Movements and habitat utilisation of radio tagged carp *(Cyprinus carpio)* in a reservoir in the Fish River, Namibia

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Preface

The telemetry project in the Hardap water reservoir was a collaboration between the Namibian Ministry of Fisheries and Marine Resources (MFMR) and the Norwegian Institute for Nature Research (NINA). Results from a pilot study are presented in this report. The main objectives were to 1) assess if and how telemetry can be used to follow the movements of carps in a southern African reservoir, and 2) study the movements and habitat preference of carps during a period of high water level and inflow into a reservoir during the rainy period. MFMR and NINA financed the study. We thank Rolly Thompson for carrying out most of the tracking. We also thank the staff at the MFMR Freshwater Fish Institute at Mariental for assistance during the fieldwork.

Windhoek and Trondheim, February 2001

Clinton J. Hay	Tor F. Næsje
Project leader, MFMR	Project leader, NINA

Abstract

Økland, F., Hay, C.J., Næsje, T.F., Thorstad, E.B. & Nickandor, N. 2001. Movements and habitat utilisation of radio tagged carp (*Cyprinus carpio*) in a reservoir in the Fish River, Namibia. - NINA•NIKU Project Report 000: 1-28.

A pilot study tagging 20 carps (total length 33-78 cm) with radio transmitters was conducted in the Hardap Reservoir, Mariental, Namibia in 2000. The carps were caught by drag netting during 16-18 February, immediately placed in a transport container and brought to concrete ponds at the Hardap Research Station. After one to three days, the fish were tagged with externally attached (n = 5) and surgically implanted (n = 15) transmitters and released back into the reservoir.

Range tests in the reservoir showed that at a distance of 1,450 m, transmitters had to be close to the surface (0-0.5 m) to be detected. At a distance of 100 m, transmitters could be detected all the way down the water column to the bottom at 12 m depth. From release (18 and 19 February) and until the end of the study (15 June), the carps were located weekly or every second week. In addition, they were located daily during the two periods 12-25 March and 27 May - 9 June. The study covered a period during the rainy season when the reservoir was full, with a gradual decrease in water level (1 m) towards the end of the tracking period.

All carps moved away from the release site soon after release. However, the 15 carps with surgically implanted transmitters did not perform well. Two transmitters were retrieved from the shoreline, one fish was probably flushed downriver when the dam gates were opened, and one transmitter failed just before release. The remaining fish with internal transmitters (n = 11) stopped moving between 3 and 30 days after release, and the reason for this must be that they died or that they expelled their transmitter. Other telemetry studies of carp in cold temperate areas have not reported any problems with handling or surgical implanting of transmitters. The carps in the present study seemed to be more vulnerable to stress due to the higher water temperature, which varied between 24 and 25 °C during catch, tagging and release. Introduced fish species may, in general, be expected to be more vulnerable to handling and tagging stress in areas with different environmental conditions than in their natural distribution area.

All five fish with external transmitters survived and were moving until the end of the study. The following results are from the five externally tagged carps (total length 33-49 cm).

Two of the carps were not released at the catch site, and both returned to the catch site. Average daily distance moved by the carps was significantly longer during the first period with daily tracking (1.45 km/day) than during the second period (0.45 km/day). Also the area utilised was significantly larger during the first period (on average 2.1 km^2) than during the second period (on average 0.3 km^2). These differences may be related to the difference in water temperature between the two periods, which varied between 21 and 27 °C during the first period and between 16 and 18 °C during the second period. Total area utilised by the carps during the entire study period was on average 4.3 km^2.

The carps mainly stayed in the north-eastern parts of the reservoir, which is a narrow open area with depths 5-25 m. They also stayed in the shallower inlets (depths 1-5 m) in this area. The bottom in these zones is dominated either by gravel and sand or mud and dead trees. Two carps were also recorded at some occasions in the shallow areas (1-5 m) in the southern parts of the reservoir, where the bottom is dominated by sand, clay and dead trees. The carps were not only associated with the littoral zone, they were localised between 3 and 380 m from the nearest shore. Average distance from the nearest shore was 117 m during both periods with daily tracking, which was not significantly different between the periods.

Key-words: telemetry - tagging method - handling

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Contents

1 Introduction

Namibia is considered one of the driest countries in the world, and perennial rivers exist only along the borders in the north, north-east and the south. The northern perennial river systems in Namibia border on Angola, Zambia and Botswana, where a number of people live near the rivers and are dependent on the fish recourses (Anon. 1995, Sandlund & Tvedten 1992). In south, the Orange River borders on South Africa. Thus, most of Namibia has temporary rivers and watersheds only running for shorter or longer periods during the rainy period. Many dams have been constructed to collect and store water, and some have the capacity to store water permanently. Fish are present in most of the reservoirs, and the reservoirs can, therefore, be an important producer of fish protein and fish for recreational fishing. However, information on how the different species will disperse and utilise the habitats in the reservoirs is scarce.

Most Namibian fish species (78 %) are floodplain-dependent for larval and juvenile stages (Barnard 1998) and are, therefore, not expected to perform well in man made dams and reservoirs. Thus, many of the species found in reservoirs are alien species like carp (*Cyprinus carpio* L.), or species introduced from aquaculture (for example Mozambique tilapia *Oreochromis mossambicus* Peters, 1852).

Today, carp is an important species for both subsistence, recreational and trophy fishing in southern Africa. From its natural distribution area (Central Asia to the Black Sea), it has been introduced into many countries around the world. It was introduced into South Africa as early as during the 1700s, and was repeatedly imported during the 1800s (Skelton, 1993). Today, carp is wide-spread throughout southern Africa, but is absent from mountain areas and restricted in the warmer tropical areas (Skelton, 1993). Little is known about their behaviour and habitat utilisation in African reservoirs.

Telemetry represents the only method to follow individual movements of fish over longer periods and has been used extensively in this type of investigations during the last decades (Baras 1991). The use of these methods requires local information about the animals to be studied to optimise the fish handling, and about water chemistry and hydrology to estimate expected detection ranges and establish tracking procedures. The main objectives in this study were to 1) assess if and how telemetry can be used to follow the movements of carps in a reservoir, and 2) study the movements and habitat preference of carps during a period of high water level and inflow during the rainy period.

2 Study site

The Hardap Reservoir (**figure 1**) is located south of Windhoek near Mariental in the southern part of Namibia (24° 52'S, 17° 52'E) and drains the Fish River, a non-perennial tributary to the Orange River. The dam was constructed in 1960 to 1962 for irrigation and domestic water supply to the Mariental area. The dam drains a catchment area of 13,699 km^2 with a mean annual rainfall of 209 mm. When full, the reservoir is 22.5 km long, up to 35 m deep and has a surface area of 28.7 km^2. The surface of the reservoir is 1,135 m above sea level. The surface water temperature is highest during the rainy season, reaching 27 to 28 °C. The high altitude and low air temperatures during winter lower the water temperature to approximately 12 °C. In addition to the common carp, the following fish species are present in the reservoir: *Barbus cf. kimberleyensis* (*B. aenus* x *B. kimberleyensis* hybrid), *B. paludisnosus* Peters, 1852, *Labeo capensis* A. Smith, 1841, *L. umbratus* A. Smith 1841, *L. capensis* x *L. umbratus* hybrid, *Clarias gariepinus* Burchell, 1822 and *O. mossambicus*. The habitats of the reservoir have been classified and described by Bloemhof (1974) and Schrader (1986) (**figure 2**).

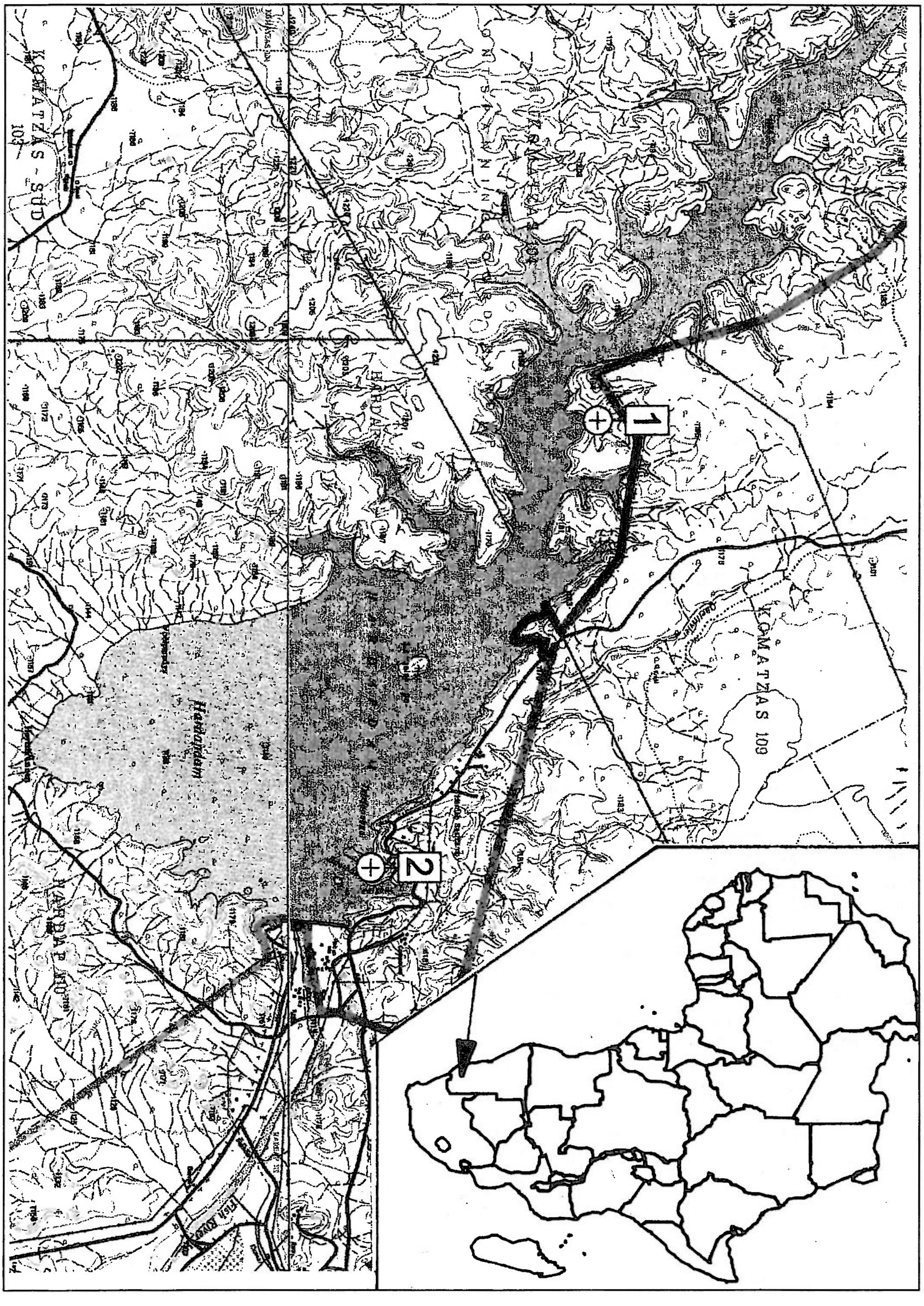


Figure 1*. The Hardap Reservoir in Namibia. The carps were caught with dragnet at location 1. After radio tagging, ten carps were released at the site of catch and ten carps at location 2.*

Figure 2*. Classification and descriptions of habitats in the Hardap Reservoir. Zone classifications are after Bloemhof (1974), and station descriptions after Schrader (1986). Zones are indicated with different hatching and stations with dots and numbers.*

Zone 1*: Depths between 5 and 27 m. Large open area of the dam.* ***Zone 2****: Depths between 1 and 5 m. Shallow area in the southwestern parts of the dam.* ***Zone 3****: Depths between 1 and 5 m. Inlets.* ***Zone 4****: Depths between 5 and 25 m. A narrow middle area of the reservoir.* ***Zone 5****: Depths between 1 and 5 m. River inlet of the dam.*

Station 1*: Gravel and sand, deep water.* ***Station 2****: Sand and clay, dead trees, open water.* ***Station 3****: Mud, deep water.* ***Station 4****: Gravel and sand, dead trees.* ***Station 5:*** *Gravel and sand, dead trees.* ***Station 6****: Gravel and sand.* ***Station 7****: Mud, dead trees.* ***Station 8****: Mud, dead trees. River habitat.* ***Station 9****: Mud, dead trees, river habitat.* ***Station 10****: Mud, river habitat.*

3 Materials and methods

3.1 Radio telemetry equipment

The fish were tracked using implanted or externally attached radio transmitters from Advanced Telemetry Systems Inc., USA (ATS). Two types of transmitters were used (**table 1**). Transmitter model 7PN-3v had a minimum duration of 280 days, weight in air of 15 g and weight in water of 5 g. Transmitter model 10-28-3v had a minimum duration of 140 days, weight in air of 9 g and weight in water of 3 g. Transmitter weight in water was less than 0.5 % of the body weight of the experimental animals. The 7PN-3v transmitters were flat (19 x 37 x 9 mm) and specially designed for external attachment. The 10-28-3v transmitters were cylindrical (56 x 12 mm) and could be used both for implantation and external attachment. All transmitters had a pulse rate of 30 pulses per minute and a signal strength of -127 dB. The transmitter frequencies were spaced approximately 10 kHz apart or more. A portable receiver (R2100, ATS) connected to a 4-element Yagi antenna were used to detect signals from the tagged fish.

