individually tested by semivariogram analysis to identify local outliers showing strong variations on short distance. As a result, 7 records were discarded from the data set. The final data set, suitable for the creation of the salinity contour map of the shallow aquifer, comprises 1,020 approved measurements of electrical conductivity plus 92 auxiliary points located in the Arabian Gulf. To express the measurements as salinity (ppm of Total Dissolved Solids), all electrical conductivity values were multiplied by the factor 0.625. After testing of distinct parameters and comparison of the resulting models, default ordinary Kriging was selected to provide most meaningful prediction of changes in groundwater tables.

Recommended actions: There are many different physical and chemical parameters that can be used to measure water quality and, therefore, there is no one answer to the question of 'what is water quality' (UNEP GEMS/Water 2006). However, what is certain is that water salinity is an incomplete measure of water quality, as it fails to represent a number of key environmental issues, such as organic pollution, nutrient pollution and acidification.

Parameters for specific water use, suggested by GEMS/Water, are presented below:

- Agriculture: Nutrients, Nitrogen, Phosphorus, Salinity, Chlorophyll A, Pathogens
- Municipal/Industrial: BOD, COD, Heavy Metals(particularly in sediment)
- Ecosystem Stability, Structure & Health: Temperature, pH – acidity, conductivity, major ions, oxygen, suspended solids, biodiversity
- Tourism and recreation: Parasites and Pathogens

The parameters used in the Water Quality Index developed by GEMS/UNEP are dissolved oxygen, pH, conductivity, nitrogen and phosphorus. The individual targets used were as follows: DO of 6 mg/L for "warm waters" (>20C) and 9.5 mg/L for "cold waters" (<20C); pH of 6.5-9.0; EC of 500 micro-Siemens/cm; P of 0.05 mg/L (or 0.025 for orthohosophate); N of 1 mg/L (or 0.5 for dissolved inorganic N or nitrate and nitrite and 0.05 for ammonia).

Dissolved Oxygen is also important when assessing the suitability of water for drinking. Low DO in source water can increase the conversion of nitrate to nitrite and sulphate to sulphide as well as increase the concentration of ferrous iron in solution, leading to discoloration in drinking water (WHO, 2004). Low DO can occur due to the addition of organic pollutants and nutrients that fuel bacterial and algal production and respiration, leading to the net consumption of oxygen in the water column (Correll, 1998; Barton and Tayler, 1996). Sources of such pollutants include agricultural runoff from manure and fertilizer, municipal areas (municipal wastewater effluent and stormwater drainage), and industrial areas (e.g., pulp and paper mill effluents). As such, the measure of dissolved oxygen will provide a good indication of the state of inland water with respect to nutrient and/or organic pollution.

pH, which is the measure of the acidity or alkalinity of a water body, is an important parameter of water quality in inland waters in that it can affect aquatic organisms both directly through impairing respiration, growth and development of fish, and indirectly, through increasing the bioavailability of certain metals such as aluminum and nickel. The inclusion of pH into a general index of water quality will provide a good indication of the state of inland water with respect to acidification and to the suitability of water for drinking.

Conductivity is a measure of the ability of water to carry an electric current which is dependent on the presence of ions. It is often used as an indirect measure of salinity and total dissolved solids (TDS). Total dissolved solids can also be estimated from conductivity by multiplying conductivity by an empirical factor (APHA, 1995). Inorganic compounds are good conductors compared to organic compounds and, as such, increases in conductivity can occur due to the input of industrial effluents, such as metal mining, making conductivity a good indicator of inorganic pollution. Salinity is of particular concern in agricultural areas where low conductivity is used to determine suitability of water for agricultural use (Hart et al, 1991). High salinity and/or TDS levels are also of concern when determining suitability of water for drinking due to objectionable taste (WHO, 2004).

Nitrogen and phosphorus are naturally-occurring elements essential for all living organisms and are often found in growth-limiting concentrations in aquatic environments. Increases in nitrogen and/or phosphorus in natural waters, largely as a result of human activities in the drainage basin (e.g., from agricultural runoff from manure and synthetic fertilizers and from municipal and industrial wastewater discharge), can result in increased biological productivity of a water body.

