This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 6.

### Freshwater shortage

“The availability of freshwater is one of the most critical environmental issues of our time and is particularly true in Africa where large portions of the continent are arid or semi-arid and the precipitation is highly variable. The relatively large population and delicate ecosystems therefore, depend on water resources that vary greatly due to climate fluctuations and human induced changes. With increasing population and development we can expect that the pressures on existing water supplies in Africa and the vulnerability of the populations dependent on these resources will continue to grow” (Coe 2001).

Freshwater shortage was considered by the GIWA Assessment to be the most important concern for the Lake Chad Basin. The considerable decline witnessed recently in the Basin's potentially available water resources, can be attributed to both natural and anthropogenic factors. The impact of freshwater shortage was ranked as severe, and it is predicted that the impact of these factors on freshwater scarcity will continue to increase in severity by the year 2020. The concern of freshwater shortage was considered as being the driving force for many of the aquatic environmental concerns and their associated socio-economic impacts.

### Table 6 Scoring table for Lake Chad Basin.

| Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter) | 
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 6 | No known impacts | 2 | Moderate impacts | 1 | Severe impacts |

<table>
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<th>[ ]</th>
<th>Environmental impacts</th>
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<th>Health impacts</th>
<th>Other community impacts</th>
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<th>Priority***</th>
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</tbody>
</table>

* This value represents an average weighted score of the environmental issues associated to the concern. For further details see Detailed scoring tables (Annex II).

** This value represents the overall score including environmental, socio-economic and likely future impacts. For further details see Detailed scoring tables (Annex II).

*** Priority refers to the ranking of GIWA concerns.
The World Resources Institute (WRI) estimated that in the Lake Chad Basin the annual water supply per capita was 7 922 m³ in 1995. However, water supply is unequally distributed. The water supply in 1995 for the Lake Chad Basin excluding the Chari-Logone Basin was less than 500 m³/person/year (Revena et al. 2000), which indicates that the majority of the Basin is facing acute water stress. For example Chad and Niger, according to the Water Poverty Index (WPI), are both in the 10 most water impoverished countries in the world, with Niger being rated second lowest (UNEP 2003). However, the fourth and fifth countries with largest volume in annual renewable water resources in Africa are Nigeria (286 km³/year) and Cameroon (285 km³/year) (Revena & Cassar 2002).

The GIWA methodology that usually separates the concerns of freshwater shortage and global change has been adapted to take into account the particularly close relationship of the two concerns in Lake Chad Basin. Presently, the roles and extent of influence of climate change and human induced stream flow modification in causing the freshwater shortage has not been determined. Both climate change and stream flow modification are contributing to the freshwater shortage situation in the region and the ecological and socio-economic impacts are therefore similar. Global and regional climate change has been considered as an issue of freshwater shortage in the GIWA region 43 Lake Chad Basin report, due to the distinct synergies between these concerns.

**Lake Chad fluctuations - Natural versus human influence**

The most obvious indicator of declining freshwater availability has been the dramatic decrease in the surface area and volume of Lake Chad. This has been attributed to regional and global climate change as well as water management practices. Rainfall over the Chad drainage basin has decreased greatly since the 1960s, largely because of a decrease in the number of large rainfall events (Le Barbé & Lebel 1997). At the same time, water diversion has increased due to the construction of many dams in the hydrologically active sector of the Basin used to supply water for mainly irrigated cultivation.

During the 1960s discharge losses due to irrigation were almost nonexistent, however after 1983, precipitation continued to be low, but irrigation withdrawals increased. The FAO (1997) estimated the gross irrigation water requirements for the Basin to be 16.5 km³/year. A change in cropping strategy from low (e.g. wheat) to high (e.g. rice) water intensive crops was a major factor causing the increase in water use, particularly in Nigeria. Although the reduction in lake size is primarily attributed to reduction in rainfall, in the climatic scenario of the past four decades water use has been unsustainable.

**Global change**

The GIWA Assessment considers global changes from anthropogenic sources. Overall climatic change has caused considerable changes in the hydrological cycle of the Basin and consequential changes in the level of Lake Chad, but this has been witnessed many times in the history of the Lake as a result of natural processes (see Regional definition, History of lake level variability). It is undetermined to what extent the changes in the hydrological cycle are attributed to this natural variability or to human influences including the emission of greenhouse gases, bush clearing and agriculture. However it is not believed that human activities are the primary cause of the climatic variability and therefore the GIWA Assessment scored global change as moderate, not severe.

There has been no documentation investigating the GIWA issues of sea level change, increased UV-B radiation as a result of ozone depletion and changes in ocean CO₂ source/sink function on the Lake Chad Basin. These issues have therefore not been assessed in this GIWA report.

**Regional climate changes**

Several studies have shown that the hydrological cycle of the Sahel region which forms almost half of the Lake Chad region has changed over the last half of the last century (Bryson 1973, Gregory 1982, Lamb 1978a and b, Nicholson 1986 in Le Barbé & Lebel 1997). These studies and more recent scientific research by Roe and Foley’s climatic data analysis (2001) have demonstrated that rainfall events in particular have reduced and in turn led to drought and increasing desertification (Nicholson 1988 in Le Barbé & Lebel 1997). Figure 31 shows a wet period prior to 1960 followed by a decreasing trend of annual rainfall recorded at N’Djamena (Chad) between 1960 and 1990. In the Sahel, the 1990s was less dry than the 1970s and 1980s and there have been recent dry years in 1994 and 1999 (L’Hôte et al. 2002). However the 1990s were still the third driest decade in the last century and the wet years remain very

![Figure 31](Source: Meteorological station at N’Djamena airport)
Isolated from each other. L’Hôte et al. (2002) concluded that the drought since 1970, had not finished by the end of the year 2000.

A comparison of isohyets of the 1950s, which is regarded as the wettest decade, with the driest in the 1980s showed considerable shift towards the south as shown in Figure 32 (Olivry et al. 1996). In particular, the 400 mm isohyet moved 200-250 km towards the south in the west of Lake Chad, 100 km towards the south in the east but only few (10s) of kilometres in Ouaddai (Chad). The 800 mm isohyets shifted by 300 km to the south at the longitude of Guera and by 200 km to the south east of Guera, in Nigeria. The shifts were controlled by orographic effects while effects on the vegetation did not exactly parallel the shift of the isohyets as the soil type also had major effect in maintaining the status quo or in accelerating the rate of degradation as do the effects of man and animals. The reduction in rainfall was about 100 mm for each 100 km of distance apart from the annual and spatial variations (LCBC 2000b). The shift showed that areas that had experienced a mean rainfall of 320 mm (e.g. over the Lake itself) received less than 210 mm (World Bank 2002b).

Gaston (1996) also studied the effects of the 1973 and the 1983-1984 droughts on the Sahelian pasture lands in the Kanem region of Chad. According to the author, the effects of the 1973 drought seen on the ground were spectacular. There were many dead trees and all woody species had disappeared, as had the perennials of the field layer. In many places, sand had been blown and heaped against the dead and fallen trees. A revised 1:500 000 map based on specially flown aerial photographs taken in 1974 showed only eight (out of 20 vegetation types represented on maps of the same scale prior to 1973) vegetation formations. The northern limit of the Sahel had moved 100 km to the south (from latitude 15° 30’ N to latitude 14° 30’ N). The movement resulted from the significant downward shifts of isohyets widely observed in the Sahel and the progressive desertification ushered in by the desiccation.

According to Le Barbé and Lebel (1997) the lasting drought that has affected the Sahel for more than 20 years is associated with a 30% reduction in the number of rainy events, rather than to a decrease of the mean event rainfall or length of rainy season, and that this decrease is more pronounced for the core of the rainy season (July/August), with the mean event rainfall or length of rainy season, and that this decrease resulted from the significant downward shifts of isohyets widely observed in the Sahel and the progressive desertification ushered in by the desiccation.

![Figure 33](source: Tschierschke 2002) Lake Chad level variation and yearly precipitation at Bol.

(Source: Tschierschke 2002)
decrease between 1970-1989 is explained by the decrease of the mean number of rainfall events during July and August, while both the length of the rainy season and mean event rainfall remained stable (Le Barbé & Lebel 1997). The fact that the length of the rainy season did not change between the wet and dry periods supports the idea that the drought is not primarily linked to a shift in the average position of the Inter-Tropical Convergence Zone (ITCZ). There is a need to identify the factor responsible for the triggering of convection (which may be a consequence of the general atmospheric circulation or of local conditions), which will provide a physical basis for understanding the diminution in the number of rainfall events.

Lake Chad’s water level has consequently responded to the variations in the number of rainfall events. In Figure 33, an extrapolation based on the water level comes to a calculated rainfall of 800 mm/year for Maiduguri (Nigeria) in the period 1870-1880 (Tschierschke 2002). This shows how the lake level at Bol (Chad) strongly correlates with the 2-3 years preceding rainfall.

**Global climate change**

Climate change is regarded as the most important global change relevant to the Lake Chad Basin. In the past 30 years, the Sahel has experienced the most substantial and sustained decline in rainfall recorded anywhere in the world within the period of instrumental measurements (IPCC 2001). Linear regression of 1901-1990 rainfall data from 24 stations in the West African Sahel yields a negative slope amounting to a decline of 19 standard deviations in the period 1950-1985 (Nicholson & Palao 1993 in IPCC 2001). Since 1971, the average of all stations fell below the 1989-year average and showed a persistent downward trend since 1951 (IPCC 2001).

Lamb (1978) showed a relationship between variations in Sea Surface Temperature (SST) patterns and rainfall patterns. Several other observational and modelling studies have suggested that the global SST anomalies have a substantial influence in producing rainfall anomalies over the Sahel and the neighbouring regions (Folland et al. 1986, Palmer 1986, Folland et al. 1991, Palmer et al. 1992, Rowell et al. 1995 in Xue & Shukla 1997). Folland et al. (1991) found that relatively minor variations in large-scale patterns of SST have played a significant role in the variability of Sahelian rainfall. They also observed that tropical oceans have a greater influence than extratropical oceans, and that Sahel droughts are associated with a warmer SST in the southern hemisphere than the northern hemisphere (Xue & Shukla 1997).

According to Demarée (1990), western Sahel underwent an abrupt hydroclimatic transition from a “wetter” to a “drier” rainfall state in the second part of the 1960s. This was marked by cooling of the oceans of the northern hemisphere and simultaneous warming in the southern hemisphere being observed. A reversal occurred around 1970, since when temperatures in both hemispheres have increased. A time series plot of SST differences between oceans of the southern hemisphere and those of the northern hemisphere, and rainfall anomalies for the Sahel, shows a strong negative correlation. The correlation between the July-September SST and Sahel rainfall for the period 1901 to 1984 was -0.62, which is significant at the 99.9% probability level. Numerical equilibrium Global Climate Model (GCM ) experiments with prescribed sea temperatures were also undertaken by the UK Meteorological Office which were able to replicate rainfall reductions in the Sahel for recent drought years (Evans 1996).

The observed and unexpected warming of the southern oceans at a faster rate was thought to be due to a reduction in the heat transfer from southern to northern hemispheres, although the detailed mechanisms of the transfer are still the subject of much research. Alternative scenarios include increased deep water circulation from 1960 to 1970 in the Atlantic and the effect of sulphate aerosols which are dominant in the northern hemisphere. If, however, the reduction in heat transfer is related to the north-south conveyor system combined with a slowdown in formation of north Atlantic deep water at high latitudes, owing to a reduction in the extent of sea ice (Street-Perrot & Perrot 1990 in Evans 1996), then the Sahelian drought may persist until the greater land mass in the northern hemisphere starts to dominate the effects of a slowdown in ocean transfer and the attenuation effect of sulphate aerosols. However, confirmation will depend on further research developments into detailed coupled transient GCM models, which can be calibrated against recent climate and sea temperatures. It is likely that the results from the equilibrium GCMs will be found wanting once more reliable coupled models have been developed (Evans 1996).

However, the relative importance of these external factors over more local causes (such as vegetation degradation) in changing Sahelian rainfall remains to be determined and understood. A combination of factors including vegetation cover, soil moisture, and SST is thought to best explain the reduction in rainfall in the Sahel. Changes in albedo, soil moisture, land surface roughness, and SST anomalies have been modelled and a rainfall deficit over the Sahel is calculated similar to observed patterns (IPCC 2001). It has been suggested that a meridional distribution of boundary-layer entropy regulates the dynamics of monsoon circulation over West Africa, explaining observed correlations of SST to rainfall and the sensitivity of monsoon circulation to land-cover changes (IPCC 2001). A coupled surface-atmosphere model indicates...
that, whether anthropogenic factors or natural variation in SST patterns initiated the Sahel drought of 1968-1973, the persistence of drought conditions could be attributed to the permanent loss of Sahel savannah vegetation (IPCC 2001).

Zeng et al. (1999) compared actual rainfall data from the period 1950-1998 with the output of a coupled atmosphere-land-vegetation model incorporating SST, soil moisture, and vegetative cover. Their results indicate that actual rainfall anomalies are only weakly correlated to SST by itself. Only when the model includes variations in vegetative cover and soil moisture does it come close to matching actual rainfall data. Modelling the importance of SST, sea ice, and vegetative cover to the abrupt desertification of the Sahara 4 000 to 6 000 years ago, Claussen et al. (1999 in IPCC 2001) show that changes in vegetative cover best explain changes in temperature and precipitation. Xue and Shukla (1997) concluded that it is likely that both SST and land surface anomalies play a role in simulation of Sahel rainfall.

Modification of stream flow

The GIWA Assessment considered anthropogenic stream flow modification as having a severe impact on freshwater availability. Although the Lake has already dried out several times in the past (Holz et al. 1984) and therefore recent shrinkage is not a new phenomenon, the trend has been severely exacerbated by human stream flow modification.

The hydrological regimes of rivers of inter-tropical Africa are directly influenced by rainfall. In areas of the Lake Chad Basin, despite the relative abundance of water at times, the flow of rivers has been constantly diminishing (Nami 2002) partly due to decreasing rainfall in the hydrologically active upstream basins but also as a consequence of the increased abstraction for human consumption (World Bank 2002b). This abstraction has dramatically modified stream flow through the construction of dams upstream of the catchment, that have not taken sufficient account of the people and ecosystems downstream of the development (Second World Water Forum 2000, LCBC 1998). Stream flow modification has been focused on the two hydrological sub-systems Chari-Logone and Komadugu-Yobe. Detailed maps are provided in Figures 46 and 49.

Modification of the Chari-Logone River

The Chari-Logone Basin has a catchment area of 650 000 km², and the annual supply of the Chari River to Lake Chad between 1930 and 1960 represented 95% of the total annual inflow from all the basin rivers. However, the discharge of the Chari-Logone River at N’Djamena has decreased by almost 55% over the last 40 years (Olivry et al. 1996).

Figure 34 Interannual variations in discharge for the Chari River at N’Djamena. (Source: Republic of Chad 2003)

Average annual discharge over 59 years covering the period 1932-1992 of the Chari-Logone river system was estimated at 33.3 billion m³ while the average discharge since 1972 has been estimated at 20.7 billion m³ in the period between 1972-1991.

Figure 34 shows interannual variations in discharge for the Chari-Logone River at N’Djamena. Birkett (2000) showed that there is a strong correlation between the height of the Chari River during the 1990s (upstream of the major irrigation extractions) and the level of the Lake Chad in one to two months.

The reduction in stream flow of the Chari-Logone River is thought to be due to both natural and anthropogenic causes. Following the Sahelian drought 1982-1984 the total run-off of the Chari River was only an estimated 20% of the long-term mean (Evans 1996), in consequence the level of the Lake fell to its lowest level this century. However, stream flow modification has occurred on the Chari-Logone River through the construction of the Maga Dam, as part of the Company for the Expansion and Modernization of Rice in Yagoua (SEMYR) irrigation project, aimed at utilising the water resources of the region.

SEMYR irrigation project (northern Cameroon): For many years prior to the droughts, it was considered that water overflowing onto the Waza-Logone floodplains from the Chari River was not reaching the Lake Chad and therefore offered no advantage to the people of the region. It was decided that by constructing dams, this freshwater could be used for agriculture and as a fisheries resource. Many development works were carried out to open up large rice growing areas in northern Cameroon as part of the SEMRY irrigation project. The 30 km earthen Maga Dam was constructed on the upper part of the Waza-Logone floodplain in 1979 to provide water for the irrigation scheme and for fish farming. At the same time, some 80 km of dykes were constructed along the bank of the Logone extending 20 km downstream from Maga Dam to prevent...
the irrigated rice fields from being flooded from over-bank flow from the Logone River (LCBC 1998, Neiland & Béné 2003). Figure 35 shows the project infrastructure and the reductions in flooding of the Waza-Logone floodplains following the construction of the Maga Dam.

An IUCN hydrodynamic study of the floodplain reviewed the impacts of the dam for three scenarios; good years, average years and drought years (Etude du Modele Hydrodynamique du Logone, Mott MacDonald/Project Waza-Logone 1999 in LCBC 2002). The "pre-dam average year" flooded area was estimated at around 3,385 km$^2$, and following dam construction around 2,420 km$^2$, a decrease of around 30% (see review: LCBC 2002).

The establishment of embankments blocked breaches of the Logone River and entrances of the tributaries of Mayo Aretékelé and Petit Goroma, and deprived the Logomatya River of its main supply (Wesseling et al. 1994 in IUCN 2003b). The Maga Dam sealed up watercourses entering the Pouss depression, stored water originating from the tributaries of Mayo Boula and Logomatya, and caused the Mayo Gougoulay to dry up. In total these construction works resulted in a 70% reduction of water supply to the floodplain from the Mandara Mountains, and an almost complete curtailment of the water supply from the Logone (IUCN 2003b).