3.2 Range test

A range test was conducted on 16 February 2000 in the southern part of the reservoir near the dam wall. One transmitter of each model was attached to a rope and lowered into the water. The greatest depth at which transmitter signals could be detected was recorded at different test sites 45-1,450 m from the receiver and antenna.

3.3 Catch and tagging

All carps were caught in the reservoir by drag netting during 16-18 February 2000. They were placed in a transport container and brought by truck to a concrete pond near the dam at the research station of the Freshwater Fish Institute, Ministry of Fisheries and Marine Resources (MFMR), where they were kept for 1-3 days before tagging and release. Fifteen carps had transmitters surgically implanted into the body cavity, and five carps had transmitters externally attached below the dorsal fin (**table 1, figure 3**).

Table 1. *Radio tagged carps in the Hardap Reservoir, Namibia, in 2000. Transmitter model: 1 = 7PN-3v, 2 = 10-28-3v. Catch and release sites are shown in* ***figure 1****. Weight was not recorded for the last four fish due to electricity failure.*

Fish no.	Catch date	Release date	Frequency	Total length (cm)	Weight (g)	Transmitter model	Transmitter attachment	Release site	Date of last recorded movement
1	16. or 17.02.	18.02.	142.024	41.5	1 326	1	Implant	2	*
2	16. or 17.02.	18.02.	142.034	41.5	1 262	1	Implant	2	24.02.
3	16. or 17.02.	18.02.	142.073	42.1	1 347	1	Implant	2	02.03.
4	16. or 17.02.	18.02.	142.062	33.0	732	1	External	2	15.06.
5	16. or 17.02.	18.02.	142.044	49.0	1 821	1	External	2	15.06.
6	16. or 17.02.	19.02.	142.173	59.5	3 593	2	Implant	1	02.03.
7	16. or 17.02.	19.02.	142.183	55.1	2 940	2	Implant	1	02.03.
8	16. or 17.02.	19.02.	142.163	57.1	3 103	2	Implant	1	15.03.
9	16. or 17.02.	19.02.	142.193	48.6	2 048	2	Implant	1	02.03.
10	16. or 17.02.	19.02.	142.104	43.0	1 456	1	External	1	15.06.
11	16. or 17.02.	19.02.	142.093	37.2	919	1	External	1	15.06.
12	16. or 17.02.	19.02.	142.013	34.2	699	1	External	1	09.06.
13	18.02.	19.02.	142.084	41.1	1 128	1	Implant	1	02.03.
14	18.02.	19.02.	142.144	53.2	2 997	2	Implant	1	02.03.
15	18.02.	19.02.	142.053	59.0	3 508	1	Implant	1	15.03.
16	18.02.	19.02.	142.152	49.2	2 215	2	Implant	2	20.02.
17	18.02.	19.02.	142.204	78.0		2	Implant	2	20.03.
18	18.02.	19.02.	142.213	60.0		2	Implant	2	14.03.
19	18.02.	19.02.	142.123	62.0		2	Implant	2	15.03.
20	18.02.	19.02.	142.133	57.2		2	Implant	2	24.02.

*Transmitter failed before release

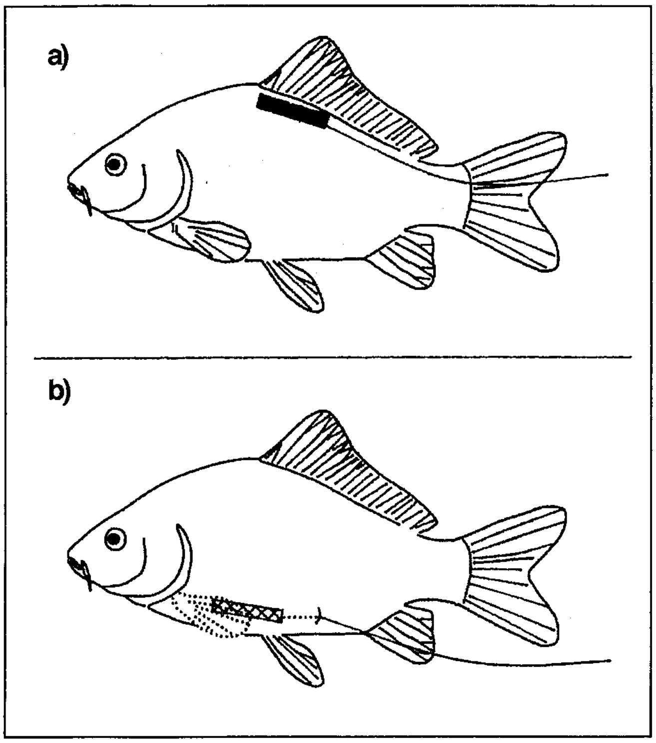


Figure 3. *Radio tagged carp with a) an externally attached radio transmitter, and b) a transmitter surgically implanted into the body cavity.*

Before surgery, the fish were placed approximately 5 minutes in an anaesthetisation bath (5 mg l^{-1} Metomidate, Marinil™, Wildlife Labs., Inc., Fort Collins, Colorado, USA). The anaesthetisation bath was changed every time the temperature reached 28 °C. Surgery was initiated when the operculum rate became slow and irregular. The fish were placed on their dorsum in a V-shaped surgical table. The gills were flushed with circulating oxygenated water containing a slightly weaker solution of Metomidate (3-4 mg/l) to keep the fish anaesthetised during surgery. A 3 cm incision was made by use of a scalpel on the ventral surface posterior to the pelvic girdle. The transmitter was inserted via the incision into the body cavity above the pelvic girdle and attached to the pelvic girdle with a single permanent silk suture. To place the antenna, a hollow needle sharpened at one end was inserted into the incision and pushed through the body wall. The antenna wire was threaded into the needle, and the needle was pulled completely through the side of the individual, leaving the antenna wire in place. The incision was closed using four to five independent permanent silk sutures (2/0 Ethicon). Surgery time was approximately 8-10 minutes. Toward the end of the surgery, the gills were flushed with fresh oxygenated water to reduce the recovery period.

For external attachment, anaesthetisation procedures were the same as for surgical implantation. The transmitter was externally attached to the fish below the dorsal fin with 0.5 mm steel wires inserted horizontally through the upper part of the musculature. The tagging procedure lasted approximately 2 minutes.

After the transmitters were attached, the length and weight of the fish were recorded. The fish were placed in a transport container with fresh, oxygenated water on a truck to recover, and they were released later the same day. Ten fish were released at the catch site and ten fish were released near the dam wall (**table 1, figure 1**).

3.4 Tracking

The tracking was carried out by boat. The fish were tracked daily to every third day from release until 24 February 2000. Subsequently, the fish were tracked weekly, or every second week at three occasions, until 15 June 2000. In addition, the fish were located daily during the two periods 12-25 March and 27 May - 9 June. All five carps moving throughout the study period (see chapter 4.2) were found during all daily trackings, except that fish no. 5, 10 and 11 were not found during one of the trackings in the first period (**table 2**). During weekly trackings, the carps were not found at several occasions (**table 2**).

Table 2. *An overview of dates when five radio tagged carps were not found during tracking in the Hardap Reservoir in 2000. Fish numbers correspond to fish numbers in* ***table 1****.*

Fish no./Date	4	5	10	11	12
19 February			x	x	x
20 February	x				
23 February	x	x			x
2 March				x	
20 March			x	x	
25 March		x			
6 April	x	x		x	
13 April		x		x	
20 April		x	x	x	x
27 April		x	x	x	x
12 May		x	x	x	x
15 June					x

The fish were usually located with a precision of ± 10 m. When the fish were away from shore in deeper waters, the precision of the trackings was ± 50 m. When fish were stationary, the precision of the trackings was increased to determine whether or not the fish were moving and alive. The locations were recorded both on maps and by use of the Global Positioning System (GPS 12 CX from GARMIN Corporation). A laser range finder (Bushnell BU Yardage 800) was used to record the distance to shore with a precision of ± 1 m.

3.5 Water level, water temperature and secchi depth

The water level was near its highest and the Hardap Reservoir was full when the fish were caught, tagged and released. During the following weeks, the water level increased further due to heavy rain, and the gates had to be opened, and water were released into the Fish River on 21 and 28 February, 6 and 27 March and 3 and 10 April. After 10 April, the water level slowly decreased by approximately 1 m until 15 June, when the tracking ended.

The surface water temperature in the reservoir was 24-25 °C during catch and release of the carps (**figure 4**). The temperature gradually decreased to 14 °C at the last tracking 15 June (**figure 4**). During the first period with daily tracking, the surface temperature was on average 24.5 °C (range 21-27) and during the second period 17.0 °C (range 16-18).

Secchi depths varied between 5 and 14 cm during the study (**figure 4**). Average secchi depth during the first period with daily tracking was 8.9 cm (range 5-13), and during the second period 9.9 cm (range 9-10).

3.6 Data analysis

The data were analysed by using the OziExplorer software, where all locations can be entered and distances and areas calculated. The statistical analyses were conducted in Statgraphics version 4.0 and SPSS version 10.0. Only fish moving were included in the analyses. Calculation of distances travelled and area utilised by the fish are minimum estimates, because we do not know the movements of the fish between fixes.

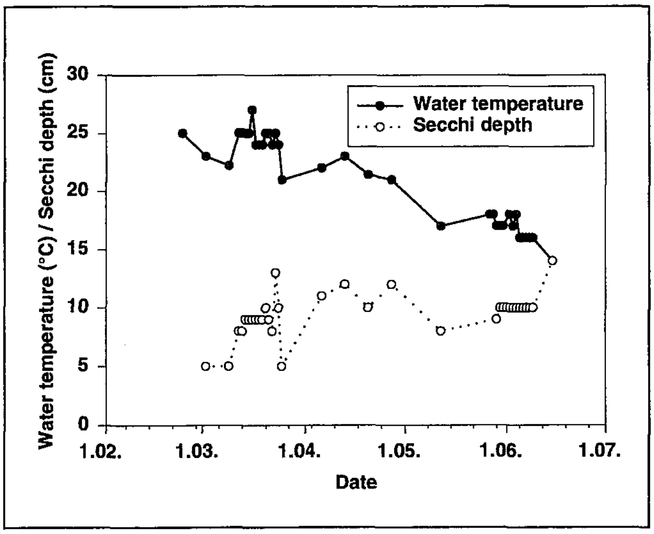


Figure 4. Surface water temperature and secchi depths in the Hardap Reservoir measured during tracking of radio tagged fish during the period 24 February - 15 June 2000.

