# Movements and habitat utilisation of cichlids in the Zambezi River, Namibia

## A radio telemetry study in 1999-2000

F. Økland, C.J. Hay, T.F. Næsje and E. Thorstad

NINA•NIKU Project Report no. 011

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# Abstract

Økland, F., Hay, C.J., Næsje, T.F. & Thorstad, E.B. 2000. Movements and habitat utilisation of cichlids in the Zambezi River, Namibia. A radio telemetry study in 1999-2000. – NINA•NIKU Project Report 011: 1-18.

In October 1999, a pilot study tagging 16 cichlids (30.5-51.0 cm) with radio transmitters was conducted in the Zambezi River near Kalimbeza Island (eight threespot tilapia *Oreochromis andersonii* Castelnau, 1861, seven pink happy *Sargochromis giardi* Pellegrin, 1903, and one humpback largemouth *Serranochromis altus* Winemiller & Kelso Winemiller, 1990). The fish were caught on rod and line, anaesthetised and tagged with external (n = 12) and implantable (n = 4) transmitters before being released into the river. Range tests showed that the main river could be controlled by boat tracking. The range of transmitters lowered to the bottom (2 m depth) was close to 1 km. The tagged fish were positioned by manual trackings until 1 March 2000, and the study covered the period of increasing water flow towards the rainy period and flooding. Nine of the tagged fish showed a downriver movement immediately after release, believed to be a behavioural reaction to catch, handling and tagging. Eleven fish were released 350 to 1000 m from the catch site. Only one (9%) was recorded later at the catch site, indicating that displaced individuals of threespot tilapia and pink happy do not show homing behaviour to the catch site. Five fish were released at the catch site, and four of these (80%) were recorded later at the catch site. Average total distance moved from 11 October (four days after tagging of the last fish) to 1 March was 375 m (range = 1-1150) for threespot tilapia and 1276 m (range = 540-1990) for pink happy. Total distance moved was significantly longer for pink happy than for threespot tilapia. The farthest position compared to the position held on 11 October was on average 220 m away (range = 0-500) for threespot tilapia and 538 m (range = 20-1500) for pink happy. The threespot tilapia were located in the main river on average 67%, backwaters 13% and mouth of backwaters 20% of the trackings. The pink happy were located in the main river on average 71%, backwaters 25% and mouth of backwaters during 4% of the trackings. It is recommended to continue the work on describing the seasonal movements, migration and habitat utilisation of important fish species in the Zambezi River, and to investigate the effects of variations in water level on migration and habitat utilisation. This basic information is needed for solving the transboundary management issues for the Zambezi River fish populations.

Key-words: *Oreochromis andersonii* - *Sargochromis giardi* - *Serranochromis altus* - threespot tilapia - pink happy - humpback largemouth - habitat utilisation

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# Contents



# Preface

The telemetry project in the Zambezi River is 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 assess if and how telemetry can be used to follow the movements of larger cichlids in the upper Zambezi River, and to study the movements and habitat preference of larger cichlids during a period of increasing water flow towards the rainy period. The study was financed by MFMR, NINA and the Norwegian Agency for Development Cooperation (NORAD). We thank Rolly Thompson for extensive help during catch and tagging of the fish and for carrying out all the tracking. We also thank Johannes May and Jerome Engelbreckt at the Freshwater Fish Institute, Mariental, for assistance during the fieldwork. Lorraine Fleming provided assistance with the English.

Windhoek and Trondheim, October 2000

Clinton J. Hay
project leader, MFMR

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project leader, NINA

# 1 Introduction

Inland fisheries in Africa are of great importance in creating jobs and providing protein-rich food. About 50% of the population in Namibia live near the northern perennial rivers (Anon. 1995). At least 100 000 people derive part of their food, income and informal employment from the inland fish resource (Anon. 1995). The northern river systems in Namibia border on Angola, Zambia and Botswana, where a number of people also live near the rivers and are dependent on the fish recourses. Inland fisheries are often seasonal and often combined with other activities (Sandlund & Tvedten 1992). This diverse activity of inland fishermen tends to reduce the pressure on fish stocks (Sandlund & Tvedten 1992). However, a major concern has been the possible depletion of the fish resource in the Okavango and Zambezi Rivers as a result of increased subsistence fishing due to the high population growth (Tvedten *et al.* 1994, Hay *et al.* 1996). Several other factors may also indirectly influence the fish stock, such as the effects of overgrazing, soil erosion, deforestation, siltation of the rivers, pollution and low floods (Tvedten *et al.* 1994). Declining fish stocks have brought about the need to review and improve legislation to protect the environment (Sandlund & Tvedten 1992).