The significantly reduced flows in the Mayo Vrick below the dam (World Bank 2002a) has had negative impacts on part of the Yaérés downstream and on the Waza National Park, drying up an area some 20 km wide and 75 km long i.e. a total of 1,500 km$^2$ representing about 40% of the floodplain downstream of Maga and less than 20% of the Yaérés (LCBC 1998).

The SEMRY irrigation scheme seriously modified the floodplain regime leading to an acceleration of the degradation of the environment caused by drought. This included the disappearance of many botanical species and the progressive invasion of meadows and natural environments by unwanted ligneous forming plants. These modifications are thought to have eliminated the flooding of some 59,000 ha of floodplain and seriously reduced another 150,000 ha which were important breeding grounds and nursery for fishes. The SEMRY project has been seen as a failure and an IUCN project is currently rehabilitating the region to restore at least part of the flooding (see review: IUCN 2003b).

Studies and experience of both the Waza-Logone floodplains and the Hadejia-Nguru wetlands (Komadugu-Yobe Basin), as well as studies of fishing in the Lake Chad Basin, have led specialists to consider the relationships between the hydroosystem and ecosystem. Instead of viewing overflows from the Logone as a loss of water for the Lake, flooding of the Yaérés is now known to play an important role for the local fauna and flora and for the entire equilibrium of the system. The re-flooding of the Yaérés by making openings in the embankment that prevented water from overflowing into the plain has partly corrected the effects of Maga Dam further downstream, in particular in the Waza National Park (LCBC 1998).

Modification of the Komadugu-Yobe River
The upstream basin of Komadugu-Yobe River contributes a total long-term natural yield of approximately 7 km$^3$/year. However the River has experienced significant changes in stream flow regime. The modification in stream flow is in part attributed to the human stream diversion and in part due to drought, but it is undetermined what role each of these factors has played. The droughts in both the 1970s and 1980s severely affected northern Nigeria, and in particular the eastern half of the Komadugu-Yobe Basin. For example, annual rainfall decreased by over 40% compared to the long-term mean (1905-1982) in Kano in 1983 and 1984 (Oyebande 1997 in Oyebande 2001). The Ngadda, Yedseram and Komadugu Gana rivers did not flow and the Misau River, which obtains water from the Komadugu Gana was completely dry at Kari (Oyebande 2001).

During the 1970s and early 1980s around 20 reservoir dams were built on the Hadejia river system, which negatively affected the hydrology of the Yobe River, the only inflowing river into Lake Chad’s northern pool.
The dams control about 80% of the total run-off of the Hadejia River. The River used to supply large amounts of water to the Lake but has now been reduced to an insignificant flow of 1% since the construction of the dams and pre-drought years (Neiland & Béné 2003). The Komadugu-Yobe River now only flows for six months of the year instead of nine, with a smaller discharge (annual modulus at Diffa: 558 million m$^3$ from 1965 to 1973 and 379 million m$^3$ from 1983 to 1996). Figure 49 provides a map with the location of major water constructions.

The largest upstream irrigation scheme at present is the Kano River Irrigation Project (KRIP), fed by the Tiga Dam completed in 1974, which has an active storage capacity of 1 400 million m$^3$ (Figure 36). Water is also released from this dam to supply Kano City in Nigeria. Before the construction of the Tiga Dam, there was a relatively strong stream flow in the Hadejia River during June-October that accounted for 98-99% of annual flow. After the dam was completed there was a 21-22% reduction in stream flow. In 1992 the height of the Tiga Dam was lowered due to structural instability, which resulted in a 31% reduction in its storage capacity (Oyebande 2001).

The Challawa Gorge Dam (972 million m$^3$ reservoir) on the Challawa River is designed to release water into the Hadejia River for subsequent storage behind the Hadejia barrage to supply the Hadejia Valley Irrigation Project. The barrage and Challawa Gorge Dam were finished in 1992. Challawa Gorge also provides water for Kano City (World Bank 2002b).

A decrease of flow upstream of Hadejia because of evaporation from the Tiga Reservoir with a rate of 425 million m$^3$ annually has caused a reduction of flow in Gashua of 56 million m$^3$ annually. When water used for irrigation and by urban centres is taken into account, the reduction in flow at Gashua is 60 million m$^3$. If all the dams located in this sub-system were operating at their designed capacity the total reduction would be 76 million m$^3$. Since the mid-1970s, dry season flood releases from the Tiga Dam during the dry season modified stream flow from zero flows during the season to a perennial regime (Oyebande & Uwa 1980 in Oyebande 2001). However, these releases did not appear to benefit the ecological systems downstream of Gashua (Oyebande 2001). Consequently the major part of this water resource has not been able to establish a natural regime through the downstream Yobe River in Nigeria and Niger for almost 30 years. The absence of an integrated river basin management strategy in the basin has further given rise to a host of other problems, such as uncoordinated operation of dams, growth of weeds and silt blockages in the Old Hadejia River preventing its contribution to the Komadugu-Yobe River, among others.

So far there has been little development on the Jama'are River with only one small dam across one of its tributaries. However, plans for a major dam at Kafin Zaki have been in existence for many years to provide water for irrigated area of around 84 000 ha. Work on the Kafin Zaki Dam has been started and stopped a number of times, most recently in 1994, and its future is at present unclear (World Bank 2002b). The water demand in the sub-basin has been estimated to be about 2.6 times the available water resources (DIYAM Consultants 1996) and according to Oyebande (2001) if the development of the Jama'are and Hadejia basins goes ahead as planned there will be reduction in flow at Gashua of at least 1 275 million m$^3$ per year, or the equivalent total flow at Gashua over an average year.

In addition, the development of large irrigation areas has not followed construction of dams so far. If all the irrigation projects of the various agencies were to be implemented, more water would be used in the upper basin, to the detriment of the downstream basin (LCBC 1998). For example in the Nigerian part of the Basin at present, 20 dams have been built or are under construction and nine more are contemplated (with reservoirs of 1 076 million m$^3$), whereas only 36 620 ha have in fact been irrigated out of the intended 188 780 ha. Much water is therefore used or lost through evaporation in the reservoirs or silted up beds on the plateau. The various dam and irrigation projects were planned without any environmental impact study and in particular without taking into account the effects on people downstream (LCBC 1998).

Reduced stream flows and the absence of large flood events have reduced the ability of the system to clear river channels of silt blockages and caused a proliferation of weeds. Flows have consequently been diverted onto the floodplains and stopped the flow in the Old Hadejia River, so that Marma Channel has received more water since the 1970s.
Due to these weed blockages the Hadejia and Burum Gana now only have a limited contribution to the flow of the Komadugu-Yobe River (Oyebande 2001).

Prior to impoundment, large volumes of floodwater nourished an extensive sub-system of floodplains and wetlands (World Bank 2002b). These upstream developments have diverted surface or groundwater for irrigation and altered the timing and size of flood flows. Downstream, increasing demand for irrigated agriculture has led to the diversion of water past wetlands through bypass channels. This sub-system presently provides 1.5 km$^3$ water per year when exiting the upper basin at Gashua and only 0.45 km$^3$ when arriving at Lake Chad. Below Gashua, flows maintain Hadejia-Nguru wetlands, where effluent flow from the watercourse recharges alluvial aquifers and pumping and diversions for small irrigation schemes. Development of irrigation by pumping has exacerbated the existing water-stress imposed by upstream impoundment. Irrigation developments coupled with decreases in precipitation have caused the maximum extent of flooding of the Hadejia-Nguru to decline from between 250 000 and 300 000 ha in the 1960s and 1970s, to 70 000 to 100 000 ha more recently (World Bank 2002b). The current contribution of the Komadugu-Yobe River to the northern part of the Lake Chad wetlands is minor in terms of the overall balance (World bank 2002b).

The stream flow modification of the Komadugu-Yobe River has impacted on the ecology of the Basin. The decline in wetland extent has proportionately decreased the fish abundance in the wetlands and in addition perhaps more than five species are no longer found in different parts of the floodplain (Oyebande 2001). The decline in fish species diversity is blamed on the reduced flooding and changes in the timing, depth and extent of flooding. Fish species that have been particularly affected include Alestres sp. and Schilbe sp. that depend on the flood regime for their migration and spawning patterns (Drijver & Van Wetten 1992 in Oyebande 2001). The number of birds in the Hadejia-Nguru wetlands is highly correlated with the extent of the wetlands. The abundance of birdlife has consequently been reduced.

**Direct modification of Lake Chad**

The South Chad Irrigation Project (SCIP) is an example of a Lake Chad development scheme that has failed due to poor management, civil strife and by the Lake’s rise and fall. SCIP is the largest irrigation project in Nigeria, with a goal of irrigating 67 000 ha with an average cropping intensity of 130% (200% would be two crops per year). The project aimed to resettle 55 000 farming families onto the irrigated land. Nigerians had already practised resettlement as a drought strategy (Figure 37); the number of villages in the Nigerian portion of Lake Chad rose from 40 to 100 between 1975 and 1988 (USGS 2001).

SCIP planning started in 1962-1963 at the very peak of the wet years. A successful 1966 pilot project irrigated 1 000 ha. The major project started in 1974, and was commissioned at 23 000 ha in 1979. A system of pumps and canals was to carry water from the lake shore intake point to farmers’ inland fields. But the plans were dependent on the lake’s level. When the Lake fell below 279.9 m (about 2 m above the baseline) no irrigation could take place. The system operated only six of the first 10 years, with a maximum of 7 000 ha irrigated. Few of the farmers got water, few crops were produced, and water efficiency was low. The canals were unlined, so water seeped into the ground, and only about half reached farmers. When water did come, many farmers overcompensated by breaching or siphoning the canals to get more water, thereby wasting water and waterlogging their fields. Some fields were also poorly prepared for irrigation (USGS 2001).

The Baga Polder Project, had a goal of irrigating 20 000 ha to produce 26 000 tonnes of wheat, 28 000 tonnes of maize and 14 000 tonnes of groundnuts annually. However, by 1996 only 1 000 ha were under irrigation and now the project concentrates on farming the receding lake waters. The original polder that was constructed for irrigation purposes is now several kilometres from the lake shore.

The farmers surrounding the Lake have adapted to the fluctuating lake levels using both traditional and improved technologies. Farmers in Lac Prefecture (Chad), to the north of the Lake, have planted in the depressions between the sand dunes exposed by the receding waters that are known as polders. The polders are fertile from alluvial deposits and source water from rainfall, residual moisture and irrigation. Rice, wheat, maize, and vegetables are grown. The Government of Chad created the Lake Chad Development Company (SODELAC) in 1967

![Figure 37](new-town-on-the-cameroon-shore-1989.jpg)
to enhance the socio-economic development of the Lac Prefecture, which resulted in the establishment of the Lake Chad Polders Project. This project promoted the development of the polders, and improved the technologies used by the farmers. Farmers of traditional polders produce one crop per year, using residual moisture as lake waters recede each season. In the improved polders, farmers use small dams and pumps which allow them to produce as many as three crops each year. SODELAC believe that the agricultural potential of the Lac Prefecture has not been utilised and with improved water management, production could increase to meet national wheat and rice consumption needs (FEWS 1997).

Pollution of existing supplies
The GIWA Assessment regarded the pollution of existing water supplies as only having a slight effect on the freshwater shortage facing the region, although further scientific justification is needed. Water quantity and quality play a significant role in the determination of availability and access to freshwater resources. In sub-Saharan Africa in general, water quality is a major problem (AEO 2002, GEO 3 2002). People may reside in an area with plenty of water and yet still not have access to it freely because of its status of purity and suitability for human consumption. Access to safe water however is an option most households in the Basin do not have. For example, in the far north provinces of Cameroon in the Lake Chad Basin sector of Cameroon, only 5% of households have access to safe water (ECAM 1996 in Amin & Dubois 1999). According to World Bank Development indicators for the countries of the Lake Chad Basin, access to an improved water resource has remained static or only increased slightly between 1990 and 2000.

Presently there is a lack of information regarding the pollution of existing water supplies in the Lake Chad Basin. There is relatively little industrial or mining activity in the region and the impact on water supplies appears to be minimal. Effluent discharges in the upstream parts of the Basin (particularly in Kano, Nigeria) from tanneries and textile production have led to localised fish kills. It is likely that untreated domestic wastes are also being discharged into the rivers of the Basin, with negative effects on water quality.

Water contamination and reduced stream flows has also caused the proliferation of weeds, mainly Kachalla grass (*Typha* sp.) that have encroached into reservoirs and clogged channels near Madachi, Kirikasama and Nguru on the Hadejia River (IUCN 1998), and hampered freshwater use. There have also been further reports expressing concern for water quality in the Hadejia River, as salinity has been increasing (World Bank 2002b). Although agriculture uses predominantly traditional methods, the production of crops such as cotton and rice that require high doses of chemical sprays suggest that water supplies are being contaminated. There is a lack of studies on the distribution of these agro-chemicals in the environment.

Changes in the water table
The GIWA Assessment considered that there are moderate changes in the water table due to reductions in aquifer recharge and the increased sinking of boreholes. There is little information concerning groundwater, but it is considered to be abundant, which does not necessarily mean that it is always easy to exploit. However, it may be stated that the cumulative rainfall shortages and virtually generalised decline in low flows has led to a reduction in groundwater reserves in the river basins, and in particular the phreatic aquifers. The reduced flooding of the plains has negatively impacted on the important role wetlands play in recharging the underground aquifers, in both the Yaéré in Cameroon and the Hadejia-Nguru plain in Nigeria (LCBC 1998).

According to Hollis et al. (1993) groundwater storage beneath the Hadejia-Nguru floodplain was largely stable between 1964-1971 and 1975-1982 but diminished by an estimated aggregate of 5 000 billion m³ as a result of the drought years and reduced flooding in the early 1970s and particularly in the 1980s. However, a study in southwest Niger by Favreau et al. (2001) concluded that the clearing of native vegetation increased the rate of groundwater recharge. Therefore, the decrease in vegetation cover experienced in the Lake Chad Basin may also influence the rate of groundwater recharge. As shown by Gaston (1996) in Chad, the northern limit of the Sahel moved 100 km to the south as a result of the 1973 drought. The dead and fallen trees were a result of inadequate soil moisture to sustain the vegetation. A net decrease in groundwater reserves would have potential impacts on the drinking water supply of a large proportion of the Basin’s population who dig wells to obtain groundwater reserves (Figure 38).

Figure 38  Women fetching water from a well in southern Niger.  
(Phot: FAO P. Cenini 1995)
Although reserves are abundant in the region, due to the recent declines in their recharge, aquifers are currently vulnerable to over-extraction exceeding their safe yield. Surface water scarcity during the drought as well as adaptation strategy increased the abstraction of groundwater for human, agricultural and pastoral purposes (Thieme et al. In preparation). It is known that there has been indiscriminate sinking of boreholes that have led to a decrease in groundwater reserves. Groundwater drawdowns of several tens of metres have been reported in the Maiduguri area of Nigeria due to the over-pumping of water. Isiorho et al. (2000), estimated that 10-25% of water in the region is utilised inefficiently and attempts to improve the situation have achieved little. The droughts of the 1980s triggered the mass drilling of 537 wash boreholes between 1985 and 1989 (CBDA 1990 in Isiorho et al. 2000). This rapid development resulted in unsatisfactory logging of wells by several contractors who were not supervised and did not use hydro-geological data when locating the wells. Most of these deep boreholes are uncapped and freeflowing. Normally the local authorities cap artesian wells, but local people uncap them and allow the water to flow out and cool so that their animals can use it. This free flow of water is very inefficient and results in vast amounts of water being lost due to the high rates of evaporation in the region (Isiorho et al. 2000).

Economic impacts

The GIWA Assessment considered freshwater shortage caused by both anthropogenic and climatic changes as having severe economic impacts. Over-abstraction of water by upstream users at unsustainable levels in a period when there has been a substantial decrease in precipitation in the watershed, has led to a reduction of the supplies for downstream users. This has essentially, had a direct negative impact on the economic activities of agricultural production (crops, livestock), forestry, fisheries, agro-processing industries, tourism and wildlife. Declining freshwater availability also impacts on the general downstream ecology thus reducing the environment’s capacity to support economic activities. The irrigation developments have taken place without consideration of impacts on the floodplain or the loss of economic benefits previously provided by the floodplain (Barbier et al. 1991 in Schuijt 2002).

Declining freshwater has impacted on water-related infrastructure. The lower recharge rates of aquifers have facilitated the need to deepen wells and increase pumping to reach the lower water table. This has been time consuming and a further financial burden in a poverty stricken region. The decrease in volume and flow of the Komadugu-Yobe River has encouraged the growth of weeds in the main river courses, causing flooding in the villages along the river banks as flow can no longer take place normally towards the downstream part of the River (LCBC 1998). The Lake’s ever-fluctuating shores are preventing the installation of permanent infrastructure and reduced river flows are reducing the accessibility for inland transport. Freshwater shortage is therefore compromising significant development and contributing to economic destitution faced by the riparian countries.