4 Results

4.1 Range test

There were no differences in detection range between the two models of transmitters used in the project (**figure 5**). At a distance of 1,450 m, transmitters had to be close to the surface (0-0.5 m) for signals to be detected, whereas at a distance of 100 m, transmitters could be detected all the way down the water column to the bottom at 12 m depth (**figure 5**).

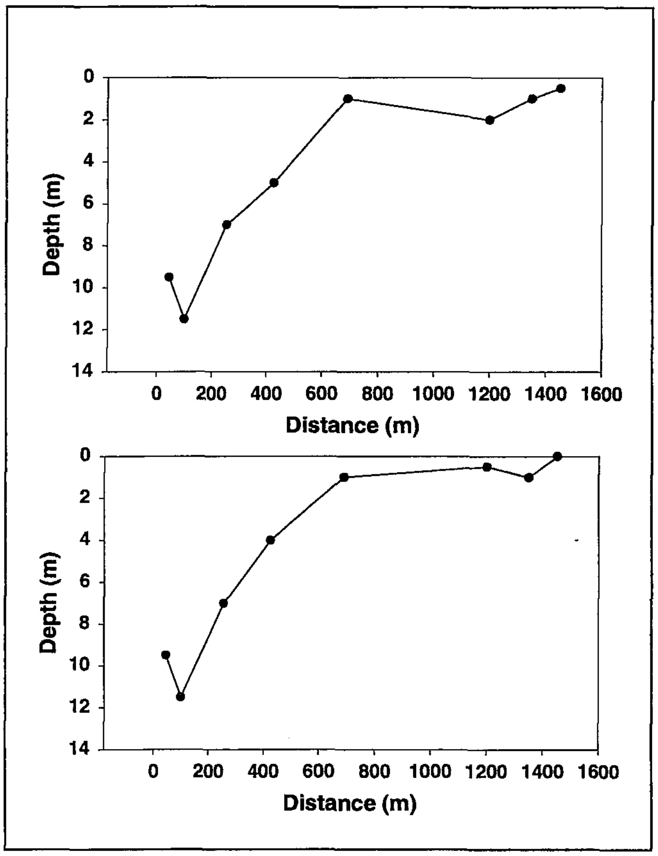


***Figure 5**. The greatest depth at which transmitter signals could be detected at different test sites from 45–1,450 m from the receiver and antenna during a range test for a) a 7PN-3v transmitter, and b) a 10-28-3v transmitter.*

4.2 Fish movements

Immediately after release, all the tagged fish moved away from the release site. However, all 15 fish with internal transmitters stopped moving or were lost before the daily tracking program was completed (**table 1**). Two of the surgically implanted transmitters were found on the shore outside the water (transmitter from fish no. 7 was found on 2 March and from fish no. 15 on 15 March). These were actually the only two fish that we were not sure that the transmitter had been successfully attached to the pelvic girdle during the surgical implantation. One transmitter failed during the transportation to the reservoir (fish no. 1). The last location of one fish (no. 16) was near the dam gate just before it was opened, and this fish was most likely flushed downriver. The rest of the carps with internal transmitters (n = 11) stopped moving before or during the first period with daily tracking (0-30 days after release, **table 1**). The five carps with external transmitters all survived and were recorded moving until the tracking terminated in June 2000 (**table 1**). The results below are from the five externally tagged carps.

The two carps that were not released at the catch site (fish no. 4 and 5) returned to the catch site (**figure 6**). They were mainly recorded close to the catch site and east and north-east of this area during the study (**figure 6**).

Average total distance moved was significantly longer for the carps during the first period with daily tracking (18 km) than during the second period (6 km) (Wilcoxon signed ranks test, n = 5, Z = -2.02, P = 0.043, **table 3, figure 7-11**). Average daily distance moved, which was adjusted according to exact number of hours between each tracking, was also longer during the first period (1.45 km/day) than during the second period (0.45 km/day) (Wilcoxon signed ranks test, n = 5, Z = -2.02, P = 0.043, **table 3**). Three of the carps moved significantly shorter during the second period with daily tracking than during the first period (Mann Whitney U-tests, fish no. 5: Z = -3.94, P < 0.001; fish no. 10: Z = -3.48, P < 0.001; fish no. 11: Z = -2.49, P = 0.013, **figure 8, 9 and 10**), whereas there was no such difference for the two other carps (Mann Whitney U-tests, fish no. 4: Z = -0.205, P = 0.84; fish no. 12: Z =-0.103, P = 0.92, **figure 7 and 11**).

Neither total distance moved or daily distance moved during the first and second period with daily tracking was dependent on body length or weight of the fish (linear regressions, all df = 4, r^2 = 0.001-0.338, P = 0.30-0.97). Weekly migration distance was not dependent on water temperature or secchi depth in any of the carps (linear regressions, df = 4-8, r^2 = 0.004 - 0.20, P = 0.34 - 0.88, data from periods with tracking every second week were excluded from the analysis).

4.3 Habitat utilisation

The carps were mainly recorded in the north-eastern part of the reservoir (**figure 6 and 12**). This part of the reservoir was classified as zone 4 by Bloemhof (1974) (**figure 2**), and is a narrow open area of the reservoir with depths 5-25 m. The fish stayed both in these open areas and in the shallower inlets (depths 1-5 m), classified as zone 5 (Bloemhof, 1974, **figure 2**). Stations in this area were described as with either gravel and sand, or with mud and dead trees (Schrader 1986, **figure 2**). The uppermost part of the area was described as river habitat (Schrader 1986, **figure 2**). Two carps were also recorded at some occasions in the southern part of the reservoir (**figure 6 and 12**). This part of the reservoir was classified as zone 2 by Bloemhof (1974) (**figure 2**), and is a shallow area with depths 1-5 m. A station in this area was described as with sand, clay and dead trees (Schrader 1986, **figure 2**).

Total area utilised by the carps during the study was on average 4.3 km^2 (range = 1.5-7.6 km^2, SD = 2.6, data from 9 March, **figure 6, table 4**). The area utilised by the carps was significantly larger during the first period with daily tracking (on average 2.1 km^2) than during the second period (on average 0.3 km^2) (Wilcoxon signed ranks test, n = 5, Z = -2.02, P = 0.043, **figure 7-11, table 3**).

Average distance the carps was recorded from nearest shore was 117 m during both periods with daily tracking, which was not significantly different between the periods (Wilcoxon signed ranks test, n = 5, Z = -0.135, P = 0.89, **table 3**). For four of the carps, there was no significant difference between the distance from shore between the two periods (Mann-Whitney U-tests; fish no. 5: Z = -0.630, P = 53; fish no. 10: Z = -1.53, P = 0.13; fish no. 11: Z = -0.53, P = 0.59; fish no. 12: Z = -0.808, P = 0.42), whereas fish no. 4 was recorded further away from the shore during the second period (Mann Whitney U-test, Z = -2.83, P = 0.0045). Neither distance from shore or total area utilised during the first and second period of daily tracking was dependent on body length or weight of the fish (linear regressions, all df = 4, r^2 = 0.000 - 0.35, P = 0.29 - 0.99).

