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Management and Ecological Note

Discovery of carp, *Cyprinus carpio*, in the already stressed fishery of Lake Naivasha, Kenya

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Lake Naivasha is a freshwater lake, approximately 160 km^2 in area, situated in the eastern rift valley of Kenya. It is shallow, bordered by papyrus, *Cyperus papyrus* L., and its aquatic macrophytes are in a state of flux (Adams, Boar, Hubble, Gikungu, Harper, Hickley & Tarras-Wahlberg 2002). The fish community was already under pressure from over-fishing, decreasing water levels, changes in aquatic macrophyte densities and inadequate species diversity (Hickley, Bailey, Harper, Kundu, Muchiri, North & Taylor 2002; Hickley & Harper 2002) when the common carp, *Cyprinus carpio* L. was discovered to be present in the lake.

Lake Naivasha originally contained only the endemic fish *Aplocheilichthys antinorii* (Vinc.) which was last recorded in 1962, but, since 1925, various fish introductions have been made, some successful and some not (Muchiri & Hickley 1991). Prior to the appearance of carp, the only fish species in the lake were *Oreochromis leucostictus* (Trewewas), *Tilapia zillii* (Gervais), *Micropterus salmoides* (Lacépède), *Barbus amphigramma* Blgr. and *Poecilia reticulata* Peters. Also present is the Louisiana red swamp crayfish, *Procambarus clarkii* (Girard). A commercial gill net fishery opened in 1959 and the mean annual species composition of the fin-fish catch for the period 1987–2000 was *O. leucostictus* 71.7%, *T. zillii* 8.8% and *M. salmoides* 19.5%.

Over the years there have been great fluctuations (21–1150 t yr^{-1}) in the amount of fish landed from the fishery of Lake Naivasha. Its status and future was examined by Hickley *et al.* (2002) and three phases of development identified: an initial boom and bust (1959–1973), a period of stability (1974–1988) and, most recently, a poorly performing fishery. During the initial phase the maximum recorded total catch of 1150 t yr^{-1} was attained prior to the fishery collapsing in the early 1970s. The middle phase was typified by total catches which fluctuated but were still relatively high with an average of 280 t yr^{-1}. Total catch for the most recent phase (1989–2000) averaged 150 t yr^{-1}, including 21 t yr^{-1}, the lowest ever, in 1997.

Hickley *et al.* (2002) concluded that the annual yield of the Lake Naivasha fishery could be enhanced. This was based upon the mean theoretical yield (about 900 t yr^{-1}) being considerably higher than the overall maximum sustainable yield (650 t yr^{-1}) as computed

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from catch-per-unit-effort data. A proposal was made that the introduction of additional fish species should be seriously considered with effort being made to draw potential candidate species from African fauna and to link such action to improved enforcement and stock conservation regimes. Based on prospective feeding guilds and the actual food web, Muchiri, Hickley, Harper & North (1994) identified that the most convincing case was for a bottom feeder, given that it was the benthic oligochaetes and chironomid larvae which were the most under-utilised, and it was suggested that one of the species of *Mormyrus* should be considered. Although the proposal for additional species had been adopted by the riparian interests (LNRA 1999) no official further introductions had been made.

As an alternative approach to providing more species, the Fisheries Department decided to try closing the fishery for a period in an attempt to facilitate its recovery. After lengthy consultations with all stakeholders, a fishing ban was imposed throughout 2001. On 18 February 2002 the fishery was re-opened with 43 canoes, just over one third of the maximum fleet, being allowed to fish.

In March 2001, whilst the fishery was closed, a fish eagle, *Haliaeetus vocifer* (Gaudin), caught and landed a large carp approximately 680 mm in length (S. Higgins, personal communication) During the period 1–15 March, soon after the fishery was re-opened, 37 carp approximately 220 mm long and 0.4 kg in weight were taken by gillnet fishing. The introduction of carp was accidental with fish escaping from a fish farm adjacent to the River Malewa, Lake Naivasha's main inflow, and into which carp fingerlings had been stocked in 1997. Table 1 shows annual fin-fish catch for the last 10 years and Table 2, monthly catches of carp.

Since the fishery re-opened the relative amount of *T. zillii* landed is noticeably higher than prior to closure and carp comprised 1% total catch by weight, 0.3% by number. During this first year of carp captures the average size of the fish increased fivefold.