INDICATOR: COASTAL CHLOROPHYLL-A CONCENTRATION

Policy / Subcategory: Sustainable water resource management/ Water quality (effects on nature)

Code: CCC

Full name: Concentration of Chlorophyll-a in the Coastal Zone

Description: Coastal Chlorophyll-a Concentrations is measured by satellite images which are converted into observed data. This sensor measures ocean color at a 9km grid cell resolution, which can be converted using an algorithm to concentrations of chlorophyll-a in micro-grams per liter. The advantage of measuring from space as opposed to *in situ* sampling is that the entire coastal zone is covered. Disadvantages include the effect of bottom reflectance on ocean color in shallow waters and cloud cover. However, measuring average concentrations over the entire coastal zone for a year minimizes the effects of these factors, since it can be safely assumed that the effects of bottom reflectance and cloud cover will remain relatively constant from year to year.

Policy relevance: High chlorophyll concentrations are potential indicators of eutrophication and are also associated with harmful algae blooms.

Target: **1.29** μg/liter

Target rational: This is the lowest average annual concentration of chlorophyll-a recorded since measurement began using SeaWiFS in 1998. Measurements before 1998 could be derived from the Coastal Zone Color Scanner (CZCS), but these would not be entirely comparable.

Target source: Sea-viewing Wide Field-of-view Sensor (SeaWiFS) processed by the Center for International Earth Science Information Network (CIESIN) at Columbia University.

Sources:

Variable:	Chlorophyll-a Concentrations
Source:	EAD
Source Definition:	SeaWiFS measures ocean color, which can be converted to chlorophyll-a concentrations using a standard algorithm.
Years Available:	1998 - 2007
Data assessment	The data are available but are of a somewhat limited time span. The SeaWiFS sensor will eventually go out of service, but other sensors will be coming online that can provide ocean color data.

Indicator methodology: There are two methods used for generating the chlorophyll a indicator: the first is to use observed data. the daily averages of concentration, when available. This is compared with the objectives, in order to calculate the compliance to target levels.

The second method of evaluating the clorophyll-a within Abu Dhabi waters is to use the SeaWiFS level 3 annual composites were downloaded from the Ocean Color Web site at Goddard Space Flight Center. The data was converted to a grid format for processing in ArcGIS 9.x. The grids were clipped using a mask representing each country's exclusive economic zone. We excluded the first 10km off the coast and measured concentrations out to a distance of 100km off the coast. Data for each grid cell for each year were brought into Excel in order to process annual average concentrations in the Emirate's entire coastal zone, and to find regions of significant change.

Because of the in situ monitoring network is limited, and the temporal coverage is too short, we use the SeaWiFS remote sensing derived concentrations for calculating the indicator.

Recommended actions: It is recommended that the Abu Dhabi Emirate track average annual chlorophyll concentrations in the coastal zone over time.

INDICATOR: HABITAT PROTECTION

Policy Category: Habitat Protection and Effective Conservation

Code: HABPROT

Full name: Protected Area Conservation by Habitat

Description: The indicator provides a measure of how much each habitat is under effective protection..Only those protected areas that have management plans are considered effective. This effectively removes from consideration those areas that are protected "on paper" but not in reality. The effective conservation indicator gives a protected area value for each terrestrial and marine habitat by overlaying the Emirate's protected areas layer, a map of habitats. The target is 12% of each habitat in the Emirate's territory effectively conserved.

Policy relevance: The percent of national territory that is protected has long been recognized as an important conservation indicator. This indicator measures the percentage habitat that has been effectively conserved within each habitat.

Target: 12% of each habitat in protected areas

Target rationale: This is the target established by EAD for the percent of the Emirate territory to be protected.

Target source: EAD

Sources:

Variable:	Protected Area Database of Abu Dhabi Emirate
Source:	EAD
Source Definition:	This is a digital map of the protected areas of ADE. Digital map of the protected areas of ADE.

Years Available:	2008
	Abu Dhabi Emirate Habitats EAD This data set provides the delineation of habitats Habitats Map of Abu Dhabi Emirate 2008
Data assessment	

Indicator methodology: The two datasets were combined to tabulate the total area and area protected of each habitat (in hectares). To create an overall proximity-to-target indicator, the percentage of each habitat protected is then capped at 12% so that over-protection of some habitats will not compensate for under-protection of others.