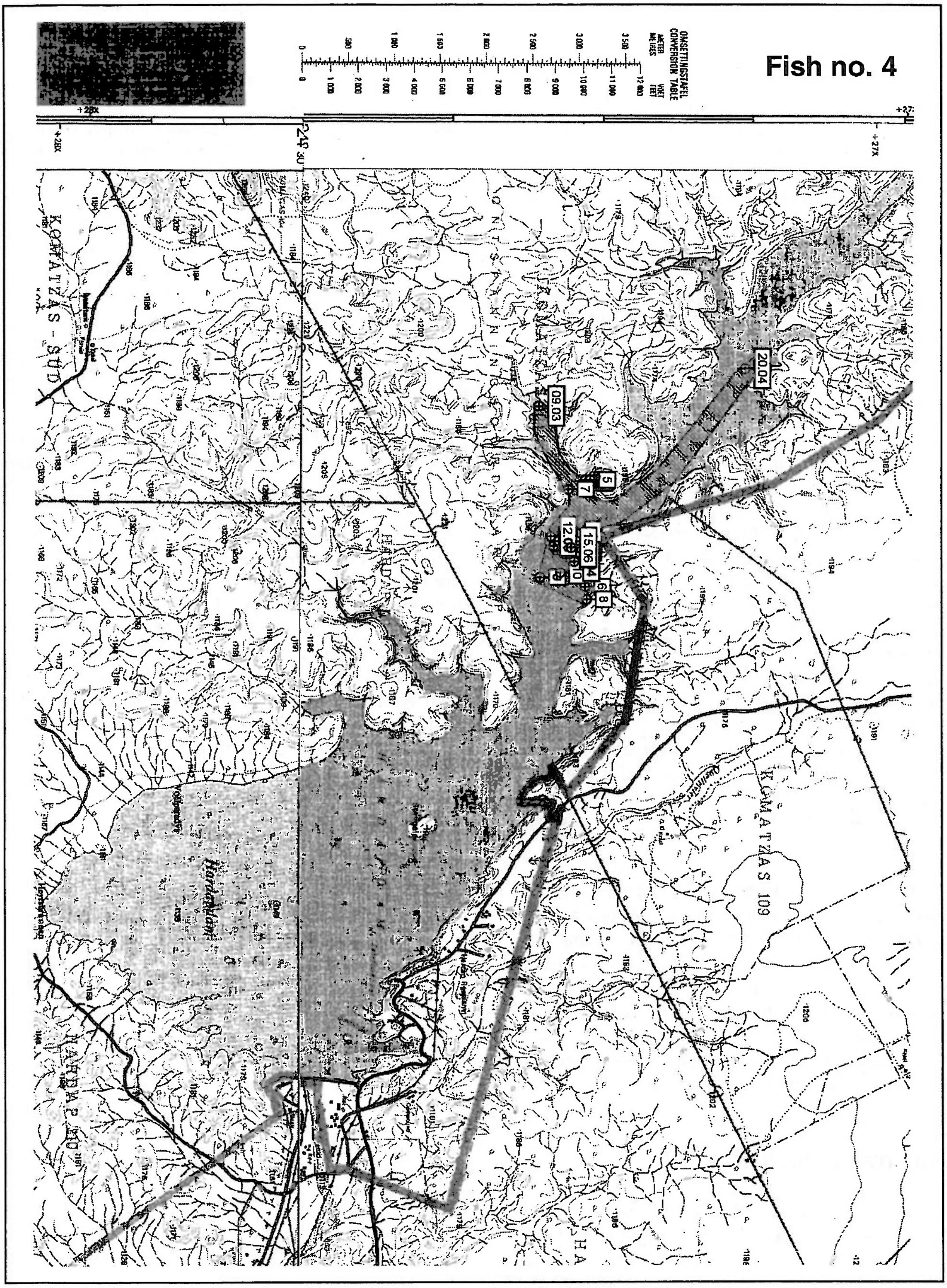
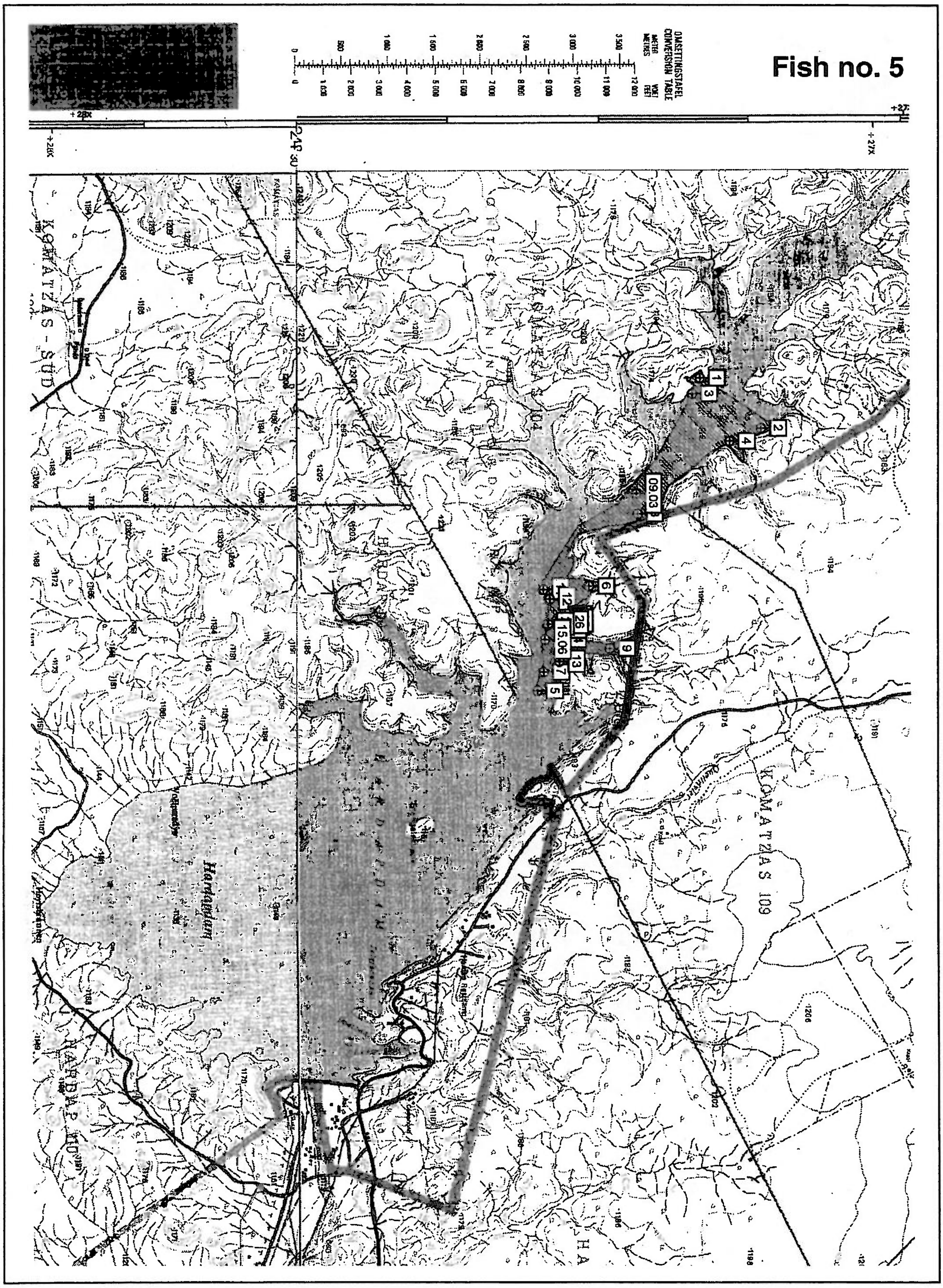
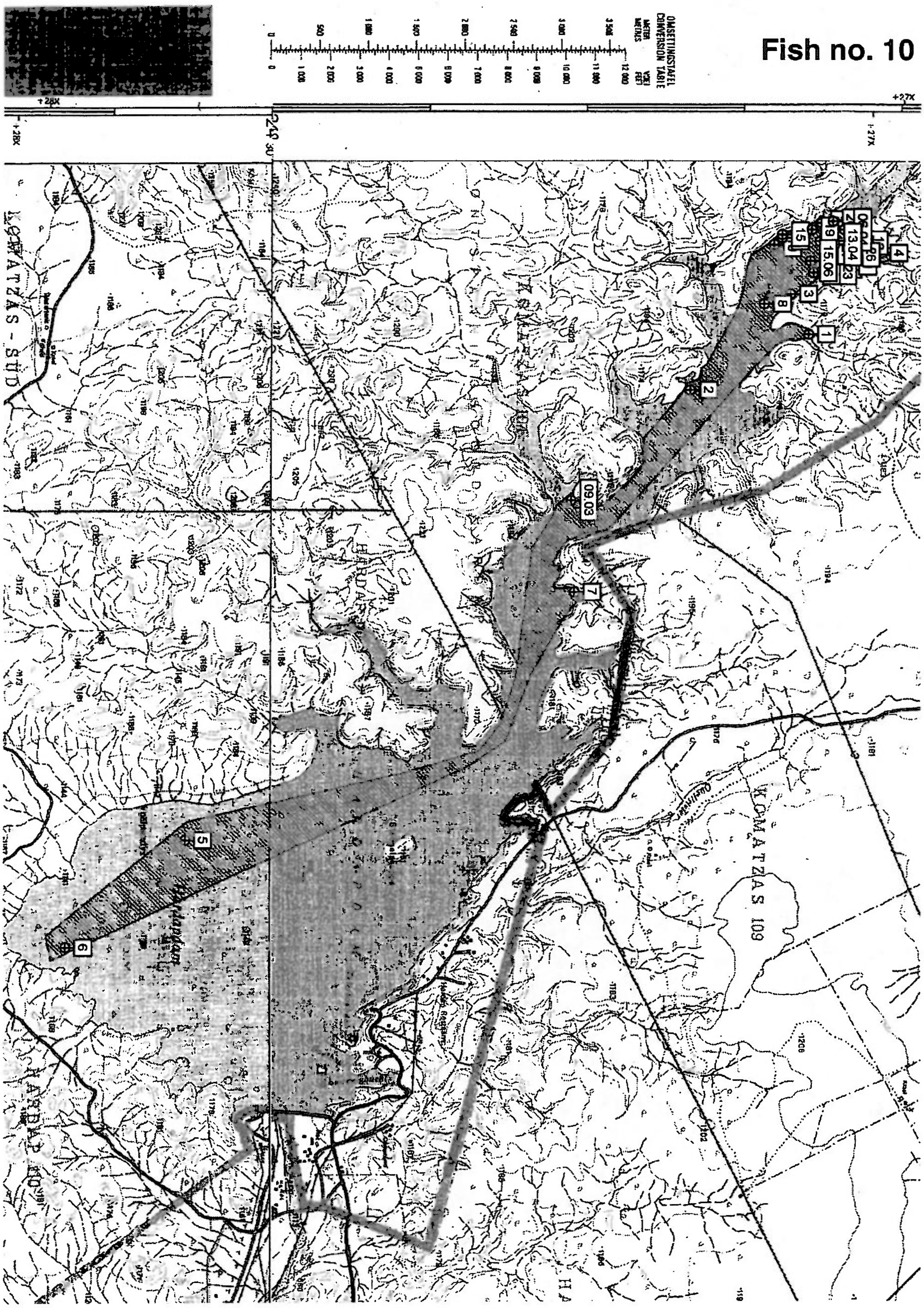


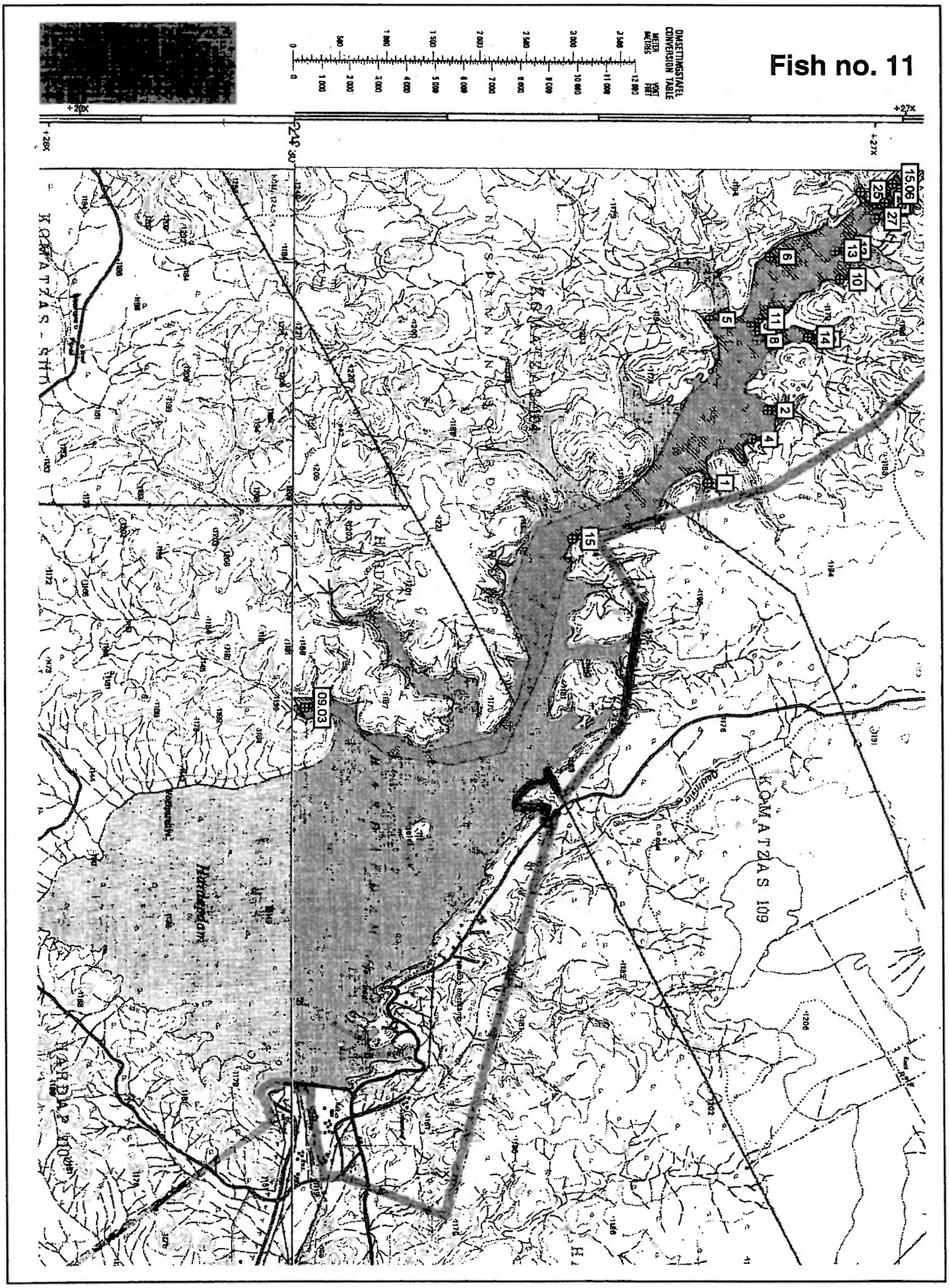
***Figure 6**. All recordings and area utilised by five individual radio tagged carps (no. 4, 5, 10, 11 and 12) in the Hardap Reservoir in Namibia during 9 March – 15 June 2000. Data from before 9 March are excluded to give a representative presentation of the area utilised, because translocated fish were recorded in the release area the first days after release. Weekly trackings are indicated by dates and daily trackings by numbers.*


Fish no. 5
OMSETTINGSTABEL
CONVERSION TABLE
1
3
2
4
09.03
6
12
26
15.06
13
9
7
5
KOMATZAS - SÜD
KOMATZAS 109
Hardangerjøkulen