The Kwando-Linyanti and Zambezi-Chobe river systems in northern Namibia have gentle gradients with extensive seasonal floodplains, backwaters and seasonal and permanent swamps. In times of exceptional flooding, the systems are inter-linked, and large parts of the eastern Caprivi area become one large flood plain (Curtis *et al.* 1998). The Caprivi wetlands have the highest overall species richness of Namibian wetland systems, and 82 fish species occur in the Namibian part of this river complex (Curtis *et al.* 1998). The floodplain ecosystems are complex and variable. With increasing water levels during and after the rains, the water-covered areas increase tremendously, and the behaviour of the fish changes accordingly. The high number of species present in these systems represents a unique natural resource, not only as protein for the local people and attractive trophy fishing for fishing lodges, but for the whole wildlife and biodiversity in this region. There is, therefore, an urgent need to regulate the fishing so this resource can be harvested sustainably.

Most Namibian fish species (78%) are floodplain-dependent for larval and juvenile stages and dependent on migration between floodplains and the main river (Barnard 1998). A sustainable fishery depends on a better understanding of the migration between the main river and the flood plains. In the Zambezi River, we still have the possibility to carry out the research required to implement and adjust management regulations before this complex ecosystem is significantly changed by over-utilisation of the fishing resources. This system, therefore, represents a unique possibility to study the natural fish migration, habitat preferences and life history, which is knowledge essential for developing legislation to secure a sustainable management of these valuable resources.

Cichlids are important species for both subsistence and trophy fishing. However, little is known about their behaviour and habitat utilisation in flood plain rivers. Telemetry represents the only available method to follow individual movements of fish over longer periods and has been used extensively in this type of investigation during the last decades (Baras 1991). Optimal 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 ranges and establish tracking procedures). The main objectives in this pilot study were to 1) assess if and how telemetry can be used to follow the movements of larger cichlids in the upper Zambezi River, and 2) study the movements and habitat preference of larger cichlids during a period of increasing water flow towards the rainy period.

# 2 Study site

The Caprivi Region in Namibia is situated about halfway between the equator and the southern tip of the continent, and midway between the Atlantic and the Indian Ocean (**figure 1**). The region borders on Botswana in the south, Angola and Zambia in the north and Zimbabwe in the east. The Okavango River forms the border to Angola, the Chobe River forms the border to Botswana and the Zambezi River forms the border to Zambia. Compared to the rest of Namibia, the Caprivi Region has a high rainfall (760 mm per year). It is a flat area, approximately 1000 m above sea level. Seasonal flooding creates extensive floodplains, especially in East Caprivi, where almost 30% of the area can be flooded.

The source of the Zambezi is the Kalene Hills in northwestern Zambia. After a short distance through Angola, the river re-enters Zambia and meanders through the Barotse plains. The Zambezi River forms the border between Zambia and Namibia from Katima Mulilo to Impalila Island, a distance of approximately 120 km. Impalila Island is at the confluence between Zambezi and the Chobe River, which enters from the west. A few kilometres into Zimbabwe lie the Victoria Falls, separating the fish populations upstream from those living further downstream. The annual variation in water level is up to 7 m, creating large floodplains. Until 1990, the fishing pressure in this section of the Zambezi River was relatively low. However, fishing seems to have increased in the 1990s. Reports of reduced catches, especially of larger breams, is a major concern (Anon. 1995). The six most common species caught are the threespot tilapia (*Oreochromis andersonii* Castelnau, 1861, 21%), catfish (*Clarias gariepinus* Burchell, 1822, and *C. ngamensis* Castelnau, 1861, 17%), greenhead tilapia (*O. macrochir* Boulenger, 1912, 16%), redbreast tilapia (*Tilapia rendalli*, Boulenger, 1896, 15%), tigerfish (*Hydrocynus vittatus*, Castelnau, 1861, 10%) and African pike (*Hepsetus odoe*, Bloch, 1794, 6%) (Anon. 1995). A total of 81 fish species occur in the Zambezi system (Anon. 1995).