The carp, originally a native of Asia, now forms the basis of major fishing and aquaculture industries across the world but can have negative impacts on the more natural aquatic environments. The carp is a benthivore and, generally, any detrimental effects of carp are associated with its characteristic feeding behaviour which involves sucking in sediments with prey items and retaining food organisms whilst sediment particles are expelled. It is this habit of feeding on bottom sediments, which uproots aquatic plants, suspends the sediment and increases water turbidity, that makes carp an unwanted species in some water bodies (Petr 2000). Examples of such impacts are available world-wide. In the USA, carp activity has controlled, uprooted or destroyed submerged vegetation and caused re-suspension of sediments (Crivelli 1983; Crowder & Painter 1991). Similarly, the presence of carp in some shallow lakes in the Netherlands has played a major role in increasing turbidity (Meijer, De Haan, Breukelaar & Buiteveld 1990). The Australian experience is that the carp has an extraordinary ability to cope with a broad variety of environmental extremes and that turbidity levels and carp densities are related (King, Robertson & Healey 1997; Robertson, Healey & King 1997). In addition, the carp acts as a nutrient pump, consuming sediment-bound nutrients

Table 1. Annual total catch (t) from the gill net fishery of Lake Naivasha 1992–2002

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Oreochromis leucostictus	192	43.8	28.4	41.0	13.2	3.7	96.2	428	363	0.0	44.4
Tilapia zillii	0.6	4.1	1.7	12.1	14.3	10.4	6.0	0.3	0.9	0.0	20.7
Micropterus salmoides	9.6	26.6	5.0	8.3	14.2	7.2	8.1	11.0	13.7	0.0	25.1
Cyprinus carpio	–	–	–	–	–	–	–	–	–	–	0.9
Total	202	74.5	35.0	61.3	41.7	21.3	110	439	377	0.0	91.2

Table 2. Monthly catch of *Cyprinus carpio* from the gill net fishery of Lake Naivasha 2002

Month 2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
No. of fish	0	117	361	192	58	72	73	101	40	28	13	1055
Weight (kg)	0	48	174	107	54	97	100	169	69	64	29	910
Mean size (kg)	–	0.41	0.48	0.56	0.92	1.34	1.37	1.67	1.73	2.27	2.23	0.86

and subsequently excreting them into the water column (Lamarra 1975).

Although a recent proposal was to introduce a new fish species into Lake Naivasha to exploit benthic chironomid larvae and oligochaetes, and the carp is capable of doing this, the feeding method of carp puts bottom material into suspension. This is in contrast to the recommended benthivorous mormyrids which use electric organs to detect food and a specialised probing snout for intake of prey. Any effects of carp on submerged macrophytes will be additive to the already detrimental impact of *P. clarkii* (Hickley & Harper 2002). Carp could be beneficial in consuming juvenile crayfish populations but for carp density to be sufficient for a noticeable impact might mean a carp population large enough to outweigh such benefit. Although direct predation on other fish species would be improbable, there could be some noticeable effects of carp presence. Being a substratum spawner, *T. zillii* could be seriously disadvantaged by the lake bed being disturbed. *Micropterus salmoides* is a visual feeder and could be compromised by any further increase in turbidity.

In population development terms, the potential success of *C. carpio* in Lake Naivasha is unlikely to be restricted. It was noted above that the species is tolerant of a degraded aquatic environment. Also, although not yet witnessed, spawning is unlikely to be limited because the normal water temperature of Lake Naivasha is 21–24 °C, above the required 18 °C (Cowx 2001), and the carp is not selective in its choice of substratum for attachment of eggs (Petr 2000). That carp can become significant in the inland fisheries of Kenya is evident from the Tana River dams where, for the period 1991–2000, the contribution to a mean annual catch of 1085 t comprised 22% carp, alongside 69% tilapias [*O. sprirulus niger* (Gunther) and *O. niloticus* L.].

Although it has been observed that the aquatic macrophytes of Lake Naivasha routinely disappear under the impact of *P. clarkii*, there have been periods of recovery when the crayfish population declines (Hickley & Harper 2002). In future, however, when crayfish populations are in a phase of decline, the presence of carp is likely to preclude the uninhibited regeneration of the macrophytes. Currently the lake is turbid and should at some stage enter another recovery phase, but with carp present in the fishery, the prognosis is not good. Regarding relative species composition within the Lake Naivasha fishery, given the experience of the Tana River dams, it is possible that, although *T. zillii* and *M. salmoides* might be threatened, *O. leucostictus* could remain unaffected. Regrettably, only time will tell.

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