Recommended actions: The current habitat data are not satisfactory. However, since no current data of habitats exist at Abu Dhabi Emirate level, the current habitat layer serves as a placeholder and methodological example for the habitat protection indicator.

INDICATOR: STATUS OF THREATENED MARINE SPECIES

Policy Category: Habitat Protection and Effective Conservation

CODE: TMS

Full name: Evolution of Estimated Population of Threatened Species (Dugongs and Marine Turtles)

Description: Threatened species are those at risk of extinction, and include endangered, vulnerable, rare, and indeterminate species as defined by the World Conservation Union (IUCN). This indicator measures the ratio between the current abundance and the previous recorded abundance for Dugongs and Sea Turtles across five zones of survey in the Abu Dhabi waters; if the highest recorded abundance is in that year, the score is 100% and the target for future years is reset (assumes standard transects and methods). The goal is to find an equal or upward sloping trend.

The purpose of this indicator is to represent the maintenance or, conversely the loss of marine species diversity.

Policy relevance: One of the Abu Dhabi target in its strategic plan is to increase the number of endangered key marine species from 1 to 3 within 4 years (2013).

Target: No decline

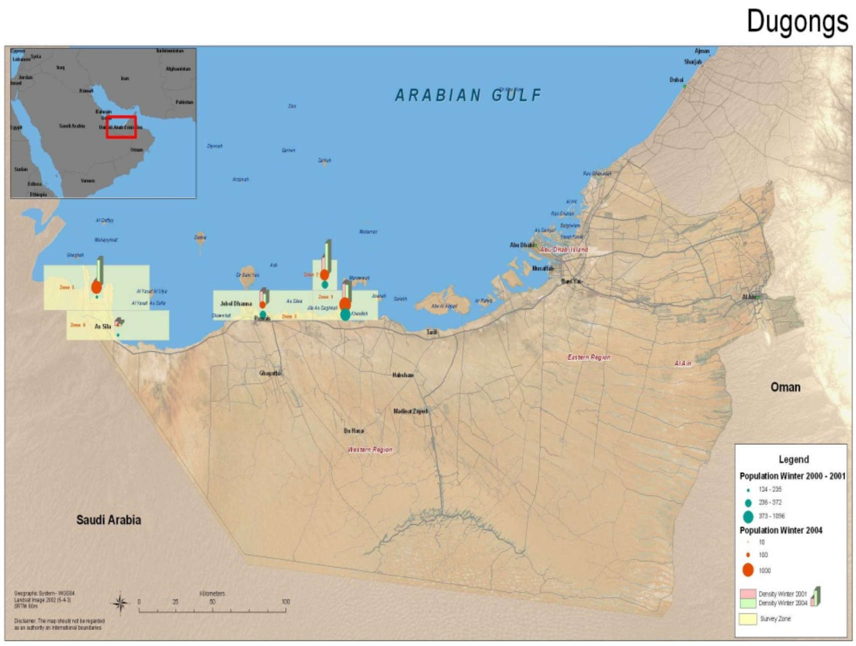
Target rationale: Tracking changes in species abundance will help the Emirate to put into place conservation mechanisms before species reach a critical state of endangerment.