Freshwater shortage is directly impacting on the following economic activities:

Impacts on agriculture

Agriculture in the drier downstream regions and around Lake Chad is more dependent on water level as low precipitation limits rain-fed agriculture. Water level is strictly dependent on the hydrology of the rivers and thus has suffered from water deficits. This bedrock economic activity is considered as being the most affected by freshwater shortages. Large irrigation projects undertaken with a view to agricultural intensification on large areas along the Chari River in Chad (SONASUT at Banda, 4 000 ha), the Logone River in Cameroon (SEMRY projects in Yagoua, Maga and Kousseri), and in Chad (Casier A, B, C at Billam Oursi, Songor, 7 120 ha, and Lai) the Komadugu-Yobe River (e.g. Kano River Irrigation Project and Hadejia Valley Project), and the SCIP project on the lake shore (northeast Nigeria), have not produced the expected results. Rather than stimulating increased agricultural production, they have reduced the flooding of large areas of farmland that was previously very productive for flood and recessional farming. The Maga Dam constructed as part of the SEMRY project (north Cameroon) abstracted water from almost 700 km² of the Yaéré floodplains that small farmers cultivated during the dry season after a good humid year. The supply of water to the floodplains became increasingly deficient due to the persistent drought, and they no longer reached all the Yaéré floodplains that are favourable to dry season agriculture (Nami 2002). A reduction in floodplain surface area has consequently led to a decline in agricultural production and has accentuated food insecurity in the region (Nami 2002).

More than 95% of crops in the Basin are traditional and therefore do not rely on the water from the irrigation project but are dependent on the rains. The reduced rainfall has therefore impacted directly on yields of sorghum and millet in the Sahel and the Sudanese zone (see review: Nami 2002). For example, in Chad annual sorghum production was less than 250 000 tonnes during the 1972-1974 droughts and...
There has been a proliferation of pests due to the droughts and water management practices employed. In Chad between 1986 and 1988, the farmers were plagued with desert locusts (Schistocerca gregaria) who were already tackling an economic downturn caused by the succession of droughts, in addition to civil wars, that had depressed cotton prices in 1985 (Keith & Plowes 1997). Box 3 describes how the failure of the South Chad Irrigation Project (SCIP) has resulted in an ecological imbalance in the region.

**Box 3 Typha australis and Quelea quelea pest infestation.**

The Nigerian Government, worried about low agricultural production in the Lake Chad Basin, took steps to intervene through the South Chad Irrigation Project (SCIP), in order to stabilise agricultural production. With a goal of irrigating 67,000 ha, the system depended on lake water levels. As these levels fell in the late 1980s, irrigation could not take place.

The irrigation channels, which were not lined, now provide suitable shallow water and marshy habitat for emergent hydrophytes (plants that grow in wet conditions). Plant biodiversity is lost in this way, as the complex variety of plants adapted to the complex rhythm of rising - steady - falling water levels are disadvantaged in favour of emergent rhizomatous plants that can survive long dry spells. The SCIP channels are clogged with one of these plants, the bulrush Typha australis.

The Typha stands is a preferred nesting ground of the avian pest Quelea quelea. Quelea infestation is an additional pressure on the already unstable livelihood systems of the Lake Basin. The regular loss of rice and other grain crops to large flocks of feeding quelea is a major concern. The Government has initiated a quelea control effort through massive aerial spraying of toxic chemical control agents. While the effectiveness of this control method is an ongoing debate, the long-term effect of these toxic chemical sprays on other life forms has not been determined.

(Source: http://www.panda.org)

**Impacts on animal husbandry**

Before the advent of persistent drought, animal production and export was the third largest source of income for families in the Basin. Since the droughts the amount of land suitable for grazing has decreased. For example, in the Hadejia-Nguru wetlands (Komadugu-Yobe River Basin) the receding floods previously allowed fresh grass to grow using the residual moisture. This allowed the wetlands to sustain large numbers of cattle during the dry season due to the high quality grazing land compared with the dry surrounding areas. However, wet season peak flows are necessary to inundate these grazing lands. With reduced peak flows the extent of high grade grazing land has declined. The Yaéré floodplain pastures (Chari-Logone River Basin) are also an important dry season grazing resource. Prior to the loss of floods, it is estimated that some 20,000 to 50,000 sheep and goats spent the dry season on the floodplain (Wesseling et al. 1994 in IUCN 2003b). Most of these formally flooded pastures have now lost their perennial grass cover, leaving only degraded grasslands of inferior quality and decreased area (IUCN 2003b). Reduced grazing land across the entire basin following the droughts of the 1970s, encouraged herders to shift from grazing animals (cattle and camels) to browsing animals (sheep and goats), which affected the area’s vegetation through the consumption of woody plants (USGS 2001).

**Impacts on fisheries**

(See also section on Unsustainable exploitation of fish).

The Sahelian droughts of 1972-1974 and 1982-1984 combined with anthropogenic stream flow modification caused a reduction in the extent of Lake Chad and the wetlands which consequently altered the fish habitat. Fisheries production has experienced large fluctuations due to these environmental changes. Annual production escalated in the early 1970s before falling significantly in the 1980s (Neiland & Verinumbe 1990), and has since increased once again (Neiland & Béné 2003).

The decline in wetlands has caused a proportional decline in the yield of fish in the wetlands (Thomas 1996 in Oyebande 2001). In the Waza-Logone floodplains there has been an estimated 90% reduction in fish yields within flood-fed wetlands (Wesseling et al. 1994 in IUCN 2002b), and a reduction in the capacity of wetlands to provide nursery grounds for fish stocks in the wider river systems of the Logone and Chari. In the Komadugu-Yobe River Basin it has been observed that in the last 20 years the quality of fish in the oxbow lakes has declined due to siltation, from reduced stream flows, making the lakes too shallow (Oyebande 2001). Low flows in rivers also constrained the seasonal fish migrations. Laguets or migrating fish, that are often migratory and more selective in spawning preference, suffered from high mortality and fewer accessible spawning sites (Bénéch 1992). Natural selection operating on the fish communities during this dry period favoured marshy species adapted to freshwater shortage conditions (Bénéch et al. 1983) (see Habitat and community modification, Modification of fish habitats).

The fisheries of the Lake Chad Basin are very important economically to the rural communities (see Regional definition, Fisheries of the Lake Chad Basin) (Neiland & Béné 2003). The fluctuations in fish production therefore have had a significant impact and have contributed to the regional poverty.

**Impacts on food security**

Freshwater shortages in the Lake Chad Basin have compromised the performance of agriculture, the fishery and livestock. Consequently the people of the Basin have become vulnerable to food insecurity (AEO 2002).

FAO Statistics have shown that the food situation in Niger and particularly Chad are precarious as a result of rainfall deficits, but more so also as a result of regional imbalances of water distribution (FAO/GIW 2001).
Food shortages have increased significantly in Chad and Niger both of which are downstream of the Komadugu-Yobe and Chari-Logone rivers. In 2000, Niger’s food supplies were 25% short of the national requirements leading to high food prices, particularly for millet. In Chad, under normal conditions cereal production only covers 75% of national food requirements and during 1999/2000 this situation was further exacerbated by erratic weather conditions resulting in food insecurity. The World Food Programme in response to food insecurity in Chad distributed emergency food to 252 000 people in 2003 (WFP 2003).

Figure 39 shows the extreme and high vulnerability zones in Africa. It can be seen that in the last 30 years famine has been experienced in the north and Sudan sectors of the Basin and that all of the countries have been subjected to either food shortages or acute malnutrition except for Nigeria, Algeria and Libya.

Health impacts
The GIWA Assessment considered the impact of freshwater shortage on the health of the Basin’s population as being moderate in terms of the number of people affected, the degree of severity, and the frequency and duration. Lack or inadequate potable water supplies coupled with poor or lack of proper sanitation are two very significant problems facing more than half of the population of the region. The problem differs from country to country with Niger, Chad and Central African Republic being at the helm of severe impacts. As a consequence of the acute freshwater shortage experienced in 1973, drought killed 100 000 people in the Sahel, and even countries in the humid zone suffered lowered rainfall and reduced crop yields (see review: AEO 2002).

During the wet season, water filters very slowly through the very clayey Karl soil causing floods. Taking into account the low levels of hygiene in riparian villages often without latrines, soiled pits overflow and spill into watercourses during the floods, the contaminated water causes various illnesses such as cholera and malaria to emerge. During periods of drought and due to the absence of plant cover, violent winds transport epidemics such as meningitis, which is permanently rife in the region (Nami 2002).

According to the World Bank (1994), out of eight major diseases or disease groups found in developing countries, four are linked to water supply and sanitation or to vectors (organisms) that breed in water. Furthermore, many water resource projects alter the environment so as to either increase the number of vectors or increase the amount of contact with disease-causing organisms (Tiffen 1989a and b). In Northern Nigeria where irrigation projects have proliferated in recent years, the number of vectors or disease-causing organisms has more than doubled (Tiffen 1989a and b). Ofozie (2002) classed Bauchi, Kano and Borno States as having hyperendemic prevalence of schistosomiasis. In Kano, the prevalence of the disease rose from 0.8% before 1973 to 37.6% after 1973 following dam construction. The communities surrounding Tiga Dam have a 46.7% prevalence of schistosomiasis (Imevbore et al. 1988, Ndifon et al. 1988). The artificial lakes, unlike other freshwater bodies such as rivers, lack currents and seasonal ponding, and subsequently provide favourable conditions for year round transmission of vector-borne diseases (Ofozie 2002).

The reduced river flow caused by these irrigation projects can also reduce the river’s waste assimilative capacity resulting in decreases in the level of sanitation. Poor sanitation is a major contributor to the spread of diseases such as diarrhoea, cholera, typhoid, intestinal worms and hepatitis (A and E). In N’Djamena 1 317 cases with 94 deaths were reported in an outbreak of cholera in 1996 (WHO 1996).

Other social and community impacts
The GIWA Assessment evaluated the impact of freshwater shortage on the social and community status as being moderate. Social pressures caused by decreased freshwater availability have aggravated human conflicts. Competition between user groups for shared resources including space has been accentuated e.g. agriculture versus tourism and conservation versus food production.
The freshwater shortages have increased the potential for upstream/downstream conflict. In the Komadugu-Yobe Basin disputes between the downstream riparian states of Borno and Yobe (Nigeria) were fuelled by the lack of adequate water for their needs. They blamed this on the upstream states that they accused of storing all the water from the Tiga and Challawa Gorge dams, and releasing too little for downstream users (Oyebande 2001). Recently there has been pro-active opposition from the downstream states of Yobe and Borno to the construction of the Kafin Zaki Dam on the Jama’are River (UCN 2003a).

During the dry seasons, the nomadic pastoralists move their stocks southwards in search of grazing areas. The continuing drought has led to further migration of pastoralists from the increasingly dry northern regions into the southern river basins. This has increased ecological stress on river basin resources and the abandonment of traditional, effective resource management practices (World Bank 2002) and has put greater pressure on the water resources in the southern river basins of the Komadugu-Yobe and Chari-Logone.

The contraction of the Lake is also a potential source of conflict due to disagreements over whether the national borders also migrate with the Lake. The political boundary is normally shifted in favour of the dominant power in the region, and has led to some clashes between neighbouring countries in the region (Isiorho et al. 2000). Fishermen have migrated following the receding lake and thus crossed political borders, notably fishers from Niger and Nigeria. There have consequently been armed clashes with local fishermen from Chad over who had the right to the declining fishing resource.

However, many fishermen in the Basin have tried to adapt their livelihood strategies to compensate for declining fish production caused by the contracting lake. Sarch and Birkett (2000) have compared the livelihood responses of fishermen on the southwesterly shore with the lake fluctuations recorded by ground gauges, satellite imagery and radar altimetry. This shows that since 1972, the communities of the western shore have made important responses to the contraction and recent expansion of the Lake. Two of these responses were resettlement and switching livelihood strategies:

As the lake levels dropped during the 1970s and 1980s, the maximum extent reached by the Lake each year receded eastwards towards the centre of the Lake Basin. Communities followed the lake shore and in some cases moved eastwards more than once.

The second response to the contraction of the Lake was to diversify from relying entirely on fishing to farming the lake floor as the floodwater receded. Although each of the village communities described how they had originally set up as fishing settlement during the 1970s and 1980s, in 1993 the majority of the households relied on farming as their main source of income (Sarch 1996 in Sarch & Allison 2000). Many of the Hausa communities that had been attracted by the fishing opportunities of the 1970s, switched to farming as the lake shore contracted and revealed the moist soils of the lake floor around their fishing settlements. Of the 80% of Hausa households who had fished Lake Chad in the past, the majority (58%) now relied on farming for more than a quarter of their annual income (Sarch 1999 in Sarch & Allison 2000).

The mobility and livelihood flexibility of the rural communities making their living on the shore of Lake Chad has enabled them to respond to the extreme fluctuations observed. This ability to react and cope with changing livelihood opportunities and constraints is characteristic of these communities whom have changed livelihood strategies many times in the past and who do not rely solely on fishing. It is not accurate to talk of fish stocks as being sustainable in the context of this level of natural fluctuation. Around Lake Chad people have adapted their livelihoods and are able to exploit the same areas of the Lake Basin in a range of environmental conditions through fishing during the flood and farming after the flood has receded. It is argued that such strategies highlight the importance of enhancing or maintaining the flexibility of lake shore livelihoods rather than constraining it with fixed fisheries production quotas, seasons or areas (Sarch & Allison 2000).

**Future outlook**

The GIWA Assessment predicts that the magnitude of freshwater shortage is to become increasingly severe by the year 2020. The Basin is set to experience major alterations and developments in the next 20 years that need to be taken into consideration.

**Future climate change**

The future variability of the climate is critical to future freshwater availability. Future climate change in Central Africa has yet to be determined as there are presently no accurate models for predicting future precipitation rates over the region. During the 1990s there has been evidence of increased precipitation and consequential increases in discharge from the Chari-Logone River. However, the climate remains drier than pre-1970s with only isolated wet years (L'Hôte et al. 2002), and it is too early to state whether this most recent cycle will persist. Some forecasts predict that the scenario between 2003 and 2020, at best, could be similar to the current status from 1973 until now (Republic of Chad 2003). This is based on the scenario of future global warming linked to a weakening in carbon sinks and radiation sinks in the polar regions with reduced deep water formation due to reduced heat.
transfers from the southern hemisphere to the north. It is postulated that reductions to the radiation and CO₂ sinks could give rise to significant positive feedbacks leading to an increase in global warming (Lewis 1989 in Evans 1996). However the future influence of these global processes on the region’s climate over local factors remains a subject of study and debate. Local factors will undoubtedly also continue to play an important role in driving the future climate of the Sahel.

Population growth
Presently, the annual population growth (2000-2005) is estimated to be 2.6% (UN Population Division 2002) and the total population for the Basin in 2020 could be over 56 million (UN Population Division 2002). This significantly enlarged population will depend on the Basin’s limited water resources for their survival. If the current trends of urbanisation continue, particularly in Nigeria, there could be an increasing demand for water supply to municipalities.

Increased water use
For the foreseeable future water demands in the Lake Chad drainage basin are expected to increase, as the population becomes more dependent on irrigation agriculture (Hutchinson et al. 1992, FEWS 1997 and 1998 in Coe & Foley 2001). Therefore it is important to learn more about the response of this very sensitive system (Coe & Foley 2001). The population trend of the conventional basin reveals that, from a standpoint of the Malthusian concept (as compared to other schools of thought, such as Virtual water, structural inequality, environmental or social scarcity, lateral pressure, etc.), the per capita renewable water availability which presently places the region in the class of “water stress” (1263 m³) could worsen to “acute water shortage” situation (698 m³) by the year 2025 (LCBC 2000b).

Water development projects
Planned water development projects, particularly those in the Komadugu-Yobe Basin will increase water requirements and outstretch available supplies. The water requirements in the Hadjeja River Basin are already at times exceeding the available water resources (Bdilaya et al. 1999) and are at a critical point where further expansion of requirements of one use will deprive other users of water. An IUCN study estimated that the potential water requirements are at least (not taking into account evaporation losses) 2.6 times greater than the mean surface water resources. In the Jama'are and Yobe river basins available water resources presently meet requirements. If the construction of the Kafin Zaki Dam is completed for the proposed Jama'are Valley Irrigation Projects and some smaller irrigation upstream of Katagum, potential water requirements for the Jama'are River Basin could be more than 1.8 times the available water resources in a mean year (Bdilaya et al. 1999).

Petroleum exploitation
The employment opportunities presented by the Chad oil exploitation that began in July 2003, will encourage migrant workers to the area and thus increase and concentrate pressure on water resources. There is a possible risk of polluting existing water supplies from run-off from the oil fields and construction sites although a comprehensive management plan has been implemented to mitigate all environmental risks (ESSO 1999). The Chad-Cameroon pipeline crosses transboundary waters several times; there is always a possibility of an oil spill incident even with stringent safety measures installed. There are six area-specific Oil Spill Response Plans in place to react to any such emergency.

Conclusions
The GiWA Assessment considered the major issues of freshwater shortage as climate change and stream flow modification, which consequently have decreased water table levels. Natural climatic variability has been exerted throughout the history of the Basin and is considered as playing an important role in fluctuations in stream flow and in the level of the Lake Chad (see Regional definition, History of Lake level variability). Recent climatic variability can be primarily attributed to these long-term climatic cycles but may have been exacerbated by recent human induced Sea Surface Temperature (SST) and land surface anomalies. The GiWA Assessment refers to anthropogenic global change and therefore it was considered as having a moderate impact. The GiWA Assessment considered anthropogenic stream flow modification as having a severe impact on freshwater availability. Although the Lake has already dried out several times in the past (Servant & Servant 1983), recent trends have been exacerbated by the diversion of water by dams for irrigation projects such as the SEMRY (north Cameroon) and the KRII (northeast Nigeria). The level of water use has been unsustainable in the climatic scenario of the past 40 years. Birkett (2000) concluded that the seasonal fluctuations of the lake level are still primarily controlled by climate, not water management practices. Nevertheless, stream diversion is a key factor in the extent of the freshwater shortage downstream of the large dam constructions and is a concern regarding the use of what water supplies that is available in the region during periods of low precipitation.