Fish no. 10



Fish no. 11



Fish no. 12

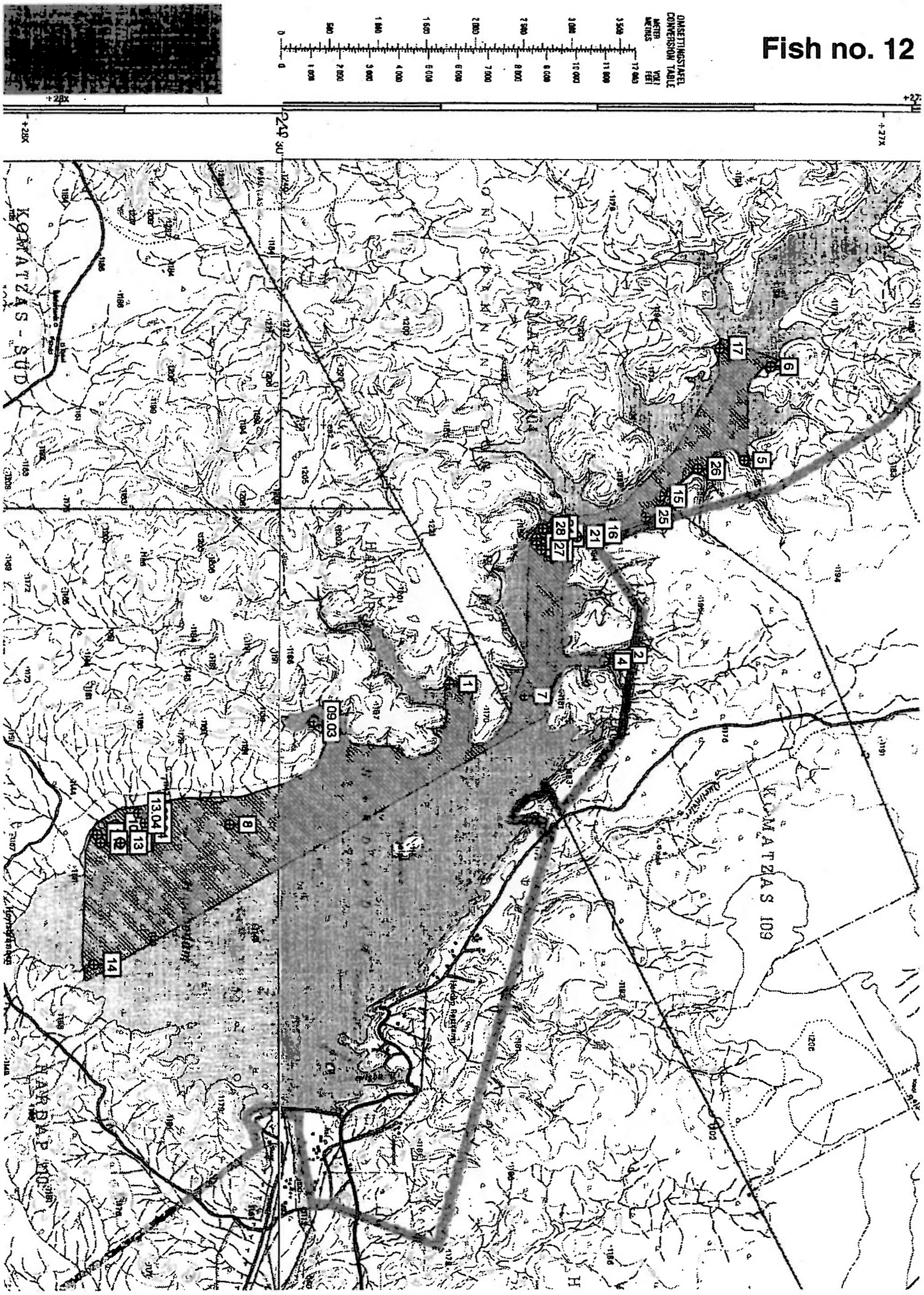


***Table 3.** Movements and habitat utilisation of five radio tagged carps during two periods (period 1: 12-25 March 2000, period 2: 27 May - 9 July 2000) with daily tracking in the Hardap Reservoir. Fish numbers correspond to fish numbers in **table 1**. Daily migration distance was corrected for an unequal number of hours between trackings.*

Fish no.	Period	Total distance moved (km)	Daily migration distance (range) (km/day)	Distance from nearest shore (range) (m)	Area utilised (km^2)
4	1	4.6	0.36 (0.014-1.45)	87 (5-285)	0.33
4	2	1.4	0.11 (0.055-0.20)	171 (30-270)	0.03
5	1	16.4	1.38 (0.13-4.00)	126 (35-370)	1.44
5	2	1.3	0.10 (0.024-0.26)	117 (23-207)	0.03
10	1	33.1	2.84 (0.17-10.62)	126 (10-380)	3.45
10	2	3.8	0.24 (0.003-0.56)	83 (30-200)	0.33
11	1	12.7	1.18 (0.11-1.78)	132 (5-290)	1.40
11	2	10.9	0.85 (0.014-5.36)	82 (19-130)	0.28
12	1	21.3	1.64 (0.052-4.96)	116 (3-300)	4.00
12	2	12.7	0.95 (0.12-3.00)	134 (38-265)	0.75

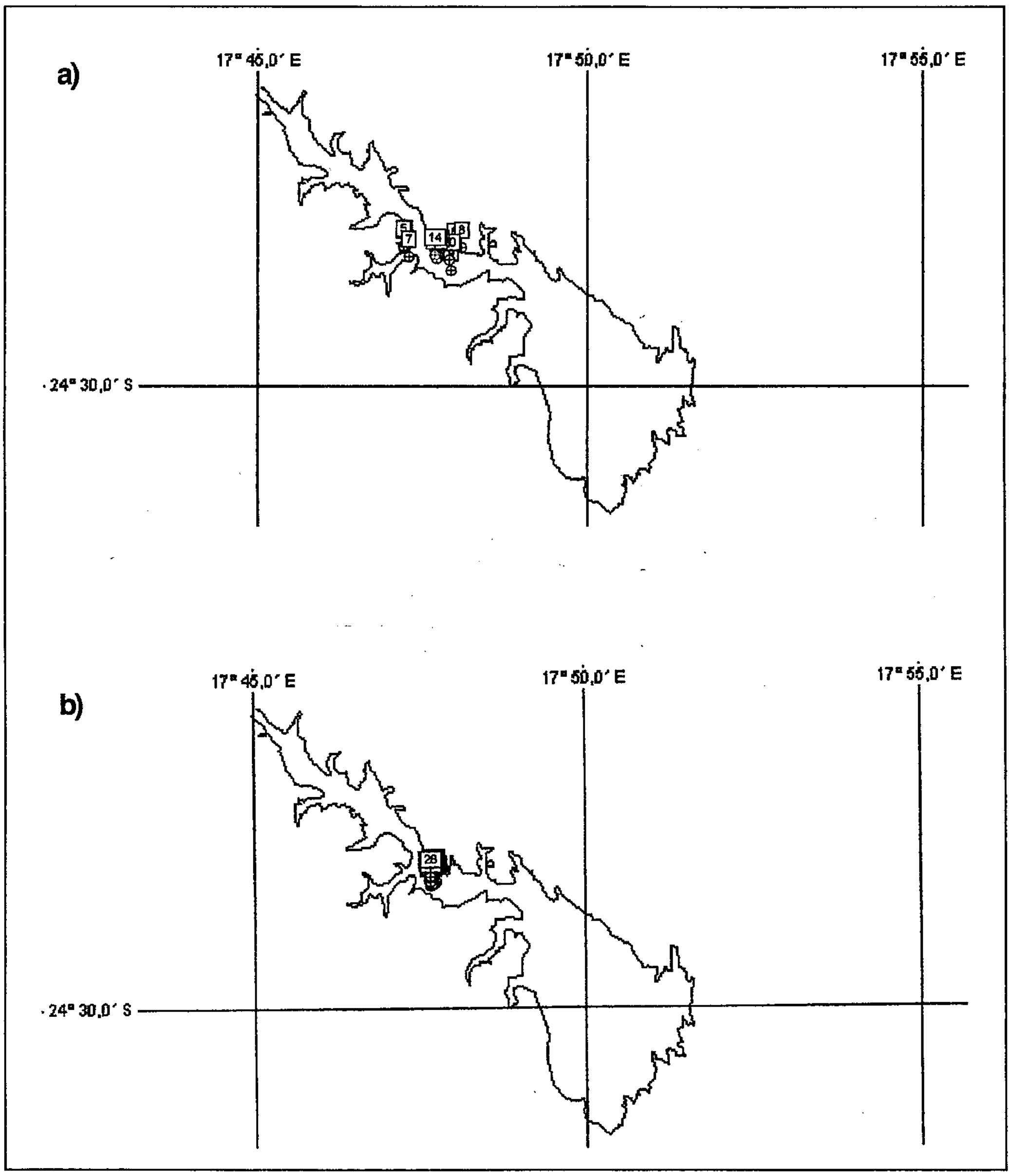


***Figure 7**. Daily locations of carp no. 4 during a) 12-25 March, and b) 27 May-9 June.*

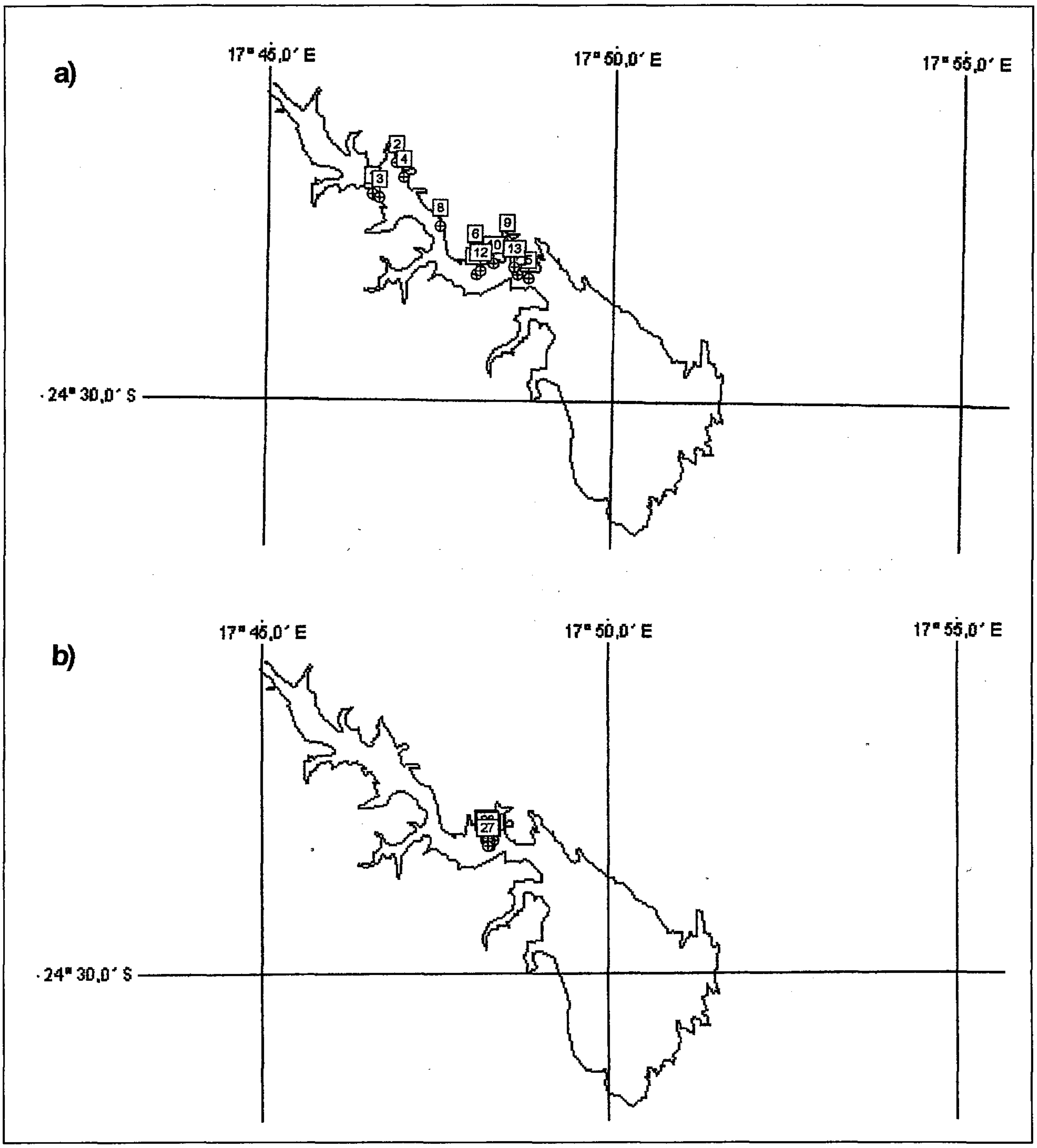


Figure 8. *Daily locations of carp no. 5 during a) 12-25 March, and b) 27 May-9 June.*