Target source: CIESIN

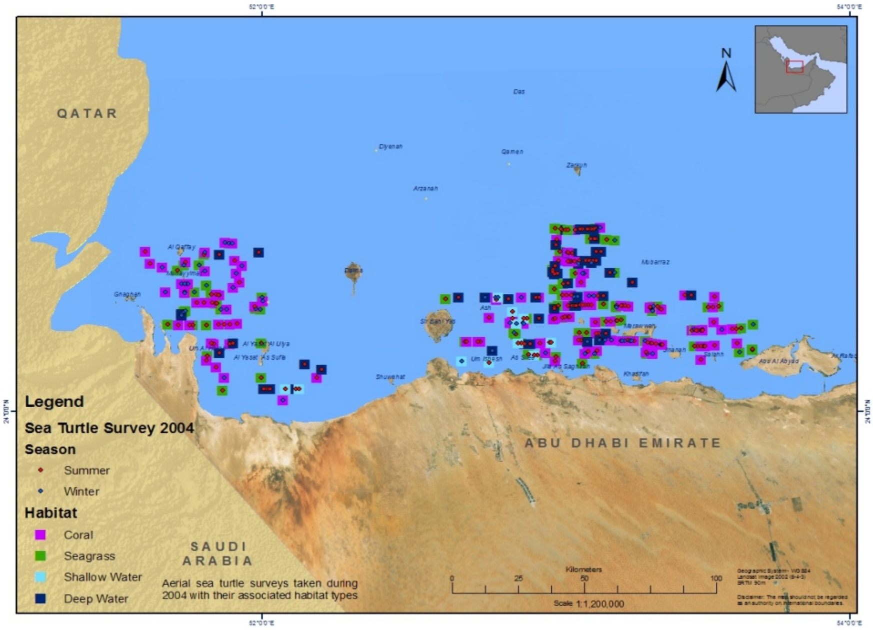
SOURCE(S)

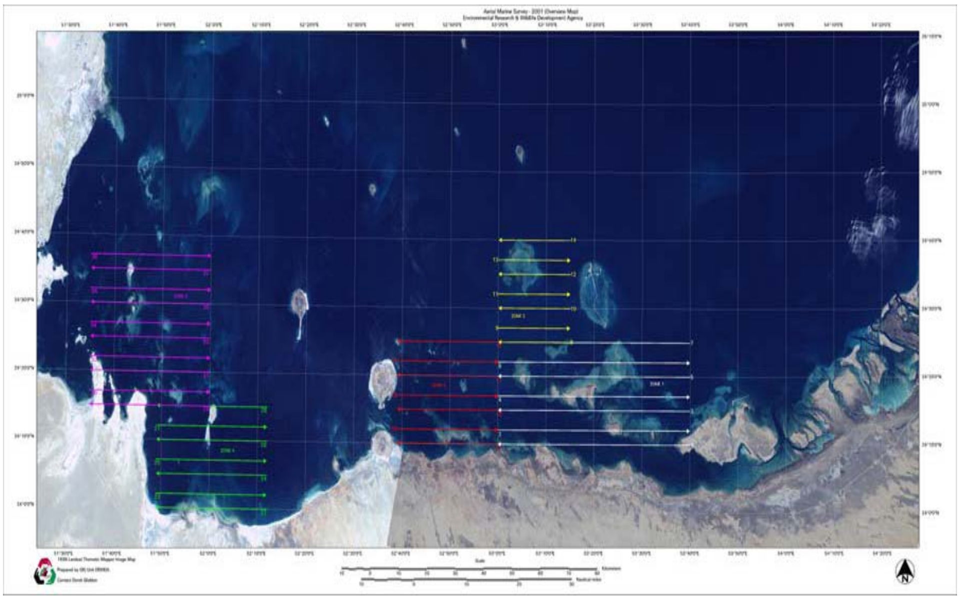
Variable:	Estimated population of dugongs and sea turtles
Source:	EAD
Source Definition:	Tabular and spatial data The following maps show spatial distribution of 1.dugongs in the summer, 2. Dugongs in the winter, and 3.Turtles in 2004. The Maps are courtesy of EAD. Dugongs distribution, Summer, 2001 - 2004

Dugongs distribution, Winter, 2001-2004



Turtles distribution, ,2004

	
Years Available:	2001 – 2004
Data assess-ment	Data is of good quality
Variable:	Area covered
Source:	EAD
Source Definition:	The following zonal areas were included in the survey: Zonal Area Survey of Marine Species
Years Available:	
Data assessment	

	 2001 Spatial and tabular data of good quality.

Indicator methodology: The data depict aerial sightings of dugongs conducted over an area of 6,454 Km2 in the inshore of Abu Dhabi waters in summer 2000, winter 2001 and summer and winter 2004. Sightings were conducted along predetermine 36 transects of dugong habitat in five zones as part of an extensive study on endangered marine mammal species in Abu Dhabi Emirate conducted by EAD.