The issue of the pollution of existing water supplies is considered as having a slight impact due to limited industrial activity in the Basin. However with the onset of petroleum exploitation in Chad, pollution of water supplies either directly from the oil projects activities or by the increased urbanisation in the region could increasingly become a concern. There may also be contamination from agro-chemicals as the production of crops such as cotton requires chemical sprays. Pollution studies will be required to monitor the impact and distribution of these
in the environment, and to assist in the formulation of regulations regarding pollution, which are lacking in the current legislative framework (see Pollution, Agricultural chemical pollution).

The issue of changes in water table was regarded as having a moderate impact due to the reduction in the wetlands and lake and therefore their aquifer recharge function, and due to the indiscriminate sinking of boreholes that are often uncapped and free flowing. There is however a lack of information on groundwater reserves and the impacts of abstraction are not known.

Overall, the concern of freshwater shortage was considered as being severe due to it driving almost all environmental concerns in the Lake Chad Basin. The ecological impacts on the wetlands and lake environment have been severe. For example, since the 1960s wetland resources within the Basin, such as the Yaérer in Cameroon and the Hadijia-Nguru floodplains in northern Nigeria, have been reduced by almost 50% (Barbier et al. 1997) and the Lake Chad was reduced in the 1990s to just 10% of its former extent prior to the 1960s. Freshwater shortage has had severe economic impacts on the fisheries, flood-recessional agriculture, livestock rearing and other wetland industries. There has consequently been severe food insecurity in the region and a proliferation of diseases. Large dam developments in the upstream catchments of the Chari-Logone and Komadugu-Yobe river basins has caused conflicts due to downstream users receiving insufficient amounts of water to meet their requirements. There has also been significant migration from the north of the Basin as "environmental refugees" have fled drought, increasing the pressure on natural resources and inciting social tensions.

Leading up to 2020 the Lake Chad Basin is set to experience some major alterations, namely the large-scale oil developments in Chad and water management projects that have the potential of changing the freshwater shortage situation for better or for worse.

Habitat and community modification

Aquatic habitat modification has primarily been a result of the freshwater shortage concern in the region. For example, wetland habitat modification can be mainly attributed to declining stream flows and the diversion of water away from the wetlands. However, the consequences of habitat modification have been severe in the Lake Chad Basin, but although the impacts are being experienced across the region they are generally localised and terrestrial. The GIWA methodology addresses transboundary water issues and therefore the concern was assessed as having only a moderate impact. However to fully understand the wider context regarding habitat modification, terrestrial and non-transboundary issues have also been discussed, but not assessed under this concern.

Modification of aquatic habitats (assessed by GIWA)

The GIWA Assessment identified community modification and habitat loss as having a moderate impact. The wetlands, lakes and rivers have all experienced habitat loss and modification to a certain degree. The most severe habitat modification has been caused by drought and the construction of dams in the Chari-Logone and Komadugu-Yobe river basins. These have altered the seasonal timing of flooding in the floodplains and have thus reduced the size of the wetlands. Stream flow modification has also significantly affected the lake environment as the habitat has changed from predominantly open-water to a marshy environment as the Lake contracted. Vegetation degradation has contributed to regional climate change and consequently the decreased rainfall experienced in the region. The GIWA Assessment predicts that the riparian countries are likely to face increasingly severe problems with the possibility of greater aridity and increased pressure on ecosystems and ecotones to support rapidly increasing populations. For example, Nigeria’s population is projected to reach 338 million by the year 2025. This figure is 123 million in excess of its carrying capacity with intermediate inputs (Nana-Sinkam 1995).

Wetland modification

Wetlands play an important role in both biological and socio-economic systems contained in the Lake Chad Basin. Wetlands are an important source of water and nutrients necessary for biological productivity (Thompson 1996 in Schuijt 2002). They provide people with fertile soils for agriculture, fish, fuel wood and raw material for mats and roofs. Wetlands also store water temporarily and recycle nutrients and human waste to improve water quality. It is clear how valuable wetlands are to a considerable portion of the population who survive by exploiting its natural resources (Acreman & Holis 1996).
The floodplains and wetlands have consequently been intensively cultivated, and the wet areas are frequented by domestic animals especially during the dry season when the pastoral groups migrate southwards in search of grazing areas. The Hadejia-Nguru wetlands, in northern Nigeria, host approximately 120,000 cattle in the wet season and 320,000 cattle in the dry season, 370,000 goats and 375,000 sheep (RIMS 1992, using aerial reconnaissance). Although the North East Arid Zone Development Programme (NEAZDP) estimated that there could be twice as many. The wetlands have also experienced intensified agricultural production. These human activities have had significant impacts on wetlands. Wetlands and other protected areas continue to be exploited by the local communities with surveys in the Yaérés (northern Cameroon) recording severe losses. The floodplains and wetlands, particularly in the Hadejia-Nguru and Yaérés have been claimed for settlements, farms, cattle grazing and as bases for fishing (see review: Mockrin & Thieme 2001).

The modification and loss of wetlands is however primarily due to the decreasing stream flows, resulting from persistent droughts and upstream dam impoundment (see section on Stream flow modification). These floodplains were once the second largest wetland in Africa, highly productive, and supporting a diversity of wildlife (USGS 2001). Since the 1960s wetland resources within the Basin, such as the Yaérés in Cameroon and the Hadejia-Nguru in Nigeria, have been reduced by almost 50%. The Hadejia-Nguru floodplains in northern Nigeria at one time covered nearly 300,000 ha, today, these wetlands have shrank to an estimated 70,000 to 90,000 ha (Barbier et al. 1997).

Before the Sahel droughts in the 1970s the southern pool was characterised by Cyperus papyrus and the northern pool was dominated by Typha australis. As the Lake contracted in the early 1970s, the northern pool became even more saline and the permanent swamps virtually disappeared. In the southern pool in particular the Cyperus papyrus communities were badly affected and replaced by Vossia cuspidata meadows (Verhoeeye & De Wulf 2001).

Kindler et al. (1990), revealed the relationship between freshwater shortage and floristic degradation. Fundamentally, the research showed that freshwater shortage led to:

- Reduced canopy coverage that increases ground temperature, soil water evaporation, and opens up the soil surface to rain drop and wind erosion;
- Change of species from perennials to annuals;
- Reduced biomass of forest products from lowered water tables or overexploitation;
- Loss of root volume that increases soil erosion;
- Reduced numbers of deep-rooted trees that recycle minerals locked in soil.

The bird life has also been threatened by decreasing water levels. Recently there have been concerns over the availability of nesting sites for the endangered West African subspecies of black-crowned crane (Balearica pavonina pavonina) and adequate wintering grounds for intercontinental migrants such as the ruff (Philomachus pugnax) (see review: Mockrin & Thieme 2001). The abundance of the 17 species of waterfowl and 49 other wetland species recorded on Lake Chad, have correlated with the extent of the water surface of Lake Chad and with wetland conditions elsewhere in West Africa (Keith & Plowes 1997). Although little is known on the range, abundance or status of the listed rare species river prinia (Prinia fluviatilis), the contraction of the wetlands is likely to have been detrimental to their populations.

The decreased inundated area of the Waza-Logone floodplain has been a major cause for the reduction in the number of kob, and the complete disappearance of buffalo, waterbuck, bushbuck and common duiker in the Waza National Park (Wesseling et al. 1994 in IUCN 2003b).

Sedimentation has increased in the Hadejia river system due to the reduced stream flows, but also because of the declining wetlands, as they play an important role in trapping sediment and in protecting river banks from erosion in upland wetlands. The riverine wetlands such as the Yaérés also regulate the floods by storing excess water.

**Modification of fish habitats**

Aquatic habitats have experienced extreme alterations due to the decreasing stream flows and consequential lake shrinkage. As the Lake contracted, it changed from hosting a predominantly open water ecosystem to marshes. The aquatic flora and faunal community structures were modified accordingly. The fisheries market species composition has been a prominent indicator of these changes.

Among the most important commercial fish species recorded in the Nigerian sector of Lake Chad before the 1972-1974 Sahelian drought (recorded 1963-1967) were Lates, Hydrocynus, Labeo, Citharinus, and Distichodus (Bukar & Gubio 1985 in Neiland & Béné 2003). Following the 1972-1974 drought these species generally disappeared and were replaced by species such as Clarias; for example, in 1972 Clarias made up 0% and Lates 52.7% of fish markets, whereas in 1976 they consisted 89.6% and 0%, respectively. These changes were accelerated by intensive opportunistic fishing effort in the northern pool in which open-water species such as Lates were easily caught. Benech et al. (1983) concluded that the natural selection operating on the fish communities during the...
drying up period (1972-1978) favoured the development of these marsh adapted species endowed with adoptions of diet, reproduction and respiration that allowed them to survive in an unstable environment, at the expense of open-water species that are generally migratory with strict preferences (Neiland & Béné 2003).

Following the total drying of the northern pool in 1975, fishermen migrated south and began to target the southern pool more seriously (Sagua 1986 in Neiland & Béné 2003). This environment, containing both open water and marshes, may explain the slight reappearance of some lacustrine species such as *Lates, Hydrocynus, Labeo* and *Distichodus* and a decline in mudfish from 1980 onwards. However, current research suggests that the majority of fish moved through the Baga-Kawa market since the Lake has evolved to its present lesser state, originate from the swamp fisheries, which surround the Lake Chad and seasonally extend northwards into the Nigerian sector (Neiland & Béné 2003).

As would be expected, data for Kinnaserum market, Chad, indicates that the species, which disappeared from the Nigerian sector of the Lake, are still found within markets serving the lacustrine environment of the southern pool. Typical examples include *Hydrocynus* and *Lates*, but also swamp species such as *Clarias* (catfish), tilapiine cichlids, *Synodontis, Gymnarchus, Mormyrus* spp. and *Mormyrops*. One reason for survival of the purely open-water species is the connection between the southern open water and the Chari-Logone river system, which can provide the refuge of deeper and well-oxygenated water. Data from Maroua market, Cameroon, which services mostly the Yaéré floodplains and Maga Reservoir traded in species common to river and floodplain environments, dominant species included *Alestes, Clarias, Petrocephalus* and tilapiine cichlids. Although time series data is not available for the Chadian and Cameroonian markets, composition of north Nigerian market species for 2000-2001 was similar to that noted during the early 1980s mid-1990s suggesting a stabilisation in environment of the lesser lake state and the associated species composition (Neiland & Béné 2003).

The change in dominance between open-water and marshy species is very rapid when there are changes in the lake environment, and as no species are restricted only to the Lake, the reconstruction of stocks is possible from river fish communities if a normal lake state reoccurs (Benech et al. 1983 in Neiland & Béné 2002b).

**Regional climate change caused by habitat modification**

The cyclic behaviour of the climate in the Sahel, where dry and wet periods persist, has been explained by biogeophysical short-term feedback processes named the ‘Joseph’ and ‘Noah’ effects; reduced vegetation leads to increased albedos and increased radiation losses, surface cooling and greater atmospheric stability which reduces rainfall and encourages persistence (Charney 1975 in Evans 1996).

According to Coe and Foley (2001) overgrazing of the savannah is a contributing factor in the shrinking of the Lake. As the climate became drier, the vegetation that supported grazing livestock began to disappear. The vegetation has a significant influence, especially in semi-arid regions, in determining weather patterns. The loss of vegetation in itself contributed to a drier climate. Human and animal populations came to rely more and more on water from the Lake. Massive irrigation projects to combat the drier climate diverted water from both the Lake and the main rivers that empty into it. Coe and Foley described this situation as a domino effect; overgrazing reduces vegetation, which in turn reduces the ecosystem’s ability to recycle moisture back into the atmosphere, and thus contributes to the retreat of the monsoons. The consequent drought conditions have triggered a huge increase in the use of lake water for irrigation, while the Sahara has gradually edged southward. This is a hypothesis and the domino effect may not necessarily affect the source area, especially in such flat lands widely open to advection/free lateral air flows. Further studies are needed regarding the influence of regional habitat modification on regional climate change.

**Economic impacts**

The GIWA Assessment regarded the economic activities most affected by habitat loss and modification as the fisheries, agriculture, livestock and wetland industries. These activities were severely impacted but primarily as a result of freshwater shortage. Wetlands provide essential income and nutrition benefits in the form of agriculture, grazing resources, non-timber forest products, fuel wood and fishing for local populations. The wetlands also serve wider regional economic purposes, such as providing dry-season grazing for semi-nomadic pastoralists, agricultural surpluses for neighbouring states, groundwater recharge of the Chad Formation aquifer and insurance resources in times of drought (Barbier 1997).

Several economic activities are severely affected by wetland destruction:

- *Agriculture*: dryland farming of sorghum and millet, seasonally flooded rice farming, flood retreat farming (mainly cowpeas) and irrigated farming. Rice is the most important crop grown in seasonally flooded areas.
- *Fishing*: is done at various times of the year with different gear. The reduced flooding of the wetlands due to dams, diversions and climatic change has caused poor fishing revenues.
Dry season grazing: grazing of sheep, goat, cattle and a few camels. Pastoralists often move into the area as the dry season develops.

Wild resources: provides materials for utensils and construction. Doum palm is a source of food, materials and income. Dried palm is harvested throughout the year to make a variety of products like mats, baskets and roofing materials. Potash is sold as an industrial raw material first to wholesalers and then to traders from other parts of the country. Households use potash as a food ingredient, a stomach medicine and an appetite stimulant for livestock. Firewood is collected mostly for subsistence by both men and women, but is also a very active trade commodity (Schuijt 2002).

According to the Ramsar Convention on Wetlands, the Hadejia-Nguru wetlands present value of the aggregate stream of agricultural, fishing and fuel wood benefits were estimated to be around 34 to 51 USD per ha (1989/1990 prices based on the maximum flood inputs) (Barbier 1997). The economic importance of the wetlands means that there will be an economic loss associated with any scheme that leads to degradation of the floodplain system, e.g. by diverting water away from them (Barbier 1997). The Hadejia-Nguru wetlands have declined by 210 000 to 230 000 ha. It is therefore estimated that decline in this wetland has had an economic cost of between 7.1 million and 11.7 million USD.

Moreover, this does not take into account perhaps the most important environmental function of the Hadejia-Nguru wetlands as its role in recharging the groundwater aquifers of the Chad Formation. Evidence presented by Hollis et al. (1993) shows that a reduction in floodplain inundation leads to a lower rate of groundwater recharge. Since 1983, when the extent of flooding dropped appreciably, groundwater recharge fell by an estimated aggregate amount of 5 000 km$^2$. Continual loss of groundwater storage and recharge will have a significant impact on the numerous small villages throughout the region that depend on well water from the aquifer for domestic use and agricultural activities (Barbier 1997).

The wetlands and lake host an array of habitats for a wide range of fauna and flora. Future tourist markets attracted by this wildlife might establish if political stability increases in the region, this however could be jeopardised by habitat loss and destruction. These ecosystems also provide a unique and important educational resource for local, regional and international education institutes and the scientific community.

**Health impacts**

The GIWA Assessment considered the impact from habitat loss and modification as to have a moderate impact on the health of the Basin’s population. In a region where poverty is widespread and access to safe water and sanitation is very limited, the habitats in the region provide vital resources to sustain the population. As these resources have become scarcer, greater effort has been required to subsist, which will ultimately impact on health.

**Other social and community impacts**

The GIWA Assessment also identified moderate social and community impacts. The drying up of the northern pool resulted in fishing communities migrating eastwards several times to follow the contracting lake. They also changed their livelihood strategy to adapt to the decreases in fish production by farming the Lake’s fertile recessional lands. This has caused social unrest with communities competing for the diminishing aquatic resources (Sarch & Allison 2000).

**Future outlook**

The GIWA Assessment predicted that in a future scenario it is likely that the impacts from habitat modification will become severe. The following factors are predicted to occur and will thus facilitate the increased severity of habitat loss and modification.

**Population increase**

Population increases will place further pressure on wetland, river and lake ecosystem resources and thus lead to increased habitat and community loss and modification. Desertification in the arid northern regions of the Basin will continue to cause a southward migration towards the Lake and the southern river basins, and consequently increase the pressure placed on these habitats.

**Freshwater availability**

The rate of habitat loss and modification is largely dependent on future variations in freshwater availability, which in turn, is dependent on the amount of human water abstraction and climatic variability. There are presently no accurate forecasts of future climate change (see Freshwater shortage, Future outlook). Greater aridity could lead to further desiccation of the wetlands and the persistence of a marshy lake environment. There is also the concern of future water management plans that do not take sufficient account of their impacts on the Basin’s habitats. Freshwater shortages could be aggravated further by proposed developments that include the construction of more dams that will further alter the wetland, lake, and fisheries habitats accordingly.

**Livelihood strategies**

The fishing communities of the Lake have changed their economic profiles to adapt to the fluctuating lake levels in the past. This has included reducing fishing effort, in order to allocate time and effort to farm the fertile recessional lake floor. The relationship between habitat resources...
and livelihood strategy is twofold; changes in the community’s profile of economic activities is often caused by the changes in the availability of the habitat’s resources, but changes in livelihood strategy also alters the distribution of pressure placed on these resources. For example if future fish production declines once again, then more pressure will be placed on the wetlands for agricultural and grazing purposes.

**Conclusions**

The GIWA Assessment regarded the overall impacts of habitat and community loss and modification as moderate, but it is predicted that this could worsen to severe by the year 2020. The modification of habitats has been primarily a function of freshwater shortage rather than a result of direct habitat modification by humans. The wetlands have been the aquatic ecosystem most affected by habitat modification with a reduction by 50% in their surface area (Barbier et al. 1997). This has been a result of stream flow modification, but high levels of agriculture and livestock activity has also increased the pressure on wetland resources. Stream flow modification has also modified the open-water habitats to a predominantly marshy environment. This has consequently changed the community structure of this region. The economic impacts were regarded as moderate, as habitat modification was primarily a result of freshwater shortage. Overgrazing may have contributed to regional climate change by reducing the Basin’s moisture recycling capacity and thus decreasing rainfall in the region.