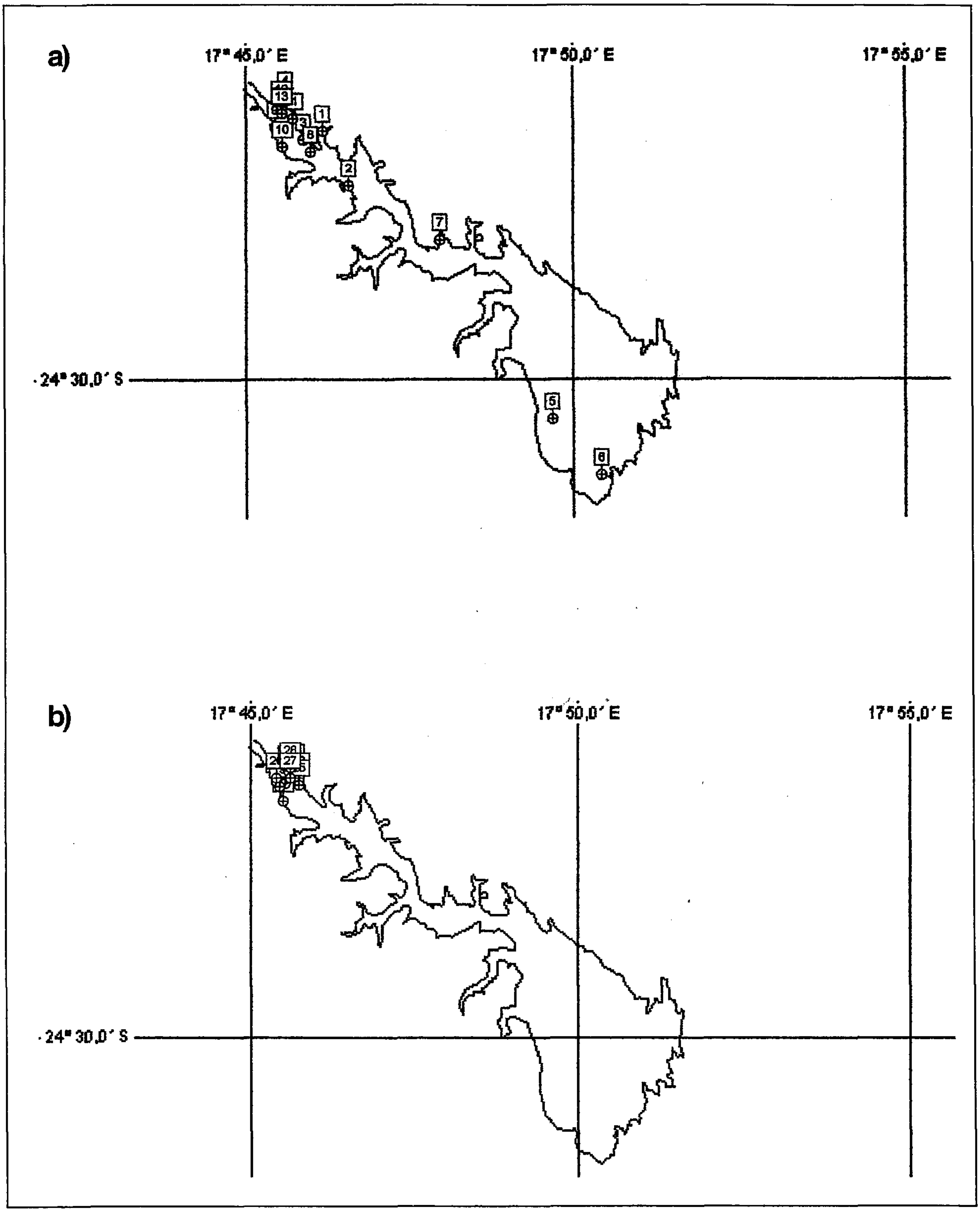


***Figure 9**. Daily locations of carp no. 10 during a) 12-25 March, and b) 27 May-9 June.*

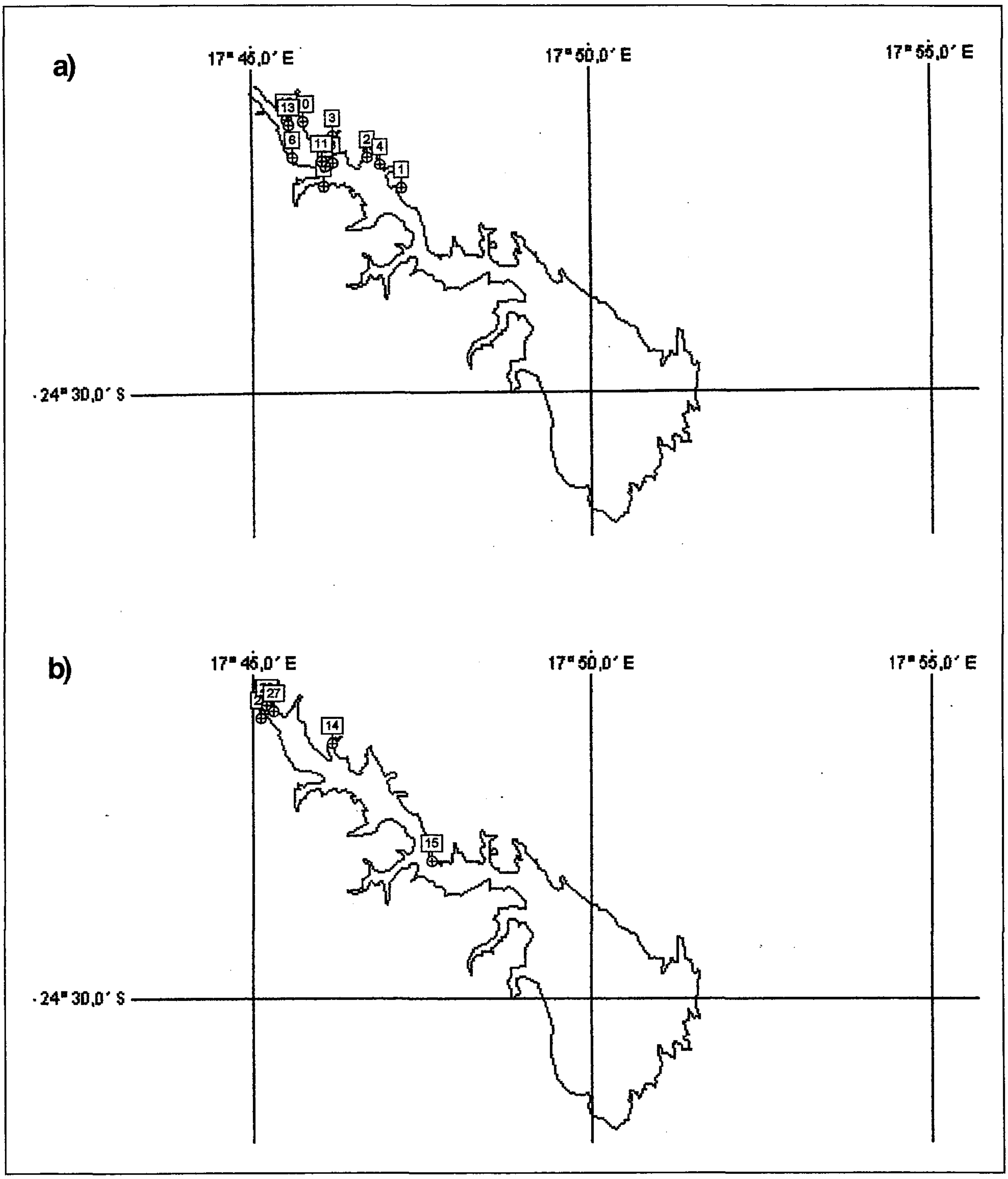


Figure 10. *Daily locations of carp no. 11 during a) 12-25 March, and b) 27 May-9 June.*

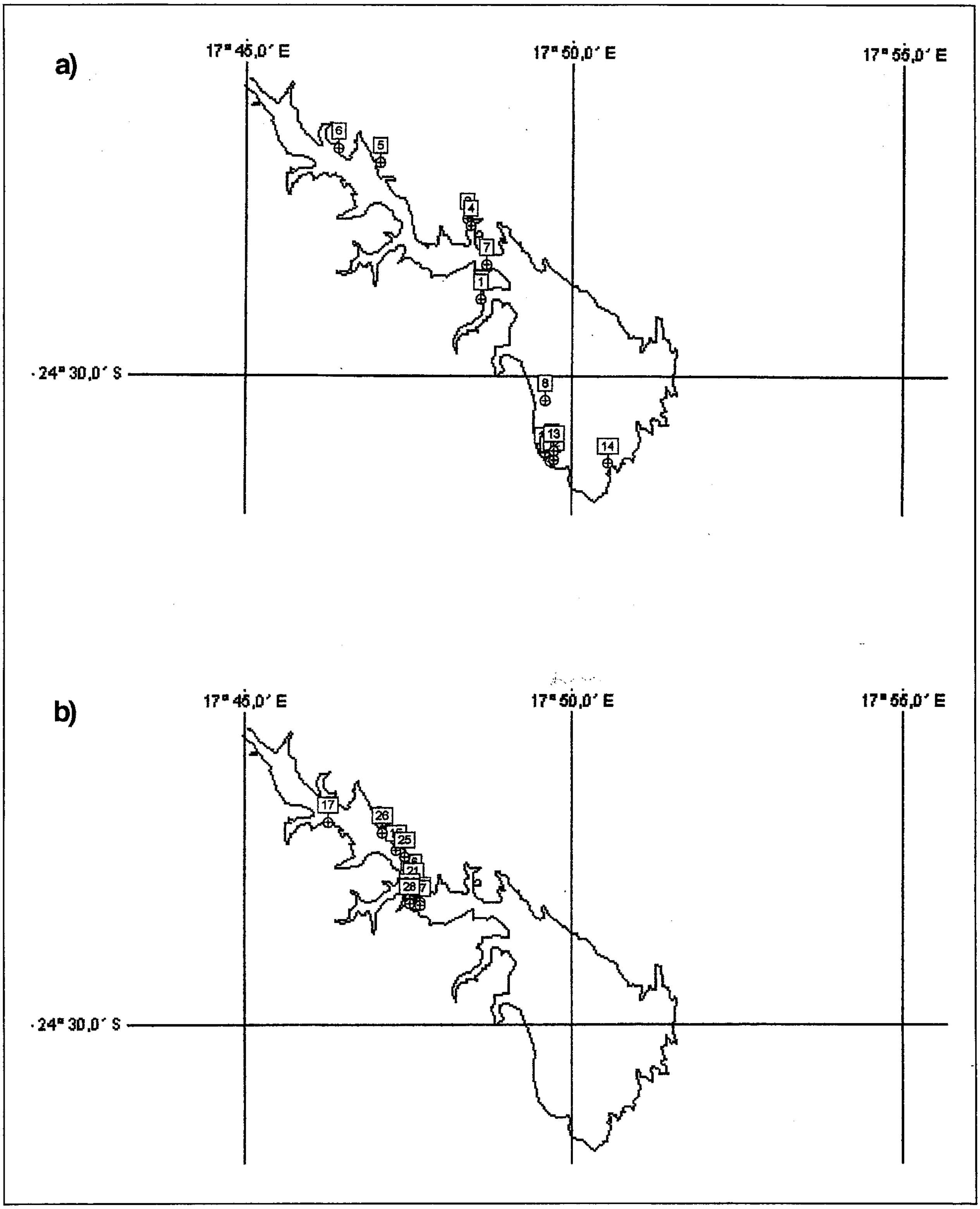


Figure 11. *Daily locations of carp no. 12 during a) 12-25 March, and b) 27 May-9 June.*