The helicopter was equipped with navigational aids and a GPS and flew during the high visibility period of the day that ranged from 07.00 hrs to 14.00 hrs, at altitudes between 300 and 560 feet and traversed transects at speeds ranging from 120 to 175 km/hr. The side doors of the helicopter were kept opened. Sightings within the 1 m2 imaginary quadrat were recorded. Transects were flown in an east-west direction, to avoid the reflection of the sunlight. The data depict the results of sea turtle surveys conducted in Spring and Summer of 2004. There are 79 records in this dataset that in addition to recoding the x, y location of the sighting also recorded the MERC Marine Protected Area (MMPA) zone, and the general type of habitat where the

Availability bias is corrected by standardizing the proportion of animals (dugongs and sea turtles) “at surface” against the equivalent proportion over very clear shallow waters where all animals (both surface and underwater) are seen. Perception bias occurs when animals are visible in the survey transect but missed by observers.

Transects in the survey area were not uniform in length and consequently the area within different transects was unequal. This factor was taken into account in the analysis. Accordingly, the ratio method was used to calculate population estimate for each zones separately using the formula below.

$$E = (N / At) \times A \times CFa \times CFp$$

Where,
E = Estimated population
N = Total number of dugongs sighted in the transect sampling
At = Area covered in the transect sampling
A = Total area of the survey zone
CFa = Availability correction factor
CFp = Perception Bias Correction Factor

Description of the area of surveys :

Zone 1	Marawah, Al-Bazm, Abu Al Abyadh, Jenanah, Al Bazm North, Mubaraz (mapped with light color on the map)
Zone 2	Bu tinha, Mubaraz, al Bazm north
Zone 3	Area between Sir BaniYas and Al-Bazm
Zone 4	Al-Yasat, umm Al Hatab, Al-Sila
Zone 5	Muhayimat, Ghagha, Kafai

For the baseline year (2001) and the most recent year available (2004), the density of species in For the baseline year (2001) and the most recent year available (2004), the density of species in the marine protected areas is calculated derived from the surface of area covered and the estimated number of population for the two given threatened species. A ratio is calculated to estimate the evolution of the population of the two species.

Recommended actions: CIESIN recommends EAD a regular data collection of these two endangered marine species in order to being able to track precisely the status of the species. CIESIN also encourages EAD to enlarge the surveys into other species.

INDICATOR: FARM AREA EXPNSION

Policy Category: Habitat Protection and Effective Conservation

Code: FARM

Full name: Percent Increase in the Area of Citizen Farms

Description: This indicator tracks the percentage change of area covered by citizen farms, which are typically 2-3 ha in size and each have two drilled wells at opposite corners of the plot(EAD, 2008). Given a time series data on the percentage of area with citizen farms, this indicator will measure the rate of expansion of citizen farms. The target is zero expansion.

Policy relevance: Anthropogenic pressure has increased in Abu Dhabi Emirate these last few decades. This has an impact not only on the water resources but also on land constraint. Agriculture is the first sector in terms of water consumption in the emirate (58% in 2003), it is then crucial to monitor the agricultural expansion in order to manage efficiently the land use, the inputs and outputs of an intensive agriculture.

Target: 0% expansion

Target rationale: This is the target established by EAD after the new regulation on water resources.

Target source: CIESIN

Variable:	Citizen farms area expansion in Abu Dhabi Emirate
Source:	EAD, Water Sector Paper 2008
Source Definition:	Spatial data
Years Available:	1985-2006
Data assessment	The data is not updated to reflect the agricultural expansion in recent years. This indictor should be generated yearly. The spatial data is currently available for Easter region only, excluding Abu Dhabi.

Indicator methodology: Little or no information are available with regard to the method of detection of citizen farms by the EAD. The current data source is the EAD Water Sector Paper, which was recently updated by AGEDI. For most of the period under study, a well supported system of subsidies promoted farm expansion, averaging 3,000 new farms per year. As well use was not regulated until a few years ago, the data used for this indicator may be estimates of historical data provided by of EAD experts.

Recommended actions: Given the demographic and economic pressure in ADE where water is a scarce resource, accurate and available data on the agricultural sector should be one of EAD's priorities.