**Modification of terrestrial habitats (not assessed by GIWA)**

Terrestrial habitat modification has had a significant impact on a large proportion of the Basin’s population. Although terrestrial and non-transboundary concerns are not included in the GIWA Assessment, to understand the wider context and linkages, it is necessary to discuss these issues.

In the past four decades there has been habitat and community loss and modification due to a combination of anthropogenic and climatic induced pressures. The persistent droughts have had a dramatic effect on ecosystem structure and combined with land use practices such as deforestation and unsustainable agricultural practices, have resulted in the exacerbation of land degradation and desertification. The intensification of land use has thus reduced diversity and the extent of habitats for wildlife (Keith & Plowes 1997).

**Desertification**

A large proportion of the Lake Chad Basin has been identified as being vulnerable to desertification, defined as land degradation in arid, semi-arid, and dry sub-humid areas resulting from different factors, including climatic variations and human activities. Land degradation is the deterioration in the quality and productive capacity of land and has been identified as one of the major environmental challenges facing Central Africa (see review: AEO 2002). For example, Nigeria’s 2002 Interim Strategy Update cites land degradation as the most serious environmental problem facing Nigeria (World Bank 2002a). The desert is said to be moving at an annual rate of 5 km in these semi-arid areas (Nana-Sinkam 1995). Human induced desertification has occurred as a result of unsustainable land use practices arising from rapidly increasing population and intensive economic activities. Figure 40 demonstrates the risk from human induced desertification in Africa; a large proportion of the Lake Chad Basin is at very high risk.

Although the countries of the Lake Chad Basin all experience desertification to some degree, there are disparities between the riparian countries. Figure 41 gives a breakdown of the total area of land...
in each country vulnerable to desertification and the level of risk it faces. Nigeria and Central African Republic have the largest percentage area of land vulnerable to desertification, but Chad, Niger and Sudan have the largest percentage of areas at very high risk.

Wind erosion is a normal phenomenon to the north and east of Lake Chad in Niger and Chad, but is intensified by poor land use practices. Overgrazing and cultivation have resulted in the loss of the vegetation that held the dunes in place (LCBC 2002). The area north of Lake Chad has virtually no surface flow and consists of moving sands and recent “ergs”. The change in rainfall patterns has moved the limits of wind erosion to the south. The changing rainfall patterns have also concentrated grazing pressure on the remaining rangeland, moving the pattern of transhumance southwards (LCBC 2002). Consequently Chad is currently experiencing the greatest vulnerability to desertification, with 58% of the area already classified as desert, and 30% classified as highly or extremely vulnerable (Reich et al. 2001). In Niger 250,000 ha are being lost each year through desertification (Eden Foundation 2000). Degradation of natural resources such as water, farmland, pastureland and forests has gone a long way toward making populations more vulnerable. All of these factors have led to the near pervasive impoverishment of land capital, the dwindling or disappearance of fallow land, overexploitation of wood resources and overgrazing, which have accelerated the process of desertification (Government of Niger 2002).

In Nigeria, desertification (together with soil erosion) accounts for about 73% of the estimated total cost of 5.1 billion USD per year the country is losing from environmental degradation. In the northern states, located in the Lake Chad Basin, it is considered as the “most pressing environmental problem” (Federal Government of Nigeria 2002). Desertification has been indicated by the gradual shift in vegetation from grasses, bushes, and occasional trees, to grass and bushes and in the final stages, expansive areas of desert-like sand. It has been estimated that between 50% and 75% of Bauchi, Borno, Jigawa, Kano and Yobe states in northern Nigeria are being affected by desertification. The country is currently losing an estimated 351,000 ha of its landmass to desert-like conditions annually, and such conditions are estimated to be advancing southwards at the rate of 0.6 km per year (Federal Government of Niger 2002).

The situation is being aggravated by the increase in human population, which appears to be stressing the natural support system. In many areas, the sustainable yield threshold of the vegetation and soils is being breached (Federal Government of Nigeria 2002). Over 37 million people depend for their livelihood on activities carried out in the Lake Chad Basin with the Nigerian Sector of the Basin supporting two thirds of this population (based on ORNL 2003).

The increasing pressure on the limited natural resources of the desertification prone zone, is exacerbated by the southward migration of people and livestock, results in overgrazing and continuous overexploitation of the marginal lands (Federal Government of Nigeria 2002). In Nigeria this pressure is being absorbed by states such as Benue, Kaduna, Kwarai, Niger, Plateau, Taraba and the Federal Capital Territory (FCT). This action leads to an intensive use of fragile lands and marginal ecosystems resulting in further degradation even during years of normal rainfall. The steady deterioration in northern Nigeria has continued largely ineffectively challenged for several years (Federal Government of Nigeria 2002).

The Central African Republic and northern Cameroon have also been experiencing desertification since the severe drought of 1972-1973 (see review: AEO 2002). In northern Cameroon the renewable resource base is being rapidly degraded due to urbanisation, resettlement due to population pressure, and the search for alternative income sources from wood cutting, commercial grazing and fishing (LCBC 2002).

Several techniques have been developed to fight against desertification or to minimise the impacts of factors that exacerbate the processes of desertification (Ahmed 2000) which can be adapted to the Basin. These techniques include the plantation of shelter belts, replication of sustainable agricultural practices and agro-forestry. There are also many other ideas for local action in water management practised in other parts of the world. Within the Lake Chad Basin, some of these innovative ideas are currently practiced by the UNEP-Belgium government Mega Chad Project, as well as NGOs including the North East Arid Zone Development Project (NEAZDP) and JEWEL in Nigeria, ONG KARKARA at Diffa in Niger, SECADERV in Chad, PDRM in Cameroon and PDRN in CAR. These techniques if widely applied in the Basin are capable of reversing some of the presently observed degradation trends in future.

**Overgrazing**

Overgrazing is considered as a major cause of desertification in the Lake Chad Basin, as grazing animals remove vegetation cover and expose the soil to processes of wind and soil erosion. Large quantities of soil can be moved by these processes and future productivity of the land limited or rendered useless for future regenerations.

Traditional animal husbandry is not very important economically but its impact on the environment constitutes a significant threat of desertification in times of drought as one third of the 300,000 km2
available to man, livestock and fauna is dedicated to animal husbandry (Nami 2002). It was estimated in 1995 that there were more than 404,000 pastoralists in Chad (about 15% of the country’s population), with pasture areas covering about 55% of the national territory (FEWS 1995 in AEO 2002).

Nomadic pastoralists have been encouraged by the sinking of boreholes to settle in locations that they previously only grazed for relatively short periods of time. This has been detrimental to wildlife that was previously allowed to regenerate (Newby 1980 in Keith & Plowes 1997).

Kindler et al. (1990) drew up a transhumance map which shows that the migration routes of herds move towards the south and towards the Lake in the dry season, thus confirming the desert’s advance to the south, and the decline of animal husbandry in the Lake Chad Basin (Nami 2002). The migration of livestock from the Sahelian zone could trigger overgrazing and a shortage of pasture in the Sudanian zone nearer to Lake Chad (FAO/GIEWS 2001). Population pressures on the land have also resulted in diminishing pastureland and, in some cases, to the narrowing or even disappearance of transit corridors for animals. This has led to a decrease in feed crop production, and at the same time livestock population has increased and placed more of a burden on plant cover than can be normally sustained (Government of Niger 2002).

**Overcultivation**

Overcultivation can lead to desertification due to the unsustainable consumption of nutrients from soil resources. Nutrients are not replaced as agricultural products are removed and the soil replanted without sufficient fallow time. This increasingly degrades the soil resulting in lower crop yields, which consequently forces farmers to plant on larger areas of land to receive the same return on their agricultural investment. Land degradation eventually becomes so severe that the land turns to desert like conditions (desertification).

The pressure exerted on the quality of soil increases with the number of farmers in an area (Nami 2002). The semi-arid zone of Nigeria located in the Lake Chad Basin, constitutes the largest grain producing area of the country and most of the livestock are concentrated here as well. In years of abundant rainfall, the region provides high yields and profitable livestock production. Conversely, in periods of poor rainfall, there is increasing pressure, which sometimes results in a food deficit and associated unfavourable consequences (Federal Government of Nigeria 2002).

Agriculture has been forced to expand due to the climate constraints, intense population pressures, reduced soil fertility, and difficult access to inputs and farming equipment. In Niger the acreage under cultivation has doubled and farming has shifted towards “marginal” lands in the north (Government of Niger 2002).

![Figure 42](Photo: Eden Foundation Sweden 2000)
Millet, the staple food crop of Niger, is widely grown in the sandy soil of valley bottoms. After some years of millet agriculture the land is left to fallow and the natural vegetation is allowed to regenerate. Fallow periods of 6-10 years are typical but, as pressure on the land has increased, less land is being left to fallow and rotation times are reduced. Land used for millet cultivation in east Niger and northeast Nigeria has consequently become barren sand dunes. Land that has been allowed to fallow for four years or more, increases in value for wildlife, with improved biodiversity. Shorter fallow cycles will result in a decreased biodiversity and abundance on these fallow lands (Keith & Plowes 1997). Figure 42 shows the vulnerability of fields to wind erosion once the millet crops have been removed.

The land in some areas is insufficient to support communities and to supplement crop production particularly during periods of food insecurity, herds of wildlife such as ostriches and bustards, and fish resources are further exploited. This is exacerbated by the ready supply of ammunitions used in combat between rival forces in the succession of civil wars in Chad that allows harvesting of wildlife at a scale not previously possible (Newby 1980 in Keith & Plowes 1997). This has resulted in a decline in animal populations.

**Vegetation removal and modification**

Extensive removal of vegetation by humans combined with a considerable fall in water level in Lake Chad and the associated aquifers has resulted in a decline in perennial vegetation. This has resulted in soil erosion and soil compacting leading to severe land degradation in the region. When vegetation is removed soil is exposed to heavy rainfall, evaporation and wind action. The main reasons for vegetation removal are commercial logging and tree cutting to provide domestic fuel, clearance of forests for commercial, or subsistence cultivation, as well as livestock browse and bush burning.

Unsustainable forestry practices to meet increased demand for firewood and lumber for local use, has resulted in the overharvesting of the Basin’s woodland resources (Keith & Plowes 1997). Deforestation exposes soil to high temperatures, which break down the organic matter, increase evaporation and make the soils vulnerable to erosion (Nana-Sinkam 1995). The removal of vegetation also alters drainage patterns and rates, increasing surface run-off, which again results in further soil erosion. The rate of forest loss in the Basin is a cause for concern in terms of its impacts on biodiversity, atmospheric change and hydrological cycles, in addition to the concerns regarding soil erosion.

Expanding agriculture to meet demand from the rapidly increasing population of the Basin, has led to habitat modification as land is cleared for cultivation, while increased grazing and cutting for firewood will accelerate destruction of wildlife habitat on the remaining non-cultivated areas. This habitat modification can decrease the ecosystem functions and eliminate vegetation essential for specific animals (Keith & Plowes 1997). Expansion of agricultural production will also put increasing pressure on the inadequately enforced parks and reserves as communities search for new land to harness for agriculture, firewood gathering, and grazing (Keith & Plowes 1997). Farming expansion has cleared large areas of greenbelt, such as north of Tanout (Niger), to make way for annual crops. Farmers have attempted to cultivate this land, but later abandon the land, as it is unsuitable for sustainable crop production. By destroying areas of green belt the desert will be able to advance more rapidly (Eden Foundation 2000).

Firewood is the predominant source of fuel for the Lake Chad Basin population. In Niger for example, 95% of households use firewood as the principal source of energy for cooking, regardless of region. This high demand and scanty supplies has resulted in fuel wood becoming a source of conflict. A number of forest reserves have been developed in the area that are being heavily exploited by commercial firewood harvesters for large urban centres (Barbier et al. 1991, Eaton & Sarch 1997).

**Deforestation in the Nigerian sector of the Lake Chad Basin**

(Source: Neiland & Verinumbe 1990).

In the Nigerian sector of the Lake Chad demand for wood probably exceeds the available supply as shown in Table 7. These figures show that an area of savannah woodland 10% greater than the total area of Nigerian sector of the Chad Basin cropped at the sustainable level of 50 tonnes/km²/year. However the relationship between supply and demand for wood is complicated by a number of factors.

<table>
<thead>
<tr>
<th>Table 7</th>
<th>Wood supply and demand in the Lake Chad Basin (Nigerian sector) for 1989.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood supply and demand in the Lake Chad Basin 1989 (Nigerian sector)</td>
<td></td>
</tr>
<tr>
<td>Total area of Chad Basin – Nigerian section (km²)</td>
<td>136 000</td>
</tr>
<tr>
<td>Human population</td>
<td>22 million</td>
</tr>
<tr>
<td>Annual domestic wood demand (tonnes)</td>
<td>7.5 million</td>
</tr>
<tr>
<td>Annual sustainable wood extraction (savannah)(tonnes/km²)</td>
<td>50</td>
</tr>
<tr>
<td>Area required to meet present demand (km²)</td>
<td>150 000</td>
</tr>
</tbody>
</table>

Note: Figures based on best reliable estimates of wood supply and demand. (Source: Neiland & Verinumbe 1990)
There is an estimated population of almost 22 million (based on ORNL 2003) residing in the Nigerian Lake Chad Basin sector with a national population growth rate of 2.9% (World Bank 2002c; estimated population growth rate for Nigeria 1980-2000). This increasingly populous region uses fuel wood and other traditional fuels (charcoal, animal and vegetable wastes) as their major fuel source, representing 67.8% (1997) of the total energy consumed by Nigeria (World Bank 2002c).

This extreme demand has to be supported by an area of woodland available for exploitation as low as 50% of the total area (due to overexploitation and agricultural clearance). The relatively slow growing savannah woodland will require time to recover from the drought conditions, and it is expected that annual sustainable yield will remain below 50 tonnes/km² for some years. This area of woodland also has to support the considerably large population of domestic animals (cattle, sheep, and goats) who depend almost entirely on fodder trees for their dry season food. Consequently, the FAO has identified northern Nigeria in general as being an area where there are acute shortages of fuel wood. In Baga (north Nigeria), easily accessible supplies close to the Lake have already been overexploited and large areas close to the Lake have been cleared for agriculture, both by local villagers and as a result of government development initiatives. The South Chad Irrigation Project (SCIP) has also cleared an area of 670 km². Disruptions during its construction led to large areas of land being devoid of vegetation and left exposed to wind erosion (Neiland & Vernumbe 1990).

Neiland and Verinumbe (1990) stated that almost certainly demand for wood products and in particular fuel wood far exceeds the available local sustainable supply. Productivity of the woodlands has also been impaired by the water shortages and severe drought over the past four decades. The inevitable result of this imbalance is overexploitation beyond the sustainable yield, leading to the destruction of the resource base (deforestation).

**Economic impacts**

**Economic impacts of desertification**

The consequences of land degradation, and of soil erosion and compaction, are manifest as a result of the declining ability to support natural or domesticated plant and animal production. Ultimately, this translates to reduced nutritional status of the population and to reduced export revenues. In addition, communities that are dependent on wild produce (such as fruits, nuts, animals, mushrooms, and fuel wood) have to search further and further a field to meet their needs, and may experience food shortages or even famine during drought years. Extreme reductions in productivity may result in people abandoning their farms and migrating to urban centres, in search of improved security (AEO 2002).

In Nigeria due to desertification entire villages and major access roads are being buried under sand dunes in the extreme northern parts of Borno, Jigawa, and Yobe states in the Nigerian sector of the Lake Chad Basin (Federal Government of Nigeria 2002) causing social and economic disruption. An agricultural survey of Niger, which constitutes the basis for calculating changes in rural poverty, indicates that farming output has declined steadily since 1992. At the same time, livestock production, which accounted for more than 35% of agricultural GDP, has been declining at nearly 2% per year (Government of Niger 2002).

**Economic impacts of deforestation**

The shortfall in supplies of local wood to meet demand has had three main economic effects in North Nigeria (Neiland & Vernumbe 1990):

- The average price of a wood bundle is significantly higher compared with areas further south.
- The demand for wood stimulated a vigorous trade in wood bundles and logs. The market demand encouraged further heavy exploitation of wood resources.
- Due to common wood shortages the people have been forced into using readily available alternatives, other than the expensive paraffin and gas. These alternative fuels include dried woody shrubs such as Calotropis procera, the papyrus sedges and grasses of the Lake, and the stalks of crops such as sorghum. Unfortunately both are of a much lighter density than acacia wood, for example, and burn very quickly, so that a large volume is required to maintain a cooking fire. This is leading to further land degradation.

**Health impacts**

Habitat and community modification has significantly contributed to the poor standards of health found in the region. The declining fertility of land has effectively decreased crop yields in an area vulnerable to food insecurity from climatic fluctuations. Scarcity of woodland is forcing villagers to have to travel further to obtain enough supplies to sustain their families, with implications on their health and also on food security for their family as their efforts are diverted away from productive activities.

**Other social and community impacts**

Desertification is creating “environmental refugees” in increasing numbers, as people are forced to abandon their land because it can no longer sustain them and migrate to other regions or to urban slums (Darkoh 1993). The southward advance of the desert is causing a southward movement of the Basin’s population and further increases the pressure on the resources of the receiving regions. Transboundary migrations are a source of conflict causing ethnic tensions, social...
upheavals and changes in traditions in an already volatile region. In addition, civil unrest or conflict can result in vast movements of refugees, many of whom are settled in marginal or fragile areas. Such social and environmental pressures were clearly demonstrated in 1997, when Central African Republic (having to cope with internal disputes) received more than 50,000 refugees from Sudan and Chad (AEO 2002).