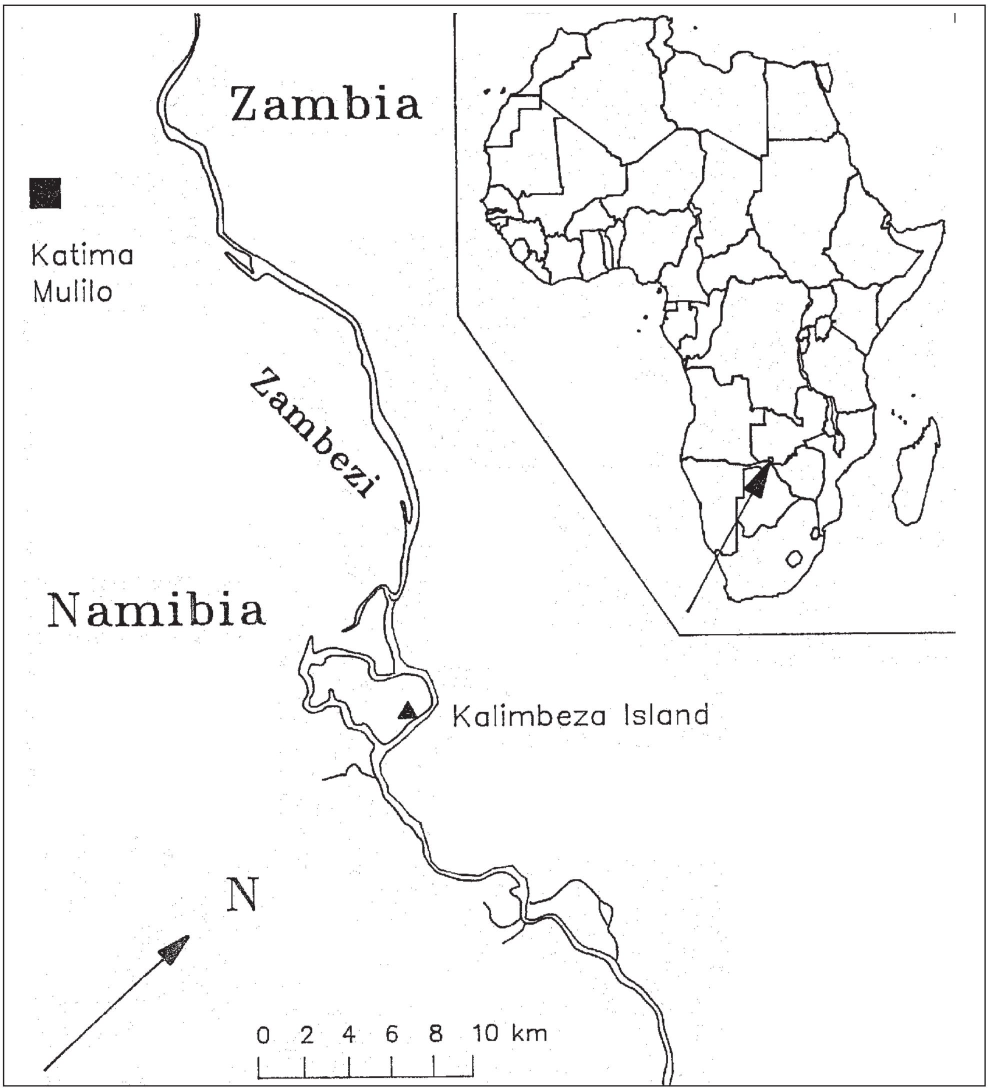



***Figure 1***
*The upper part of the Zambezi River in north-eastern Namibia. The solid triangle shows the site where fish were caught, radio-tagged and released at Kalimbeza Island during 5-7 October 1999.*

# 3 Materials and methods

## 3.1 Radio telemetry equipment

The fish were tracked by use of implantable or externally attached radio transmitters from Advanced Telemetry Systems Inc. (ATS, USA, **table 1**). Transmitter weight in water was less than 5 g, or less than 1% of the body weight of the experimental animals. The transmitters emitted signals within the 142.120-142.432 MHz band, and transmitter frequencies were spaced at least 10 kHz apart. A portable receiver (R2100, ATS) connected to a 4 element Yagi antenna detected the transmitted radio signals. Trackings were carried out by boat.