Vegetation can be detected on satellite images, and was previously analyzed in the Status Report of Water resources. A delineation of cultivated areas based on satellite images from March 2000 to June 2000 was conducted in Eastern Region, for forest sites, agricultural areas, and urban green. As a further step, the ground-truth analysis can be performed, similarly as for the 2002 satellite images for agricultural areas.

INDICATOR: MARINE TROPHIC INDEX

Policy Category: Habitat Protection and Effective Conservation

Code: MTI

Full name: Marine Trophic Index

Description: Expresses the trophic composition of marine fish landings by measuring the mean trophic level of fish catches made in Abu Dhabi waters. Fish species are given a MTI value from 1 to 5 based on their diet composition. The indicator gives a time series to show the trend in the trophic composition of the landed catch. The minimum target is to have a zero slope trend.

Measures the balance between quantity of fish harvest and trophic level. FiB therefore indicates two trends: the FiB identifies if the decrease in MTI is related to the increase in fish catches or to another phenomenon (for example the result of a voluntary fishing down policy). A second measure the FiB also indicates when fisheries have changed (expanded) geographically. Given an estimate of the transfer efficiency between trophic level, the FiB is designed to maintain a value of zero when a decrease in trophic level is matched by an appropriate catch increase (and conversely). The target is to have a positive trend.

Policy relevance: One of the EAD target is to increase the Fisheries Resources Status to 20 Key Species. The MTI indicator will help in monitoring the sustainability of fisheries in ADE water.

Target: 0 or positive trend

Target rationale: Expert judgment

Target source: Sea Around Us Project

Indicator methodology: The MTI calculation is derived from the D. Pauly (Sea Around Us) methodology using a cut-off 3.25 in order to emphasize changes in the relative abundance of the more threatened high-TL fishes.

The MTI calculation is based on the landing catches from 2005 to 2007 and estimates for over 74

Variable:	Marine Trophic Index
Source:	EAD
Source Definition:	Tabular data
Years Available:	2005 - 2006 - 2007
Data assessment	Data is of high quality.

fish species in the ADE waters. These landings do not include statistics on discards.

$$\overline{\mathrm{TL}}_k = \frac{\sum_i (\mathrm{TL}_i) \cdot (Y_{ik})}{\sum_i Y_{ik}};$$

Mean Trophic Levels (TLs) were then computed, for each year *k* from where Y_i refers to the landings of species (group) *i*, as included in fisheries statistics. Note that, ideally, mean TL should be based on catches, i.e. all animals killed by fishing (i.e. landings and discards; Alverson *et al.* 1994), rather than only on the landings included in FAO statistics, a problem to which we return below.

This indicator measures the slope of the trend line in the MTI for the years available.

If the slope is 0 = fishery stable

If the slope > 0 = fishery is improving

If the slope < 0 = fishery is declining

If the average slope means a declining fishery (slope <0), it means that the overall trophic structure of the marine ecosystem is becoming depleted of larger fish higher up in food chain, and that smaller and smaller fish are being caught.

The FiB is derived from the MTI calculation above. The FiB index is defined as

$$\mathrm{FiB}_k = \log[Y_k \cdot (1/\mathrm{TE})^{\mathrm{TL}_k}] - \log[Y_0 \cdot (1/\mathrm{TE})^{\mathrm{TL}_0}],$$

where *Y* is the catch in year *k*, TL the mean trophic level in the catch, TE the mean TE (specific to an ecosystem, often set at 0.1; Pauly & Christensen 1995), *i* refers to species (groups) in the catch and 0 refers to any year used as a baseline to normalize the index.

a. FiB remains = 0 if TL changes are matched by 'ecologically correct' changes in catch;
b. FiB will increase (>0) either if bottom-up effect occurs, or if a geographical expansion of the fishery occurs, and the 'ecosystem' that is exploited by the fishery has been in fact expanded;
c. FiB will decrease (<0) if discarding occurs that is not considered in the 'catches', or if the fisheries withdraw so much biomass from the ecosystem that its functioning is impaired.

Recommended actions: CIESIN also recommends to EAD to collect data on discards fishes; this will add accuracy on the FiB and MTI calculations. CIESIN recommends EAD to continue to collect MTI data on the species basis.