Future outlook

Future climate change

The influence of future climate change on the Central African region has yet to be determined as there are presently no accurate models for predicting future precipitation rates over the region (see Freshwater shortage, Future outlook). If there is greater aridity there could be a greater vulnerability to land degradation, which may result in a food security crisis and even famine as food production is already at a critical level. The riparian countries cannot afford to lose further productive land to desertification.

Population growth

Future population growth rates for the Basin are predicted to be high (2.6%). A larger population will increase demand for land resources and fuel wood supplies. Further desertification will result in a large influx of migrants from the rural communities into the swelling urban slums. This will result in social upheaval in the urban centres of the south of the Basin and other large urban areas in Central and West Africa.

Habitat and community modification from oil development

An oil project on the scale of the Chad-Cameroon Project will ultimately result in a degree of habitat and community modification. The pipeline is set to traverse areas of dense jungle inhabited by the Bagyeli ethnic group, or Pygmies, as they are popularly known (ESSO 2002). The pipeline route, as originally proposed, transacted the core area of the Mbere Rift Valley, and there was concern that induced access rights would disturb sensitive habitats. Environmental assessments on Cameroon raised this concern, as the construction of the pipeline route would have a negative impact on habitat and would have failed to meet World Bank directives for the protection of natural habitats. Biological field research has identified a need to protect some IUCN-listed species that are known or have the potential to occur in some areas of the Wooded Savanna in northern Cameroon. These species include elephant, hippopotamus, bushback, kob, waterbuck, reedbuck, red-flanked duiker and oribi. Faunal and floral species could also be threatened by the upgrading of existing seasonal roads that will increase the accessibility for illegal poaching and logging of habitats previously protected by the area's remoteness (ESSO 2002).

The habitat and faunal communities will be further altered by increased land use pressure by the large numbers of transboundary migrants attracted by employment opportunities presented directly and indirectly by the oil project. These populations concentrated on the oil fields will have severe impacts on wildlife and fishstocks through increased fishing and hunting activity. This transboundary migration could cause ethnic tensions, social upheaval, and disruption of rural farmer's traditions. Environmental pressure groups have also expressed concerns over whether Chad's current political situation after 30 years of civil war is too unstable to accommodate such a large-scale oil project.

These potential environmental and social concerns have prompted the consortium to make adjustments and apply a comprehensive set of mitigation measures to limit the impact of the project. To avoid environmentally sensitive areas such as the Mbere Valley numerous adjustments have been made to the route of the pipeline. The pipeline will run entirely underground (ESSO 2002) and techniques are being employed to answer concerns over rehabilitation after construction due to the disturbance of top soil. To date, all local ethnic groups have been compensated for land they lost to the pipeline project (ESSO 1999). The pipeline route has been sited to avoid/minimise impacts on the Bagyeli pygmies and a compensation mechanism is in place for those who may suffer any losses to crops or housing structures. The Indigenous People Plan, in addition, provides for a 25-year programme of support for the Bakola, which should result in improving their living conditions and their empowerment as full citizens of Cameroon.

The threat of habitat modification from oil development could become increasingly severe as the existing agreement between the consortium and Chad allows for oil exploration not only in the Doba region, but in four other regions (Lake Chad, Salamat, Bongor and Doseo) covering a surface area of 104,223 km². The proposed pipeline, whose capacity exceeds the oil flow that can be provided by the Doba fields, could be the first step of further oil development projects in the region.

Conclusions

The Lake Chad Basin has experienced severe terrestrial habitat and community loss and modification. The persistent drought has been the catalyst for land degradation but has been exacerbated by unsustainable land use practices. Agriculture and livestock rearing are the predominant economic activity; 60% of the administrative units of the Lake Chad Basin depend on agriculture as their main activity (Nami 2002) and livestock covers extensive areas of the Basin (50% of Chad's National territory). Unsustainable forestry practices to meet increased demand for firewood and lumber for local use, has resulted in the
overharvesting of the Basin’s woodland resources (Keith & Plowes 1997). These activities have encouraged deterioration in soil structure and quality, and thus enhanced the vulnerability to erosion. Desertification has consequently become a serious threat to the diversity and extent of habitats, and the livelihood and survival of many of the agricultural and pastoral dependent communities.

Poverty and environmental degradation are closely correlated in the Lake Chad Basin with agriculture forced increasingly on marginal lands. Measures to tackle the environmental issues are severely limited by this regional poverty (World Bank 2002a). Villages traditionally have values and restrictions for the sharing of resources common to people within a village and neighbouring villages. Civil strife, herder-villager conflicts as well as the endemic poverty have compromised the rules for use of common resources and contributed to the overexploitation of these resources (Keith & Plowes 1997).

Habitat and community loss and modification could increase in severity in future years. Greater aridity and increased pressure on diminishing biotic and abiotic resources will further encourage desertification and the southward advance of the Sahara.

Unsustainable exploitation of fish and other living resources

The GIWA Assessment identified Unsustainable exploitation of fish and other living resources as having a moderate impact. Although fish production has fluctuated greatly over the past 50 years, this has primarily been attributed to climatic variability and poor water governance, and the associated environmental changes, rather than unsustainable exploitation of fish. Present data does not suggest that the viability of fish stocks is affected by pollution and disease, or that biological or genetic diversity has been modified. Excessive by-catch and discards is not thought to be a significant issue because, although there has been increased juvenile catch due to use of smaller mesh, all of the catch is used and not discarded.

Within the arid and difficult environment of the Sahelian region, the Lake Chad has always played an extremely important role in the livelihoods of the thousands of people living in its vicinities. However due to the remoteness, poor continuity of information systems, recent political instability of the region and limited funding for research and management, the whole basin is now suffering an important information deficit. FAO for instance considers the national statistics for this region to be unreliable and incomplete (FAO 1995). Currently, it is extremely difficult to make any accurate and up-to-date assessment of the economic status of the inland fisheries activities within the Basin (Neiland & Béné 2003) because there is very little time series data on fisheries (Jolley 2001). Small-scale fishermen in and around the wetlands and floodplains do not document their catches thus making it difficult to provide precise figures. In the past there has been comparatively few international studies of the Lake Chad Basin, despite the fact that most fisheries straddle international borders and their characteristics and dynamics are transboundary, determined by factors within the Basin as a whole (e.g. supply of water and movements of fish stocks).

Faced with this lack of information, national policy makers and planners but also international development agencies are severely constrained in their ability to generate and implement rural development policies appropriate and adapted to this area (Neiland & Béné 2003).

Overexploitation

The GIWA Assessment considered overexploitation of fish resources to have a moderate impact, as the primary reason for the fluctuations in fish production witnessed in the Basin over the past 40 years has been caused by fluctuations in water levels in the Lake Chad and in the timing and extent of flooding, rather than due to unsustainable exploitation of the fish resources. The term overexploitation is difficult to apply to the Lake Chad Basin fisheries due to difficulties in defining a measurement level in such a large dynamic system.

Figure 43 shows how fisheries production has fluctuated between 1969 and 2001. The increases in production from 1969 to 1972 was attributable in part to the rapid development of the fishery pre-droughts years (1960-1972), from decreased competition from fish imports, increased fishing effort, and increased Catch per Unit Effort.
industry. Not the primary threat to the aquatic ecosystems and the fisheries (Béné 2003). Therefore it can be concluded that overexploitation is retaining a relatively large and important biomass of fish (Neiland & Béné 2003). This would suggest that the Chad Basin fisheries have specific characteristics, which makes them exceptional production systems estimating to be over 60 000 tonnes.

The severe Sahelian droughts of 1972 and 1973 led to a drastic reduction of open water in both the northern and southern pools resulting in concentrations of fish with greater vulnerability to fishing gears. This explains the largest production estimate recorded of more than 200 000 tonnes in 1974. The fall in production noted during 1975 was the result of the drying of the northern pool and very low water levels found within the southern pool during the same period. Reduced water levels lead to scarcity of space for fishes, oxygen depletion and increased organic pollution. As the northern pool dried out, fishermen migrated with the receding waters and fish production stabilised between 90 000 and 100 000 tonnes up until 1982 (Durand 1979 and 1980, Sagua 1986). In 1982 the fisheries collapsed with production estimated at only 21 704 tonnes, there are believed to be two reasons for this; firstly as a result of decreased inflow from the Chari-Logone River Basin (see Freshwater shortage, Modification of the Chari-Logone River) due to the Sahelian droughts of 1982 and 1984, which adversely affected fish recruitment due to reduced flooding of the floodplain, an important nursery ground and breeding ground for the Lake Chad; and secondly because of reduced fishing activity due to the Chadian Civil War. Overall production has steadily recovered since then to an estimated 68 783 tonnes in 1996 (Neiland et al. 1997) and is presently estimated to be over 60 000 tonnes.

This would suggest that the Chad Basin fisheries have specific characteristics, which makes them exceptional production systems retaining a relatively large and important biomass of fish (Neiland & Béné 2003). Therefore it can be concluded that overexploitation is not the primary threat to the aquatic ecosystems and the fisheries industry.

### Destructive fishing practices

In general, traditional gears are used for fishing in the Basin, however increasingly modern materials such as nylon twine or rope for nets are being manufactured locally or imported from elsewhere (Neiland & Béné 2003). According to Quensière (1990), studies around N’Djamena, on the Logone and around the Chari delta have allowed a comparison of the fishing techniques used in 1989 with those being used during the 1970s. There was a marked reduction in the mesh size of nets during the period and an increase in the use of cast-nets. Modern casting nets, in particular, have many advantages over the heavy traditional nets. Fishermen are able to exploit new ecosystem niches, such as the deep parts of the Logone River, with these lighter more mobile nets. These new fishing grounds are not controlled by the traditional restrictions upheld by the Kotoko ethnic group in the Logone floodplain so fishers have unlimited access (Van Est 1999). Among other new techniques is the increasing use of baits. In addition to baits placed in basket traps, balls of bait comprising bran and mud are used to lure fish to gather together. They are then easier to catch by the use, for example, of a cast-net. The major development is however the use of boats. Prior to the end of the 1970s, the traditional dug-out canoe was the only type of boat used by local fishermen. Currently, the traditional canoe has almost disappeared and been replaced by much more stable boats made from plywood. This innovation has allowed much better exploitation of the whole lake area. The use of outboard engines has also developed very rapidly for both transport and fishing. The intensified use of modern equipment has decreased the access of the poorer fishers who are left with the remaining fish that have escaped dragnets (Van Est 1999).

During the recession season in the Yaéré floodplains (north Cameroon and south Chad), a large number of fishing fences are set up across channels connecting the floodplain areas to the Logone River and its tributaries (Logomatia or Petit Goroma in Cameroon, Salamat in Chad). These fences catch migratory fish leaving the floodplains especially Alestres spp. An example of this type of fishing technique is the “malan” fences used on the Bahr lli tributary of the Logone River in Chad. The local fishermen from Kotoko ethnic group set up a dam made of wooden fences across a channel or shallow part of the River. In front of this fence, on its upstream side, many “kotoko” traps are attached to tall wooden sticks fixed in the riverbed. The traps have their mouth orientated downstream and catch fish as they turn back to try and escape the fences. Few fish are able to escape the traps and those that do are often caught downstream. The yield from this fishing method is very high and can be several tonnes per day in the peak season.
The contraction of the Lake has encouraged the "dumba" method of fishing to become increasingly popular, particularly along the western shore of Lake Chad, in Nigeria. A dumba is a row of Malian fish traps that are placed across a channel of receding lake water. The traps are linked by small meshed netting, which forces the fish into the traps. The dumba is especially effective, as fish retreating the flood cannot escape them, and they do not need to be baited (Sarch 2001).

In 1992 the Federal Government of Nigeria promulgated the Inland Fisheries Decree, which charged the Commissioner for Agriculture in each state with the responsibility for licensing and regulating inland fishing (Federal Government of Nigeria 1992). The aim of the decree was to "give maximum protection to our precious inland fisheries resource … (and) enhance the optimum productivity and utilisation of the inland fisheries resources …" (Ita 1993 in Sarch 2001). A key implication of the decree for fishing at Lake Chad was the ban on fishing techniques that obstructed the free movement of fish. In effect, this has prohibited the use of barrages of fish traps dumba set across channels of receding lake water (Sarch & Allison 2000). The Lake Chad Basin Commission’s Joint Regulations on Flora and Fauna also effectively ban dumbas (Sarch 2001).

Although both federal and local governments have tried to manage fishing at Lake Chad, compliance with measures such as this is limited by the inability of fisheries staff to reach the most productive fishing areas on the Lake and enforce them. Although broadly benevolent and similar in their aims to sustain fish stocks, the efforts of the federal Fisheries Department and local government have conflicted and resulted in failure. Illegal fishing persists and local government have little direct control over it (Krings 1998, Sarch 2000).

**Economics impacts**

The GIWA Assessment rated impacts on the economic and public sectors as moderate as although the economic impacts of the decreased fish production experienced at times during the last 40 years has had a severe affect on the fisheries, fish production has increased once again more recently. These economic impacts have also been primarily a result of environmental changes caused by the freshwater concern in the region rather than as a result of overexploitation of fish.

The fisheries of the Lake Chad Basin are very important economically with current lands of about 60 000 to 100 000 tonnes per year contributing over 24 million USD to national, regional riparian economies (Neiland & Béné 2003). The industry provides employment for the majority of rural households on a seasonal and part-time basis for fishermen and also in associated fish processing and trading industries. Fluctuations in fish production therefore have a significant impact on the rural community. The fisheries collapse following the Sahelian droughts of the 1970s and 1980s, occurred at a time when all economic activities were significantly affected by the droughts. The situation was further exacerbated by the numerous people hoping to capitalise from fishing as well as by later arrivals from the outlying Sahel who were trying to escape from drought and famine. The poorest households of the Lake Chad Basin felt the impact of the decreased fish production greatest. For example, a survey by Béné et al. (2000) noted that dwindling fish stocks in the Yaéré floodplains of northern Cameroon impacted most severely on the poorest households. In part, the survey stated, “the richest fishers are those with ownership and access rights, whereas the poorest fishers are marginalized or excluded entirely from the most productive fisheries”.

However, given that such a high percentage of the community are involved in fishing, the fluctuations did not have as severe effect as would be expected. This can be explained by the long history of climatic variability forcing the local communities to adopt a diversification strategy to minimise risks imposed by fluctuating environmental and economic conditions, with so called fishing households earning most of their income from a combination of fishing, farming and other occupations (Neiland & Béné 2003).

**Health impacts**

The GIWA Assessment considered the impacts on health from the Unsustainable exploitation of fish to be moderate regarding the number of people affected but only having a slight impact in terms of severity, duration and frequency. Fisheries production has fluctuated dramatically and at times contributed to food insecurity and caused economic hardship, which has in turn contributed to the poor health in the region.

**Other social and community impacts**

The GIWA Assessment regarded social and community impacts of the Unsustainable exploitation of fish to be slight. The contracting Lake Chad induced the fishing communities to migrate to follow the receding waters and also to make a number of livelihood strategy changes to adapt to the changing environment (see Freshwater shortage, Other social and community impacts).

The collapse of the fisheries in the northern pool followed by the southern in the end forced many fishermen to emigrate elsewhere in search of a living, mainly to the south, or to the larger towns and cities of Nigeria, Chad and Cameroon (Neiland & Vennumbe 1990). This migration has contributed to the rapid urbanisation that has been experienced in the southern urban centres of the Lake Chad Basin.
Future outlook

The GIWA Assessment predicted that the Unsustainable exploitation of fish and other living resources could be severe by the year 2020.

Future climatic and environmental change

The future size and composition of fish stocks will be integrally linked to the size, duration and timing of the annual floods in the Basin, thus future fish production will largely depend on the discharge rates of the Basin’s rivers. In recent years rainfall has increased again, which could lead to the rejuvenation of the floodplains and their standing stock of fish and increase the potential fish production. Overall production estimates have indicated that overall production is moving back towards levels noted following the collapse of the fishery in 1982. However the persistence of this recovery will be determined by future climate change, which is yet to be determined for the region. Some forecasts predict higher aridity, which could again lead to a decline in the fisheries (see Freshwater shortage, Future outlook). If current environmental conditions remain stable then the dominance of small-sized and hardy fish such as Clarias and tilapine cichlids is likely to continue as long as the flood levels remain restricted and fishing effort remains relatively high (Neiland & Béné 2003).

Population growth

The average population growth for the Basin is predicted to be 2.6% (UN Population Division 2002). The fisheries resource will consequently be under increasing pressure as food demand increases and greater competition and possible conflict is provoked over rights to access fishing grounds. The well-developed markets particularly in Nigeria continue to grow and trade in Lake Chad processed fish is expected to expand as fishing redevelops. This market growth is associated with a population growth rate of 2.9% (World Bank 2002c: 1980-2000 growth rate), the high rate of urbanisation in southern Nigeria, and the increasing demand for protein foods such as fish. The urban population of Nigeria has increased from 19.1 million to 55.8 million between 1980 and 2000 (World Bank 2002c). It is to these large urban areas that an estimated 80% of fish production from Lake Chad is sent (Neiland & Verinumbe 1990). This increase in demand will have to be met by the Lake Chad fisheries, as well as from the other sources of fish production that includes large dam reservoirs, aquaculture and ocean/lagoon fisheries.

Further desertification in the northern regions of the Basin will lead to greater numbers of environmental refugees migrating to the south of the Basin. Traditional management systems may not be sufficient in managing the increased fishermen population. There are presently no restrictions on the number of fishers, as long as a designated fee is paid to the village leaders. Migrant fishermen are therefore often welcomed as they pay higher fees than local fishermen. Traditional authorities may therefore inadequately control the quantity of fish extracted from the fisheries resource. It is likely that the poor households will face further poverty as they are marginalised by their inability to afford access rights to the fisheries resource.