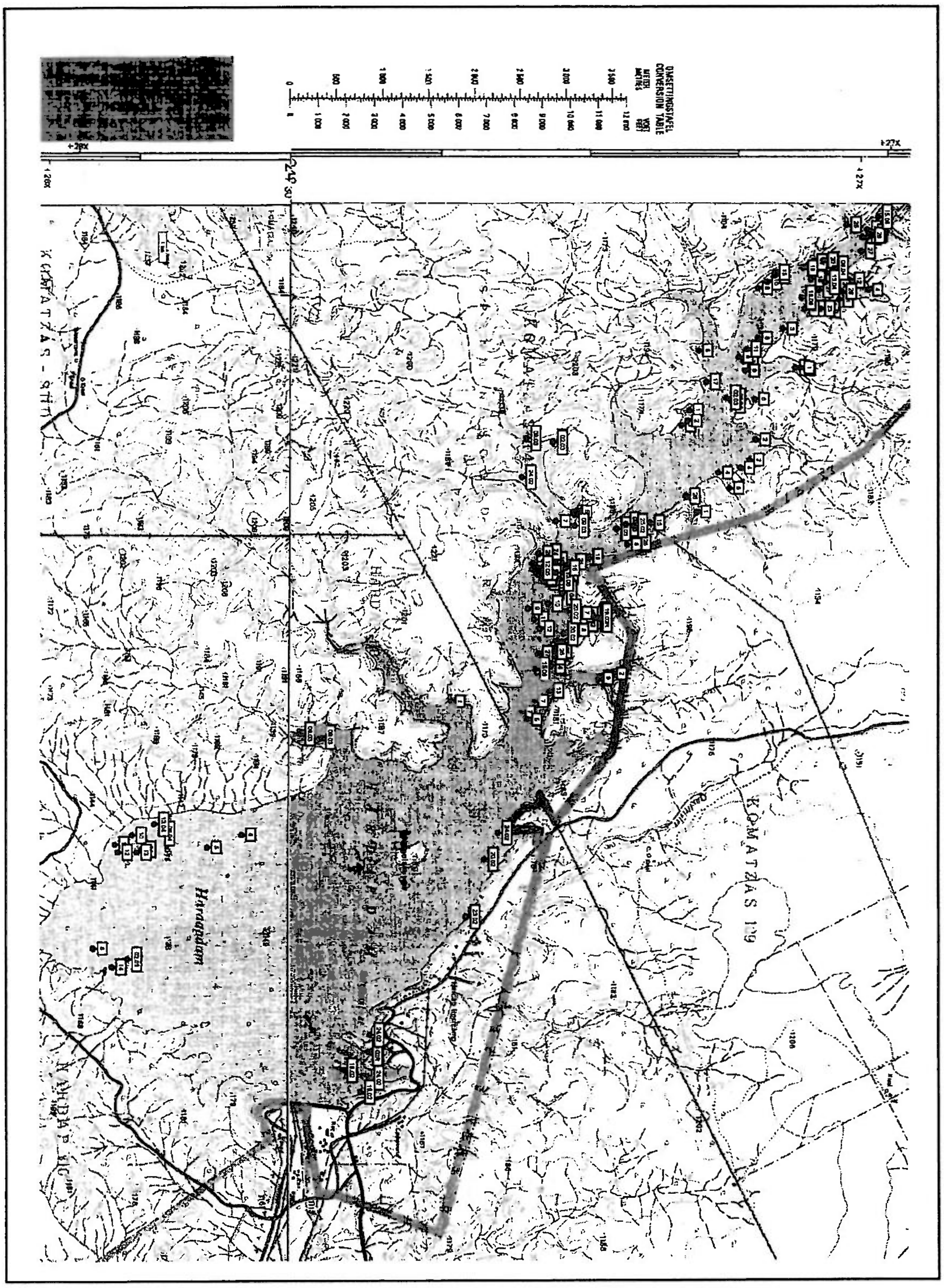
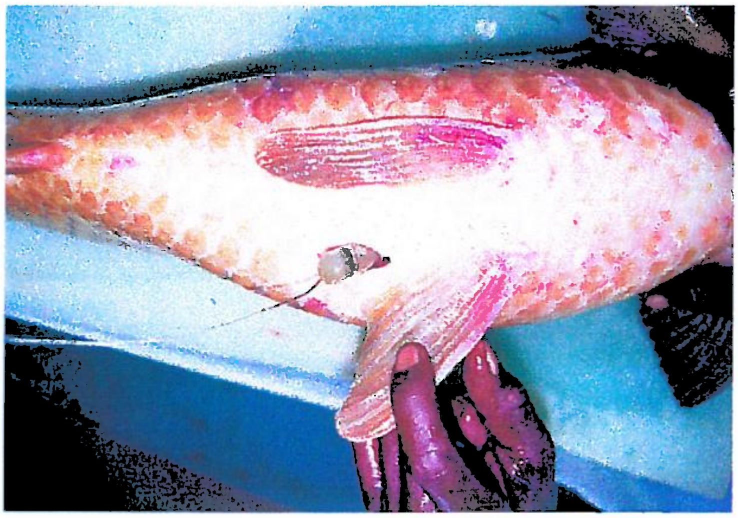


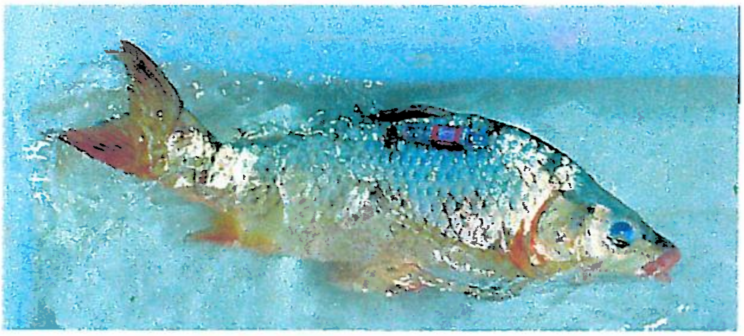
Figure 12*. All recordings of fish no. 4, 5, 10, 11 and 12 in the Hardap Reservoir during radio tracking in the period 24 February - 15 June 2000. Weekly trackings are indicated by dates and daily trackings by numbers.*

Table 4*. Total area utilised by five radio tagged carps in the Hardap Reservoir during the study period 9 March - 15 June 2000. Fish numbers correspond to fish numbers in* ***table 1****.*

Fish no.	Area utilised (km^2)
4	1.45
5	1.86
10	5.85
11	4.63
12	7.56

Photos opposite page:
Upper left and right*: Transmitter being surgically implanted into the body cavity through an incision in the ventral skin.*
Middle left*: Fish being transported by truck to the release site in the Hardap Reservoir.*
Middle right*: Fish with an externally attached transmitter.*
Lower*: Catch of the carps by drag netting.*
Photos by Finn Økland and Tor F. Næsje.




5 Discussion

5.1 Evaluation of methods

The reason why all carps with surgically implanted transmitters in this study stopped moving between 3 and 30 days after release must be that 1) they died, or 2) they expelled their transmitter. The last explanation is least likely, because the implanted transmitters were attached to internal bone structures by a permanent silk suture. Telemetry has been used to study the behaviour of carp in a few other published studies (Johnsen & Hasler 1977, Otis & Weber 1982, Gusar et al. 1989, Verrill & Berry 1995, Cooke & McKinley 1999), and neither of these reported any problems with handling and tagging carp, or with expulsion of transmitters (surgically implanted transmitters were used in all these studies, except in Gusar et al. (1989), who used externally attached transmitters). The catch and handling may have been more rough in our study than in these studies. Cooke & McKinley (1999) caught their carps by angling, whereas Otis & Weber (1982) caught them by electroshocking. However, both Verrill & Berry (1995) and Johnsen & Hasler (1977) caught the fish by seining and transported the fish over some distances, which seems to be a comparable treatment to the one in our study. Verrill & Berry (1995) also tagged carps of a similar size (50-75 cm), but used heavier transmitters (21 g in air) than ours. Johnsen & Hasler (1977) mainly tagged larger fish (58-79 cm) and used a larger transmitter (80 x 20 mm, 10 g in water). Most likely, the carps in our study were more vulnerable to treatment due to the high water temperatures. None of the above cited studies were carried out in tropical or warm temperate areas, and most of them aimed at studying carp behaviour during the winter. Presumably, water temperatures during catch, handling and tagging were considerably lower than in our study. Introduced fish species may, in general, be expected to be more vulnerable to handling and tagging stress in areas with different environmental conditions than in their natural distribution area.

We recommend from the experiences in this study that great caution should be made during catch, handling and tagging of carp, especially during high water temperatures. Angling may be a less stressful catch method than netting and imply less damage of fish mucus and skin. Nets, when used, should fish for as short time as possible to minimise handling stress, and caution should be taken to minimise injuries on the fish. Dip netting should be avoided to minimise damage of the mucus layer and skin, and the fish should rather be carried in plastic bags. If the catch can be carried out without too much stress, it may be better to tag and release the fish immediately than transporting and keeping them in tanks. If the catch is very stressful, the combined stress from catch and tagging may be too high and detrimental. In that case, it is better to ensure that the fish can recover under calm conditions in a cage or a tank between each stressor (catch, handling, tagging and transport). In this study, it may have been a better idea to let the carps recover between tagging and release instead of performing tagging, transport and release the same day.

The reason for the 100 % survival with externally attached transmitters (n = 5) and 100 % mortality or tag loss with surgically implanted transmitters (n = 15) is not known. One reason may be that the smaller fish are less vulnerable to stress than the larger fish, but this is probably not the sole explanation, because several of the fish with implanted transmitters were as small as the ones with external transmitters. The anaesthetisation procedure was the same for the two groups of fish, so it seems that the negative effects of the tagging procedure or carrying the tag was greater for surgical implantation than for external attachment. The body shape and consistency of the carps seem well suited for external tagging, and we recommend to use this tagging method for carp studies at high water temperatures or under other stressful conditions.

5.2 Movements and habitat utilisation

The carp is widespread due to extensive farming and introductions and is one of the most common freshwater fishes in the world. They are found in a variety of aquatic systems, thriving in lakes as well as rivers (e.g. Trautman 1957, Pflieger 1975, Jubb 1978, Smith 1985). It is suggested that their high adaptability is related to their variety of diet, high fecundity, fast growth and tolerance for a wide range of water quality conditions (Conklin et al. 1996). The carp has some benefit to fisheries (Sheddan 1987), but is usually considered a pest (e.g. Crivelli 1983, Meijer et al. 1990). In the Fish River in Namibia, carp was introduced by early German settlers (Schrader 1986). Only a few carps were caught during a survey in the Fish River (Hay 1991), whereas they have commonly been caught during surveys in the Hardap Reservoir (Bloemhof 1974, Schrader 1986, 1992).

In temperate areas, carp spawn in the spring and early summer, laying sticky eggs in shallow vegetation (Skelton 1993). Carps may become mature from age 3 to 5, females later than males. Minimum length at maturity for carp recorded in the Hardap Reservoir was 23 cm for males and 39 cm for females (Schrader 1986). Lengths at which 50 % of the carps were mature, was 31 cm for males and 41 cm for females (Schrader 1986). Thus, most of the radio tagged carps in this study were probably mature individuals.