INDICATOR: FISHERIES RESOURCE STATUS

Policy Category: Habitat Protection and Effective Conservation

Code: FRS

Full name: Relative Spawner Biomass per Recruit (SBR)

Description: Relative spawner biomass per recruit is a proxy for the adult stock size used to evaluate the status of fisheries resources. It is routinely calculated on an annual basis for the three most important commercially exploited species in the demersal fishery of Abu Dhabi; *Epinephelus coioides* (Hamour), *Lethrinus nebulosus* (Shaari),and *Diagramma pictum* (Farsh). The indicator is derived from a population model with input parameters that relate to population dynamics (eg. growth rate and the age at maturity) and fishery characteristics (eg. the age at first capture and fishing mortality rate). Meta analyses of the relationships between stock sizes and recruitment (Mace, 1994) have produced biological reference points against which the SBR is compared in order to infer the status of the population (if it is over-exploited or not).

The target reference point is a SBR of 40% and the limit reference point is a SBR of 30% which management should avoid in order to prevent stock declines. Given these reference points, we are mainly interested in how far Abu Dhabi is from the target score that allow a sustainable fishery.

Policy relevance: This indicator is used to monitor the status of commercially exploited fish in Abu Dhabi waters in order to provide the scientific basis for fisheries management regulations and policy.

Target: SBR = 40%.

Target rationale: Meta analyses indicate that ground fish (demersal) stocks can be exploited sustainably without normal reproductive processes being impaired if the adult stock size is reduced to 40% of its virgin, unexploited size (SBR = 40%). This is a commonly used international convention for fisheries management.

Target source: EAD

Sources:

Variable:	Relative Spawner Biomass per Recruit
Source:	EAD
Source Definition:	Tabular data
Years Available:	2001 - 2008
Data assessment	Data is of good quality.

Indicator methodology: The FRS is a complex indicator derived from multiple biological and fishery parameters. The following table gives the SBR for the three studied fish species from 2001 to 2008:

Spawning Biomass per Recruit for the three commercial species in Abu Dhabi waters

Year	Epinephelus coioides	Lethrinus nebulosus	Diagramma pictum
2001	0.77	20.8	No data
2002	0.71	12	6.7
2003	0.51	12.2	5.9
2004	0.68	6.7	4.7
2005	1.25	6.7	6.6
2006	1.99	6.3	5.1
2007	13.7	28.5	8
2008	13.3	35.3	8.6

Grandcourt *et al.* 2005 provide details of the sampling protocol and analytical procedures.

Biological data were collected from specimens purchased from commercial catches. Age based parameters were derived from sagittal otoliths.

The age of each fish was estimated from the number of opaque bands observed in transverse sections of sagittae. Growth was investigated by fitting the von Bertalanffy growth (VBGF) function (von Bertalanffy, 1938) to size-at-age data, using non-linear least-squares regression.

Size-at-age data were used to construct an age–length key following the method of Ricker (1975). The instantaneous rate of total mortality (Z) was subsequently estimated using the age-based catch curve method (Beverton and Holt, 1957). The instantaneous rate of natural mortality (M) was estimated using the empirical equation derived by Hoenig (1983). The instantaneous rate of fishing mortality (F) was calculated for each year by subtracting the natural mortality rate (M) from the total mortality rate (Z) derived from age-based catch curves.

Spawning Biomass per Recruit (SBR), expressed as a proportion of the unexploited level, was calculated as:

SBR = $\sum_{t0}^{tmax} Nt, Wt, Gt,$ where:

Gt = fraction of mature fish at age t

Wt = mean weight at age t

Nt = Number of fish surviving to age t

Setting the SBR 40% of the unexploited level as the Abu Dhabi fishery target management, we assume that above this reference point, fisheries are sustainable, and below this point, fish are over-exploited.

From the values of table above, we then calculate how far Abu Dhabi is from this target point.

References:

Grandcourt, E. M., T. Z. Al Abdessalaam, F. Francis, A. T. Al Shamsi. 2005. Population biology and assessment of the orange-spotted grouper, *Epinephelus coioides* (Hamilton, 1822), in the Southern Arabian Gulf. Fisheries Research. 74, 55-68.

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