Development plans

Ongoing water management plans for the Basin such as the construction of more dams, continue to not take sufficient account of their impact on fish and other natural resources (Neiland & Béné 2003). Further stream flow modification and associated habitat modification could jeopardise the redevelopment of the fisheries. For example if construction of the Kafin Zaki Dam (Jama’are River) in the Komadugu-Yobe River is completed it could lead to a reduction at Gashua of at least 1.275 million m$^3$ per year (Oyebande 2001) with consequential impacts on the fish stocks of the Hadejia-Nguru floodplains.

Fishing method developments

The increasing use of modern fishing methods such as more stable boats, the use of outboard engines and new fishing gears, will allow further fishing grounds to be exploited. These may be out of the jurisdiction of the traditional management systems, and are therefore not subject to regulation.

Conclusions

The GIWA Assessment regarded the Unsustainable exploitation of fish and other living resources as having a moderate impact. There have been substantial changes in the taxonomic composition, distribution, diversity and production of the fisheries over the past 40 years in the Lake Chad Basin. However, this can be primarily attributed to climatic variability and anthropogenic stream flow modification and the associated environmental changes, rather than unsustainable exploitation of fish. The Sahelian droughts and human water diversion reduced stream flow, which changed the distribution of aquatic habitats of both the floodplains and Lake Chad environment. Fisheries production fluctuated accordingly and fisheries species composition changed from predominantly open water species to predominantly marshy species (see Modification of fish habitats). The fishing methods presently employed by the fishermen do not pose a significant threat to the health of the aquatic ecosystems, when compared with the large-scale habitat modifications caused by stream flow modification (climatic and human).

Despite climatic and environmental fluctuations, a naturally high productivity of the lake system results from complex and diverse mechanisms bound by particular environmental characteristics. In comparison to other continental fluvio-lake systems, the Lake Chad displays exceptional performance in terms of productive capacity and
resources available to fishermen (estimated 170,000 full and part time fishers) (Neiland & Béné 2003). Overall, there is no need to be over-pessimistic about the level of exploitation in the Chad Basin. Recent production estimates have indicated a significant recovery of the fishery since the collapse of 1982, which demonstrates the Basin’s natural ability to regenerate. The fish fauna of Lake Chad and its basin consists of about 140 species, with about 84 species in the Lake itself with only three species endemic to the Lake. The reconstruction of stocks is always possible from river fish communities if a “normal” lake state reoccurs.

The significant issue regarding the fisheries in the Lake Chad Basin is that of governance. Fisheries management cannot operate effectively because there is confusion over which agencies have jurisdictions over which areas, the formulation of regulations cannot keep up with dynamics of the Lake, and the organisations charged with enforcement are so poorly resourced that their staff are rarely in a position to enforce a regulation (Sarch & Allison 2000). There are weaknesses in all of the riparian states, as well as in the Lake Chad Basin Commission (LCBC), in institutional capacity and enforcement of fisheries regulations. Traditional management systems, enforced by village leaders are still the predominant fisheries regulators in the Basin, and analysis suggests that these traditional authorities only tolerate central authorities, rather than fully integrate them in the process of fisheries management (Neiland & Béné 2003). The present lack of fisheries governance can be attributed, in part, to the attempt to centralise fisheries management away from the local communities, and by central authorities trying to control, rather than cooperate with, traditional systems.

Although the fisheries are very productive and generate significant wealth, at least 40% of the rural population remain impoverished and the poorest households face chronic food shortages. While the traditional management systems function very effectively in regulating fishing activity, they create socio-economic differentiation in the communities. Open access rights are seldom found and to the contrary access is usually under regulation. The predominance of traditional management systems at a local level, and the absence of strong modern systems, has resulted in the majority of the benefits from the fisheries being retained by a powerful elite minority, including local leaders, their extended families, and other prominent people and their associates. It can therefore be concluded that the poverty associated with the fisheries in the Basin, is more a result of limited access to fishing opportunities and to the benefits which might be realised from fisheries activities including fishing, fish processing and fish trading, than a function of the catch level. The question has to be asked whether traditional management systems are a significant barrier to the future social and economic development of the Lake Chad Basin (Benech et al. 1983 in Neiland & Béné 2003).

### Pollution

Pollution was assessed by GIWA as having a slight impact under present conditions but has a potential to escalate to moderate by the year 2020. There is however an extreme lack of scientific data regarding pollution and therefore ranking was primarily made using expert opinion. There is presently no evidence of impacts from radionuclide pollution and spills in the Basin. It is important to note that the Lake Chad Basin as an inland drainage basin with no outlet to the sea, the Lake Chad itself is the final receptacle of any pollution admitted into the Basin’s hydrological sub-systems (LCBC 2000b).

#### Chemical pollution

The Lake Chad Basin has very limited industrial development; however oil exploitation in Chad, which began in July 2003, may generate opportunities encouraging industrial development (Republic of Chad 2003). Chemical pollution may therefore be an increasing concern for the Basin.

#### Industrial chemical pollution

The Lake Chad Basin has a proliferation of textiles and tanneries in the upstream parts of the Basin (particularly in Kano and Maroua). These industries contribute to pollution of surface water supplies and in severe but rare cases cause localised fish kills. Wastewater discharges from settlements along the Chari-Logone and Komadugu-Yobe River courses particularly from abattoirs, hotels and hospitals are also thought to contribute to microbial and chemical pollution.

It is believed that industrial discharges are in low enough quantities to not severely affect water quality, although studies are needed to confirm this. For example, the refinement and processing of sugar cane in Banda (Chad) discharges sodium carbonate and dissolved organic matter in unknown quantities into the surrounding rivers. The sodium carbonate, rejected by this factory and by a brewery at Moundou, is however dissipated in surrounding waters dissolving as it reacts with CO₂, thus causing limited long-term consequences. The effects of these industries are therefore considered as minimal (Republic of Chad 2003).

#### Chemical pollution from mining

Mining activity, excluding oil production is still very limited in the Lake Chad Basin and is concentrated primarily in the CAR and southern Chad. Diamonds are essentially the main mineral exploited in Chad, with mining activity on the border with the CAR and gold mining in the regions of Tandjile and Mayo Kebi (Republic of Chad 2003). Mining in the CAR has the potential for chemical pollution, but the current levels...
Agricultural chemical pollution

There is a lack of data on agricultural pollution in the Lake Chad Basin, however, the LCBC Strategic Action Plan (LCBC 1998) recognised that there is a possible pollution threat to water by pesticides used in agriculture, especially during periods of low flow and high temperatures. In Chad, the quantities of pesticides used are between 500 to 1,000 m³ per year. The cotton industry uses the largest amounts of insecticides, in 1999 and 2000 4.5 m³ were used (Republic of Chad 2003). The type of insecticides currently used in Chad are considered as highly toxic and if in high enough concentrations can lead to mortalities, thus reducing the abundance and diversity of vertebrate and invertebrate organisms as well as the flora of wetlands. The organophosphate insecticide, monocrotophos, has been banned in other regions of the world due to it killing birds, and although there are alternatives available, it is still used extensively in the cotton industries of Chad (Keith & Plowes 1997). Herbicides can kill non-intended plants after entering aquatic systems decreasing the diversity of wetland flora. Pesticides can be potentially detrimental to migratory birds and there have been studies expressing concern for species in West Africa (Balk & Koeman 1984, Mullie et al. 1991 in Keith & Plowes 1997).

In the upper parts of the Logone Basin upstream of Bongor, there are also significant amounts of pesticides used in the cotton industries. The quantities are unknown and there needs to be an assessment of their possible impact on the environment (Lemoalle 1997). Lemoalle (1997) identified the transfer and degradation of pesticides in the Logone upstream of Bongor (CAR) originating from the cotton industry as one of the main risks to the area. Generally, there is a lack of studies in the Lake Chad Basin that analyse the distribution of pesticides in the aquatic environment (Lemoalle 1997).

Rice farmers use large quantities of fertilisers and apply illegal insecticides including deltamethrine, malathion, fenitrothion and an organochlorine, lindane (Keith & Plowes 1997). Nearby lakes and streams can be contaminated by agro-chemicals by the return flow of waters and also run-off and percolation from the irrigated fields (Richards & Baker 1992 in Keith & Plowes 1997). The SCIP project in northern Nigeria extracts water from Lake Chad, which is applied to the irrigated fields with agro-chemicals. Surface and ground flows carry these chemicals directly into the Lake. There is an inadequate pollution regulatory framework in the Basin and the region is therefore vulnerable to increases in agro-chemical contamination. For example in Chad, there is no legislation regarding pesticides in terms of their registration, food residue tolerances or pesticide safety. There also appears to be a lack of information available for pesticide application and recommendations for pest control on crops other than cotton.

In southern Chad the rich alluvial soils by the rivers and lake provide conditions suitable for vegetable gardens. The produce from these markets are sold in local markets and provide a relatively profitable source of income. They therefore justify investment in fertilisers and pesticides that consequently contaminate streams, rivers and lakes (Keith & Plowes 1997).

Chemical degradation also occurs, because of intensive cultivation of marginal areas without sufficient fallowing and through salinisation from irrigation with poor quality water (AEO 2002), these impacts are however again mainly localised. Lack of data makes it impossible to determine the exact impact of agricultural chemical pollution, but the predominance of cotton and rice crops that require high doses of chemical sprays on the irrigated farms, suggests that contamination of water supplies could be occurring.

Eutrophication

Production of crops such as cotton and rice require high doses of fertiliser, nutrient loading of water supplies is therefore not out of the question. Environmental impacts of nutrient loading from upstream developments (irrigated and urban discharges) directly impact on downstream cities and populations. Eutrophication cases have been identified in small sections of the Hadeija-Jama'are-Komadugu-Yobe River Basin (Madachi, Kirikasama and Nguru) as well as the edges of Lake Chad. The numerous irrigation projects along the Komadugu-Yobe River have been identified as sources of nutrient loading with subsequent impacts on water quality.

Industries within the Basin have been reported as discharging organic wastes into the streams. The slaughterhouse of Farcha (Chad) ejects about 4 m³ of organic matter per day resulting from the slaughtering of 800 ruminants (cattle, goats and sheep) per day (Republic of Chad 2003).
These activities can cause nutrient loading due to the high nitrogen content of wastes and should therefore be monitored. However, in order to limit this sedimentation processes are used to extract waste solids before the wastewater is discharged and the nitrogen rich wastes are then utilised in agricultural activities (Republic of Chad 2003). There are reports of organic pollution in areas where recession agriculture is practised around the Lake and other wetlands, where crops are left after harvest; this however is not considered as posing a major threat to water quality.

Water enrichment can support heavy growth of algae that during the summer forms thick algal mats over extensive areas of open water. Both algal mats and suspended sediments in water can restrict penetration of sunlight and the production of plants rooted to the bottoms of marshes and lakes. Decay of algae reduces the dissolved oxygen content of water and, over time, most fish species and other aquatic organisms that require high levels of dissolved oxygen can be eliminated. On Lake Chad, there is an abundance of macrophytes, phytoplankton and also blue-green algae (cyanobacteria), known to be a rich source of proteins. *Arthrospira* sp. (*Spirulina*) is blue-green algae, found on ponds surrounding the Lake Chad, which possesses a few environments worldwide where this type of blue-green algae thrives due to the very narrow range of pH values that the species survives in.

Fertilisers can increase the growth of emergent plants, and therefore reduce areas of open water (Keith & Plowes 1997). Parts of the Lake are reported to have emerging macrophytes (*Phragmites australis* aubsp. *Altissimus*, *Typha australis*, *Vossia cuspidata*, *Cyperus papyrus*, *C. laevigtus*, *Leersia hexandra*, *Echinoclaoa* sp.); floating macrophytes (*Pistia stratiotes*, *Lemma perpusilla*, *Spirodela polyrhiza*, *Azolla africana*, *Nymphaeas spp.*, *Ipomoea aquatica*, *Neptunai Oleracea*); submerged macrophyte (*Potamogeton* spp. *Vallisneria* spp. *Ceratophyllum demersum*, *Utricularia* spp.); and phytoplankton (*Closterium aciculare*, *Pediastrum*, *Botryoccus*, *Microcystis*, *Anabaena*, *Melosira granulata* and *Surirella muelleri*). Proliferation of these water weeds may clearly signify an increasing amount of nutrients in the lake waters. During periods when there is insufficient flows from the Komadugu-Yobe River to support the northern pool eutrophication is exacerbated and all areas see the exposure of more paleo-dunes which are rapidly colonised by vegetation (primary acacia and papyrus), and aquatic weeds. Navigation is impeded if not made impossible by shallow depths and floating islands of vegetation (Holz et al. 1984).

**Suspended solids**

The northern sector of the region is naturally prone to wind erosion that significantly leads to deposition of sand into the Lake and rivers. However declining productivity and soil structure in the Sahelian zones of Chad and Cameroon combined with unpredictable rainfall and drought has resulted in extreme degradation and desertification. Desertification has lead to sandstorms from increased wind erosion that deposits huge amounts of debris in the Lake and rivers causing greater turbidity.

Land degradation in the Basin has been caused by many years of inappropriate agricultural practices, commercial logging, soil compacting as a result of extensive removal of vegetation and bush burning. These factors have exposed the soils to heavy rainfall, increased evaporation and wind erosion which has consequently increased the sediment load of rivers causing siltation on the lake bottom and has thus reduced the effective lake volume. This has been exacerbated by the growth of rhizomatous hydrophytes that encourage soil accretion and increases water loss through increased evapotranspiration (see review: Obot 2000). The problem of siltation has increased along river channels due to upstream reservoirs and reduced peak flows downstream.

Migratory fish spawning grounds such as those in the extensive Logomata marshes reached through the El Beid and Chari-Logone river systems could be altered and degraded with the intensification of agriculture. This is occurring as a consequence of increased sediment and agro-chemical pollution carried by the rivers (Keith & Plowes 1997).

In Chad and Central African Republic, the exploitation of diamonds and gold mining, in the regions of Tandjile and Mayo Kebbi and along the Aouak River in the upper Chari Basin, has increased the load of suspended solids in the surrounding rivers, with unknown impacts on river ecology and possibly disrupting the migration and reproduction cycles of fish in the seasonal rivers of southeast Chad (Lemoalle 1997, Republic of Chad 2003).

**Microbiological pollution**

There is no relevant documentation on the extent of microbiological pollution; this issue was therefore unable to be ranked by the GIWA Assessment. However, water-borne diseases are rampant in the region as a whole, indicating that there could be possible cause for concern.

Waste management facilities are very poorly developed in the Basin. In Niger for example, rural and urban sanitation is grossly inadequate, due
to accelerating urban growth and the depletion of municipal resources. Enormous quantities of waste are consequently produced and with most neighbourhoods having no sewerage system, the accumulated household waste represents a vector for many diseases. In Chad no town (except the Doba oil well site) has a functioning wastewater evacuation system and collection networks are dilapidated (IMF 2003).

Microbiological pollution is suspected of being prominent around settlements and on riverbanks of major waterways, where population densities are highest. The heavily concentrated numbers of settlements surrounding the Lake Chad are a particular focus of pollution, where there are occurrences of direct discharges of industrial and domestic waste. Factories and other unhealthy installations in urban areas also constitute sources of pollution of surface and groundwaters (Government of Niger 2002). Lemoalle (1997) identified the increased discharge of sewage into the rivers upstream of Bongor in Logone River Basin and the upper Chari River Basin in the Central African Republic and from increased urbanisation as one of the major environmental risks in the region, especially at times of low flow when effluent discharges are poorly diluted.

Socio-economic impacts

The economic, health and social impacts of pollution were all considered as slight. There is a lack of data outlining the impacts of pollution in the Basin and scores were assigned based on expert opinion. A significant number of people are at risk from water quality problems but this is influenced not specifically by pollution but by a combination of other concerns including freshwater, global change and habitat modification. In the basin water-borne epidemics are resurgent, particularly among young children. Several diseases are rampant in the region including malaria, various forms of diarrhoea, acute respiratory infections, measles, tetanus, yellow fever, diphtheria and chicken pox. However, there are no studies identifying the role water pollution plays in the proliferation of these diseases.

Future outlook

With the start of oil exploitation in the region and the increased application of fertilisers and pesticides due to the expansion of large-scale irrigation, pollution could become moderate by the year 2020. This scenario is likely in the current environmental legislative framework, where there are limited constraints on industry. Although presently pesticides are not extensively used, as irrigated and shoreline agriculture increases, larger amounts of agro-chemicals will be utilised as they become increasingly affordable and available. Insecticide use will most likely be used primarily for high value crops and therefore its effect of toxicity to fish and wildlife will be localised rather than widespread (Keith & Plowes 1997). The Lake would be highly vulnerable to increases in pollution as it is the final recipient of the Basin’s rivers and in its current ‘lesser’ size has a limited dissimilative capacity (LCBC 2000b).

Petroleum exploitation in the region has presented itself as a solution to the poverty situation. The project has the potential to transform the economic status and structure of the region. It is likely that industrial activity will become increasingly significant with the expected increased foreign capital injected into the economies of Chad and Cameroon from oil revenues and associated industries. The actual oil project and the increased industrial activity will subsequently pose a pollution threat. The World Bank project documents and nongovernmental organisations have identified the following possible pollution impacts of the oil project and an action plan has been prepared and implemented to mitigate all of these risks (ESSO 1999):

Chemical pollution: Recent oil development in Chad and Cameroon could result in chemical pollution through the discharge of industrial and domestic effluents, and contamination from site run-off.