It is not known when or where the carps spawn in the Fish River system. Therefore, we do not know whether the movements in the present study were related to spawning activity or not. In the Verwoerd Dam in South Africa, the carp population has two breeding peaks, one during October and one during March and April (Hamman 1981). In the Hartbeespoort Dam in South Africa, spawning takes place during November and December (Cochrane 1985a). In an Australian river system, it was found that carps did not have any spawning migrations and only had random, short movements in the river (Reynolds 1983). In contrast, carps in a Spanish reservoir left the reservoir to spawn in the stream, and the upstream spawning migration seemed to be influenced by temperature (Rodriguez-Ruiz & Granado-Lorencio 1992). According to Cochrane (1985a), carp can breed in the absence of a water influx. Length frequencies of carp in the Hardap Reservoir also indicated that they did breed in the absence of an inflow (Schrader 1986).

Movements of carp have mainly been recorded in cold areas during winter (e.g. Johnsen & Hasler 1977, Johnsen 1980, Schwartz 1987, Gusar et al. 1989, Verrill & Berry 1995, Cooke & McKinley 1999). In some lakes, carps form large aggregations during winter (Johnsen & Hasler 1977, Johnsen 1980, Schwartz 1987). In the Lake Winnebago, carps moved over a large area in summer, but concentrated in a much smaller portion of their home range most of the time (Otis & Weber 1982). The results from the present study indicate the same movement pattern for carps in the Hardap Reservoir during the study period as was reported from the Lake Winnebago.

The two carps that were intentionally displaced returned to the catch site, which is similar to the results in other studies with experimental displacement of carp (Otis & Weber 1982, Reynolds 1983, Schwartz 1987). In contrast, displaced individuals of radio tagged threespot tilapia (*Oreochromis andersonii* Castelnau, 1861) and pink happy (*Sargochromis giardi* Pellegrin, 1903) in the Zambezi River did not show homing behaviour (Økland et al. 2000).

The movements and habitat utilisation of carp are influenced by many interrelated factors, such as spawning, habitat availability, social interactions, water temperature and other seasonal factors (Otis & Weber 1982 and references therein). In the Hardap Reservoir, area utilised and average total distance moved were significantly longer for the carps during the first than during the second period with daily tracking. We suggest that this was related to the lower water temperature during the second (16-18 °C) compared to the first period (21-27 °C), even though we did not find any relationship between weekly migration distance and water temperature throughout the study period. The differences may also be connected with spawning related activities. A seasonal movement pattern for carp was also found by Otis & Weber (1982). Home ranges in their study were three times larger during summer than winter. We did not find any relationship between fish size and distances moved, but sample size in this study is small. However, our results are in accordance with other studies not finding any relationship between fish size and movement patterns or habitat utilisation (Johnsen & Hasler 1977, Grossman et al. 1987, Cooke & McKinley 1999).

Habitat preferences may be related to feeding strategies. Carps are omnivorous and consume a variety of plant and animal tissues, mainly by grubbing in sediments (Skelton, 1993). In addition to their usual bottom feeding, they are also observed feeding directly from the surface (Scott & Crossman 1998) or on pelagic zooplankton (Brabrand & Saltveit 1989). Carp are often associated with and seem to prefer submerged vegetation (Johnsen & Hasler 1977, Otis & Weber 1982, Escudero-Garcia et al. 1997). Sand, sand mixed with silt and mud-silt substrate were the most abundant substrate types utilised by carp in a river studied by Conklin et al. (1996), and they related this to the feeding strategy of probing the bottom for invertebrates. The carps in the Hardap Reservoir also mainly stayed in areas with sand, clay, mud and dead trees. Areas utilised by carps in the reservoir had depths from 1 to 25 m. However, it was not possible to record the carps during all trackings, which indicate that they stayed in the deeper areas in periods, outside the range of the receiver. Depths in areas utilised by carp seem to vary a lot, with reported depths from less than 2 m to more than 2 m to more than 60 m (e.g. Johnsen & Hasler 1977, Cochrane 1985b, Grossman et al. 1987, Hubert & O'Shea 1992).

The carps in this study were mainly recorded in the north-eastern part of the Hardap Reservoir, which was the same area as most carps were caught during a gill net survey in the reservoir (Schrader 1986). Introduced carp in a man-made reservoir in Wyoming were also more abundant in the upstream portion of the reservoir throughout the summer, and it was suggested that higher nutrient levels in the upstream end of reservoirs can lead to greater phytoplankton productivity and thereby attracting fish (Hubert & O'Shea 1992).

The carp is a highly variable and adaptable species with a wide range of movement, migration and habitat utilisation patterns, according to the above cited studies. Most studies have been carried out in the colder northern temperate areas, and many are based on mark-recapture methods or fish samplings. Information on movements, migration and habitat utilisation by carp in tropic and warm temperate areas is scarce. By using telemetry methods, individual fish can be followed to record movements, migrations and habitat utilisation for different size groups during the different seasons. Such basic information is needed for interpreting monitoring data, for the accomplishment of a sustainable management of fish resources, and for attempts to control and limit negative effects of introduced species.

6 References

Anon. 1995. White Paper on the Responsible Management of the Inland Fisheries of Namibia. - Ministry of Fisheries and Marine Resources, Directorate: Resource Management, Section. - Inland Fish, 52 pp.

Baras, E. 1991. A bibliography on underwater telemetry, 1956-1990. - Can. Tech. Rep. Fish. Aquat. Sci. 1819: 1-55.

Barnard, P. (ed.) 1998. Biological diversity in Namibia: a country study. - Namibian National Biodiversity Task Force, Windhoek, 332 pp.

Bloemhof, H.J. 1974. 'n Ondersoek na lengte, massa en ouderdom van die hengelvissoorte in Hardapdam SWA. - Finale report. Department of Nature Conservation and Tourism S.W.A. Administration, 109 pp.

Brabrand, Å. & Saltveit, S.J. 1989. Ecological aspects of the fish fauna in three Portuguese reservoirs. - Arch. Hydrobiol. 114: 575-589.

Cochrane, K.L. 1985a. The population dynamics and sustainable yield of the major fish species in Hartbeespoort Dam. - Ph.D. dissertation, University of the Wtwatersrand, South Africa.

Cochrane, K.L. 1985b. Distribution of the three major species of fish in the Hartbeespoort Dam in relation to some environmental factors. - S. Afr. J. Zool. 21: 177-182.

Conklin, D.J. Jr., Canton, S.P., Chadwick, J.W. & Miller, W.J.- 1996. Habitat suitability curves for selected fish species in the central Platte River, Nebraska. - Rivers 5: 250-266.

Cooke, S.J. & McKinley, R.S. 1999. Winter residency and activity patterns of channel catfish, *Ictalurus punctatus* (Rafinesque), and common carp, *Cyprinius carpio* L., in a thermal discharge canal. - Fish. Manage. Ecol. 6: 515-526.

Crivelli, A.J. 1983. The destruction of aquatic vegetation by carp. - Hydrobiologia 106: 37-41.

Escudero-Garcia, J.C., Garcia-Ceballos, E., Martin-Gallardo, J. & Perez-Regadera, J.J. 1997. Model for the study of the selection of environmental parameters in freshwater fish. - Pol. Arch. Hydrobiol. 44: 359-375.

Grossman, G.D., de Sostoa, A., Freeman, M.C. & Lobon-Cerviá, J. 1987. Microhabitat use in a mediterranean riverine fish assemblage. Fishes of the lower Matarraña. - Oecologia 73: 490-500.

Gusar, A.G., Barus, V., Pavlov, D.S., Gajdusek, J. & Halacka, K. 1989. The results of ultrasonic telemetry of the carp, *Cyprinius carpio*, in a wintering pond during the wintering period. - Folia Zoologica 38: 87-95.

Hamman, K.C.D. 1981. Aspekte van die visbevolkingsdinamika van die Hendrik Verwoerddam met verwysing na die ontwikkeling van 'n visserybestuursplan. - Ph.D. dissertation, Rand Afrikaans University, South Africa.

Hay, C.J. 1991. The distribution of fish in the Fish River, Namibia. - Madoqua 17: 211-215.

Hubert, W.A. & O'Shea, D.T. 1992. Use of spatial resources by fishes in Grayrocks Reservoir, Wyoming. - J. Freshw. Ecol. 2: 219-225.

Johnsen, P.B. 1980. The use of longterm ultrasonic implants for the location and harvest of schooling fish. - pp. 777-780 in Amlaner, C.J. Jr. & MacDonald, D.W., eds. A handbook on biotelemetry and radio tracking. Proceedings of an International Conference on Telemetry and Radio Tracking in Biology and Medicine Oxford, 20-22 March 1979, Pergamon Press.

Johnsen, P.B. & Hasler, A.D. 1977. Winter aggregations of carp (*Cyprinius carpio*) as revealed by ultrasonic tracking. - Trans. Am. Fish. Soc. 106: 556-559.

Jubb, R.A. 1978. The distribution of the common carp, *Cyprinus carpio* in Southern Africa. - Piscator 103: 63-65.

Meijer, M.L., de Haan, M.W., Breukelaar, A.W. & Buiteveld, H. 1990. Is reduction of the benthivorous fish an important cause of high transparency following biomanipulation in shallow lakes? - Hydrobiologia 200/201: 303-315.

Otis, K.J. & Weber, J.J. 1982. Movement of carp in the Lake Winnebago system determined by radio telemetry. - Technical Bulletin No. 134, Department of Natural Resources, Madison, Wisconsin, 16 pp.

Pflieger, W.L. 1975. The fishes of Missouri. - Springfield: Missouri Department of Conservation.

Reynolds, L.F. 1983. Migration patterns of five fish species in the Murray-Darling River system. - Aust. J. Mar. Freshw. Res. 34: 857-871.

Roderiguez-Ruiz, A. & Granado-Lorencio, C. 1992. Spawning period and migration of three species of cyprinids in a stream with Mediterranean regimen (SW Spain). - J. Fish Biol. 41: 545-556.

Sandlund, O.T. & Tvedten, I. 1992. Pre-feasibility study on Namibian freshwater fish management. - Norwegian Institute for Nature Research (NINA) Report, 46 pp.

Schrader, H.J. 1986. 'n Ondersoek na die potensiële maksimale, volgehoue visopbrengs in Hardapdam en die moontlike invloed van kommersiële ontginning op hengel en visvretende watervoëls. - M. Sc. Thesis, Rand Afrikaans University, South Africa, 134 pp.

Schrader, H.J. 1992. Die visbevolkingsdinamika in vier staatsopgaardamme in Namibië met verwysing na Watervoëlspredasie, kommersiële ontginning en hengeltoestande. - Dr. Thesis, Rand Afrikaans University, South Africa, 345 pp.

Schwartz, F.J. 1987. Homing behaviour of tagged and displaced carp, *Cyprinus carpio*, in Pymatuning Lake, Pennsylvania/Ohio. - Ohio J. Sci. 87: 15-22.

Scott, W.B. & Crossman, E.J. 1998. Freshwater fishes of Canada. - Galt House Publications LTD, Oakville, Ontario, Canada, 966 pp.

Sheddan, T.L. 1987. Promoting carp. - pp. 69-81 in Cooper, E.L., ed. Carp in North America. American Fisheries Society, Bethesda, Maryland.

Skelton, P. 1993. A complete guide to the freshwater fishes of Southern Africa. - Southern Book Publishers (Pty) Ltd, Halfway House, South Africa, 388 pp.

Smith, C.L. 1985. The inland fishes of New York State. - Albany: The New York Department of Environmental Conservation.

Trautman, M.B. 1957. The fishes of Ohio. – Columbus: The Ohio State University Press.

Verrill, D.D. & Berry, C.R. Jr. 1995. Effectiveness of an electrical barrier and lake drawdown for reducing common carp and bigmouth buffalo abundances. – N. Am. J. Fish. Man. 15: 137-141.

Økland, F., Hay, C.J., Næsje, T.F. & Thorstad, E. 2000. Movements and habitat utilisation of cichlids in the Zambezi River, Namibia. A radio telemetry study in 1999-2000. - NINA•NIKU Project Report no. 011: 1-25.