Environmental assessments for the Doba oil well site identified that there were possible risks from domestic and industrial effluents from extraction site during and after construction (Republic of Chad 2003). The exploitation of the oil field of Sedigui, north of Kanem, will also pose a threat from extraction effluents. In Sedigui however, further caution is needed due to the relationship between groundwater and surface waters in this region, which are particularly vulnerable to contamination (Republic of Chad 2003).

Oil in the Doba Basin will contain a significant percentage of water that must be extracted from the crude oil before shipment. This water will need to be disposed of safely, so that there is no contamination of local water supplies (ESSO 1999).

However, mitigation measures have been applied to minimise the risk of possible pollution incidents to comply with World Bank specifications. The exploitation of oil in the region has been presented by project sponsors as having no effect on the aquatic environment (Republic of Chad 2003).

Oil spill/leakage: Oil development in Chad has a potential risk of pipeline leakage, groundwater contamination and freshwater pollution. Although mitigation measures have been installed, there is always a risk of an oil spill event (ESSO 1999), even if the best available technology is adopted. The pipeline traverses several major rivers contained in the Lake Chad Basin including the Nya, Loule, Lim and Mba rivers and crosses
the Mbere River twice. The Mbere River, forms part of the boundary between Cameroon and Chad, and Cameroon and the Central African Republic and the area contains tributaries to Lake Chad. A spill incident would have international implications (ESSO 1999) with even one leak endangering communities all along the pipeline as they rely on surface water systems for most of their water needs. Leak prevention measures have included the pipe being buried at a safe depth and reinforced pipe walls at river crossings. An emergency response plan has been formulated in compliance with World Bank specifications although it has been critised for not going far enough in being site-specific. Concerns raised during public consultations resulted in the oil pipeline being constructed to pass around Lake Chad, to avoid risks of pollution incidents (spills) into the Lake (Republic of Chad 2003).

Suspended solids: Environmental assessments at the Doba oil well identified that there could be possible risks of erosion resulting from landscape modification during construction of the pipeline and sediment could subsequently run-off into the surrounding streams. However, mitigation measures have been employed to minimise the effect of particulate pollution before it is able to reach the rivers (Republic of Chad 2003).

**Conclusions**

The GiWA Assessment considered pollution as having the least impact on the Lake Chad Basin. Although there is very little current scientific data to confirm this assumption, it is presumed that due to the current lack of industrial development and limited application of fertilisers in agriculture because of financial constraints, that pollution is slight. The pollution that is occurring is released in insignificant quantities that do not exceed the ecosystems’ carrying capacity and the impacts are generally localised. Studies are needed to identify the status and distribution of pollution in the environment. With the increasing use of agro-chemicals and the exploitation of oil in the region and associated industrial growth, mitigation measures need to be installed in an adequate environmental legislative framework.

**Priority concerns**

Freshwater shortage was ranked severe and was considered the priority concern in the GiWA region 43, Lake Chad Basin. All of the other concerns except for pollution have had a moderate impact. Although there has been significant modification of habitats and significant fluctuations in fish production, these are a function of freshwater shortage, rather than a consequence of direct habitat modification or unsustainable exploitation of fish. Table 8 shows the overall rating and justification for each concern.

**Table 8** The overall rating and justification for the GiWA assessed concerns.

<table>
<thead>
<tr>
<th>Concern</th>
<th>Overall severity</th>
<th>Justification/Indicators for current severity</th>
<th>Future severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater shortage</td>
<td>Severe</td>
<td>Lake Chad shrinkage: A 90% reduction in surface area. Stream flow modification: the Chari-Logone River discharges 25% less water into the Lake Chad (Olivry et al. 1996).</td>
<td>Severe</td>
</tr>
<tr>
<td>Habitat and community modification</td>
<td>Moderate</td>
<td>Wetland modification: Wetlands resources have been decreased by 50% (Burbere et al. 1997), Fisheries habitat modification: Open-water species previously made up approximately 52% of the fish market species composition, currently they make up less than 1% (Neiland &amp; Bene 2003).</td>
<td>Severe</td>
</tr>
<tr>
<td>Unsustainable exploitation of living resources</td>
<td>Moderate</td>
<td>The terms overexploitation and unsustainable are difficult to apply to such a dynamic system. Large fluctuations in fish production have been more a function of environmental changes than overexploitation. Fisheries governance and its relationship with socio-economic differentiation within the communities are the significant issues affecting the fisheries sector.</td>
<td>Severe</td>
</tr>
<tr>
<td>Pollution</td>
<td>Slight</td>
<td>There is a lack of industrial and mining activity and there is moderate application of agricultural fertilisers, although there is an extreme lack of data to justify this presumption.</td>
<td>Moderate</td>
</tr>
<tr>
<td>Global change</td>
<td>Moderate</td>
<td>Climate change has had a severe impact on freshwater shortage. However the Basin has exhibited a history of climatic variability (Holz et al. 1984). The impact of recent anthropogenically induced climate change is unclear but is considered as playing a role in freshwater shortage.</td>
<td>Severe</td>
</tr>
</tbody>
</table>

The overall scores did not dictate a priority order for all of the concerns. The priorities were assigned on the basis of common judgement built on intense discussion during the GiWA workshop, hosted by the LCBC, and further assessment of the individual scores. The concerns for the Lake Chad Basin were ranked in descending order:

1. Freshwater shortage
2. Global climate change
3. Habitat and community modification
4. Unsustainable exploitation of fish and other living resources
5. Pollution

Freshwater shortage was considered by the GiWA Assessment to have the highest severity of impact. Climatic variability and anthropogenic...
freshwater shortage issues, namely stream flow modification, were identified as the two immediate causes of the concern. Although climate change has depleted the water resources in the region, it is believed that the level of stream diversion and abstraction has been unsustainable in the climatic scenario of the past four decades. Figure 44 is an illustration of the impacts of the freshwater shortage concern, in the Chari-Logone Basin and Lake Chad. It demonstrates how freshwater availability drives the other GIWA assessed concerns and highlights some of the related ecological and socio-economic impacts.

There are very prominent indicators of freshwater shortage including the shrinkage of the Lake Chad by 90% in the past four decades (Lemoalle 1991, USGS 2001) and reduced river discharges, for example the Chari-Logone River now discharges 55% less than in wet years prior to the 1970s (Olivry 1996). Freshwater shortage has impacted heavily on the Basin’s economic activities including the fisheries, agriculture, animal husbandry, fuel wood provision, and wetland economic services. There has been consequential food insecurity in the region and combined with a lack of potable water has had implications on the health status of the Basin’s population. Social impacts are linked to water supplies not meeting the population’s requirements, and have included upstream/downstream conflict over water allocation, due to the construction of dams upstream without sufficient provisions for people and the ecosystems that support these people downstream of the development (Oyebande 2001). Freshwater shortage has caused social tensions from the migration of people from the drought stricken northern regions of the Basin into areas surrounding the Lake and associated river sub-systems (World Bank 2002a).

Global change has influenced directly and indirectly all of the assessed concerns (except for pollution) that affect the Lake Chad Basin. Climatic variability exerted throughout the history of the Basin is therefore considered as playing the most important role in the reduced rainfall in the region. Changes in precipitation in the Sahel (that includes the Lake Chad Basin) have been linked with Sea Surface Temperature (SST) patterns (Lamb 1978). These changes have been attributed to changes in heat transfer between the Southern and Northern hemisphere (Evans 1996). Possible scenarios include increased deep water circulation in the Atlantic affected by the reduction in extent of sea ice, and the effect of sulphate aerosols which are dominant in the Northern hemisphere. It is believed that local land surface anomalies (such as vegetation degradation) have also played a role in the rainfall variability (Evans 1996). A combination of factors including vegetation cover, soil moisture, and SST is thought to best explain the reduction in rainfall in the Sahel (Xue & Shukla 1997). The role of anthropogenic climate change in the recent episode of freshwater shortage is therefore undetermined. Further research developments into detailed coupled transient GCM models may be able to confirm the roles of ‘natural’ and human influences.

**Figure 44** Illustration of the driving influence of the GIWA freshwater shortage concern on the other assessed concerns and the associated environmental and social impacts.

*Note: Please see the Causal chain analysis for the root causes of the freshwater shortage concern.*
Habitat and community modification of the aquatic ecosystems of the Basin has been primarily focused on the wetland ecosystem that have been intensively cultivated and frequented by large numbers of domestic animals. The wetlands have primarily decreased in extent due to changes in the seasonal timing and extent of flooding (Oyebande 2001). Consequently, since the 1960s, wetland resources in the Basin, such as the Yaërés in Cameroon and Hadejia-Nguru in Nigeria, have been reduced by almost 50% (Barbier et al. 1997). The fish habitat has altered from being an open water environment to being a predominantly marshy environment and the fish species composition has changed to reflect this (Neiland & Bene 2003). Although there has been significant habitat modification this has been largely due to freshwater shortage.

Unsustainable exploitation of fish and other living resources was not considered as the primary reason for the fluctuations in fisheries production over the past four decades. The terms unsustainable exploitation and overexploitation are inappropriate for the Lake Chad Basin fisheries due to difficulties defining a baseline level and due to the dynamic nature of the system. Freshwater shortage and the consequential habitat modification were regarded as the main influencing factors. Annual fish production fell from over 200 000 tonnes in the early 1970s to some 20 000 tonnes in 1987 (Neiland & Verinumbe 1990), and is presently estimated at over 60 000 tonnes (Neiland & Béné 2003). Prior to the drought years the fisheries had developed rapidly with fishing effort increasing by 50 times from 1967-1972 (Durand 1973). The contracting lake and wetlands caused fish to be concentrated and more vulnerable to fishing gears, eventually the fisheries collapsed in the northern pool followed by the southern pool fisheries by 1982. The fishing communities migrated eastwards following the receding waters; they also changed their livelihood strategies to take advantage of the fertile lake recessional floor for agriculture. Since 1982, the fisheries have shown a good recovery, which demonstrates the Lake’s ability to regenerate the fisheries as freshwater availability increases once again (Neiland & Béné 2003).

Pollution is presumed due to the lack of industry and limited application of agricultural fertilisers to have the least impact out of all the concerns assessed. It is considered that pollution is discharged in quantities that do not exceed the ecosystem’s assimilative capacity. However, further studies are needed to scientifically justify this presumption; there is currently a severe lack of monitoring and information networks regarding pollution.

**Future scenarios of priority concerns**

All of the concerns assessed are predicted to increase in severity by the year 2020. Consequently, the concerns of Freshwater shortage, Habitat and community modification, Unsustainable exploitation of living resources, and Global change are predicted to have severe impacts on the ecosystems and population of the Lake Chad Basin. The threat of Pollution, which is currently assessed as having a slight impact, is predicted to become increasingly significant in the future.

Future climate change will directly and indirectly play an important role in determining the future severity of freshwater shortage and subsequently the other inter-connected concerns (see Inter-linkages and synergies). The number of rainfall events in the region will be influential in conditioning freshwater inputs and consequently, if water resources continue to be used at an unsustainable level in the Basin, freshwater shortage. However, the influence of future climate change in the Central African region has yet to be determined as there are presently no accurate models for predicting future precipitation rates over the region. There have been several indications that the drought is ending in the Sahel. There have been only three wet years (1975, 1994 and 1999) in the last 30 years, but they were always separated from each other by at least four non-wet years (L'Hôte et al. 2002). The 1990s were indeed less dry than the 1970s and 1980s, and in the wet year of 1999 increases in precipitation led to the flooding of the northern pool once again. However the 1990s was still the third driest decade of the 20th century and the wet years were isolated events (L'Hôte et al. 2002). Consequently there appears to be no sustained upward trend since the 1970s and the Lake remains in its ‘lesser state’. According to L'Hôte et al. (2002) the drought had not finished by the end of 2000 and it is therefore premature to state whether recent increases in precipitation are part of a larger climatic trend.

Some predictions have envisaged greater aridity and a scenario between 2001 and 2020 similar to the current status from 1973 until now (Republic of Chad 2003). This is based on a future scenario of increased global warming linked to a weakening in carbon sinks and radiation sinks in the polar regions with reduced deep water formation due to reduced heat transfers from the southern hemisphere to the north. Positive feedbacks from reductions to the radiation and CO₂ sinks could lead to an increase in global warming (Lewis 1989 in Evans 1996).

Available water supplies will be further overexploited if planned water development projects go ahead. An IUCN study estimated that in the Hadejia river system the potential water requirements are at least (not taking into account evaporation losses) 2.6 times greater than the mean surface water resources (Bdílaya et al. 1999). Although currently the water requirements in the Jama’are and Yobe river basins are met by available water resources, if the construction of the Kafin Zaki Dam is completed they could be outstretched. Water will be used for the proposed Jama’are Valley Irrigation Project and some smaller irrigation...
schemes upstream of Katagum. Potential water requirements for the Jama'are river system could consequently be more than 1.8 times the available water resources in a mean year (Bdilaya et al. 1999).

The average population growth for the Basin is predicted to be 2.6% which could lead to an estimated population of over 56 million by 2020 (UN Population Division 2002). This will increase the pressure on natural resources and therefore increase water use, habitat modification and pressure on the fisheries. A larger population could inflict further economic stress on the countries of the Basin, which may lead to a greater employment of unsustainable practices by communities to allow them to subsist. The further southward advance of the Sahara due to desertification will potentially lead to greater migration from the northern provinces to the south and exacerbate the major concerns faced in the in-taking regions.

The severity of the assessed concerns could increase due to greater demand and use of resources. For the foreseeable future water demands in the Lake Chad drainage basin are expected to increase, as the population becomes more dependent on irrigation agriculture (Hutchinson et al. 1992, FEWS 1997 and 1998 in Coe & Foley 2001). In the southern markets of Nigeria there is increasing demand for protein foods such as fish (Neiland & Verinumbe 1990), which will result in greater pressure on the Lake Chad fisheries as the majority of fish production from the Basin, is sold in these markets. Future technological improvements in the fisheries have also the potential to expand fisheries production.

The recent Chad-Cameroon oil development has the potential to transform the economies of the two countries. It is expected to account for 45 to 50% of Chad's national budget (World Bank 2003b). This could influence the severity of the assessed concerns. Employment opportunities will encourage migration into the Chari-Logone Basin where the Doba oil field is located. This has a potential to enhance the pressure on natural resources due to increased use of water, habitat services and the fisheries resource. The boosted economy is expected to generate opportunities for industrial development that may impact on the pollution concern especially under the current weak environmental legislative framework. Although the project sponsors have installed comprehensive mitigation measures there is always a risk of pipeline leakage, groundwater contamination and freshwater pollution (ESSO 1999). Pollution from the agricultural sector should also be closely monitored, with potential contamination of lakes and rivers from agro-chemicals. The increase in irrigated rice and cotton production which both require large amounts of pesticides and herbicides could increasingly become a threat to ecological systems as well as human health, if mitigation measures are not installed. Pollution is therefore expected to have a moderate impact (rather than its current ‘slight’), before the year 2020.

**Inter-linkages and synergies between the concerns of the Lake Chad Basin**

**Freshwater shortage linkages with Habitat modification**

Freshwater shortage has significantly modified the habitats and community structure of the Basin's ecosystems. Stream flow modification as a result of decreased rainfall events and upstream dam impoundments primarily in the Chari-Logone and Komadugu-Yobe river systems has impacted on the habitats downstream. Wetlands have been the most affected as a result of changes in the timing and extent of seasonal flooding. The reduction in the stream flow has also caused the Lake Chad to shrink to less than 10% of its former surface area (Lemoalle 1991, USGS 2001). This has significantly altered the Lake from being an open water environment to being a predominantly marshy environment. The fish species composition has correspondingly also been modified. A lowering of water tables has caused a reduction in perennial vegetation.

**Freshwater shortage linkages with the Unsustainable exploitation of fish and other living resources**

The size and composition of fish stocks is integrally linked to the size, duration and timing of the annual floods and the level of Lake Chad. Changes in stream flows changed the distribution of aquatic habitats of both the floodplains and Lake Chad environment and fisheries production fluctuated accordingly. Recent production estimates have indicated a significant recovery of the fishery since the collapse of 1982, which demonstrates the Basin's capacity to regenerate its fish stocks when water levels increase (Neiland & Béné 2003).

**Global change linkage to Freshwater shortage**

Climate variability is considered as a key determining factor in freshwater availability in the Basin. In the past four decades there has been a persistent reduction in rainfall over the Lake Chad Basin. Stream flows have consequently decreased and available water supplies have been unable to meet the water requirements of the Basin.

**Habitat modification linkages with the fisheries**

Aquatic habitats have been altered from being predominantly open water to a marshy ecosystem. Fish species have also modified accordingly from ‘open water’ species to ‘marshy’ species. ‘Open water’ species have therefore been more vulnerable to fishing gears. Wetland habitat modification has also contributed to considerable losses of both riverine and lake fisheries, as they provide habitats for fish in general and spawning in particular.
Habitat modification linkages with global climate change
Climate change can partially be attributed to regional habitat modification. Vegetation in semi-arid regions such as the Lake Chad Basin has a significant influence in determining weather patterns. As the climate became drier over the past 40 years and overgrazing continued, vegetation declined. The ability of the ecosystem to recycle moisture back into the atmosphere was thus reduced, contributing to the retreat of the monsoons (Coe & Foley 2001).

Pollution linkages with other assessed concerns
Although there is limited information regarding the influence of pollution in the Basin, it is presumed due to the lack of industrial activities and limited application of agricultural fertiliser that pollution has had a minimal effect on the four other concerns.

Figure 45 shows a model of the inter-linkages and synergies of the five assessed concerns of the Lake Chad Basin. Thickness of line indicates extent of influence of a concern on another concern assessed.