## 3.2 Range test

A range test was conducted in the channel outside Kalimbeza Island. Transmitters were attached to a rope and lowered to 1.0 m, 1.5 m and 2.0 m depth (bottom). The signal strength from the test transmitters was -127 dB.

## 3.3 Catch and tagging

Eight threespot tilapia, seven pink happy (*Sargochromis giardi* Pellegrin, 1903) and one humpback largemouth (*Serranochromis altus* Winemiller & Kelso Winemiller, 1990) were caught at Kalimbeza Island during 5 - 7 October 1999 (**table 1**, **figure 1**). The fish were caught on rod and line and brought quickly to shore and placed directly into the anaesthetisation bath (5 mg $l^{-1}$ Metomidate, Marinil™, Wildlife Labs., Inc., Fort Collins, Colorado, USA.).

Four fish had the transmitter surgically implanted into the body cavity (**table 1, figure 2**). 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 $l^{-1}$) 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. 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 three independent permanent silk sutures (2/0 Ethicon). Surgery time was approximately 4-6 min. Towards the end of the surgery, the gills were flushed with fresh oxygenated water to reduce the recovery period.

***Table 1.*** *Radio tagged fish in the Zambezi River, Namibia, during 5 - 7 October 1999. Species: 1 = threespot tilapia, 2 = pink happy and 3 = humpback largemouth. Sex: 1 = male, 2 = female. Release site is given as distance from catch site.*

| **Fish no.** | **Date** | **Species** | **Sex** | **Length** (cm) | **Weight** (g) | **Transmitter attachment** | **Transmitter size** (L x W x H) | **Release site** | **Number of positionings from 11 October** | **Tracking period** (days) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 Oct | 1 | 1 | 39.5 | 1246 | external | 50x18x9 | -500 | 31 | 120 |
| 2 | 5 Oct | 1 | 2 | 31.0 | 630 | external | 38x18x9 | -500 | 31 | 120 |
| 3 | 6 Oct | 1 | 2 | 35.5 | 750 | external | 53x18x9 | -1000 | 31 | 120 |
| 4 | 6 Oct | 1 | 2 | 31.0 | 660 | external | 38x18x9 | -1000 | 25 | 120 |
| 5 | 6 Oct | 2 | 1 | 43.0 | 2000 | external | 53x18x8 | 0 | 0 | 3 |
| 6 | 6 Oct | 2 | ? | 32.0 | 906 | external | 38x18x9 | -500 | 27 | 120 |
| 7 | 6 Oct | 3 | 1 | 41.0 | | external | 57x18x10 | -500 | 18 | 120 |
| 8 | 6 Oct | 1 | 1 | 37.0 | | external | 53x18x8 | 350 | 23 | 120 |
| 9 | 6 Oct | 2 | 1 | 34.0 | | external | 38x18x9 | -500 | 30 | 120 |
| 10 | 6 Oct | 2 | 1 | 27.0 | | external | 48x18x8 | -1000 | 1 | 5 |
| 11 | 6 Oct | 1 | 1 | 46.0 | | external | 53x18x8 | 350 | 24 | 120 |
| 12 | 6 Oct | 2 | 1 | 31.5 | | external | 50x18x8 | -1000 | 6 | 15 |
| 13 | 7 Oct | 2 | 1 | 30.5 | 599 | implant | 50x10* | 0 | 27 | 110 |
| 14 | 7 Oct | 1 | 1 | 44.0 | 1300 | implant | 50x10* | 0 | 6 | 12 |
| 15 | 7 Oct | 2 | 1 | 34.0 | | implant | 50x10* | 0 | 27 | 115 |
| 16 | 7 Oct | 1 | 1 | 51.0 | | implant | 50x10* | 0 | 1 | 3 |

*circular transmitters, size given as D x L.

Twelve fish had the transmitter externally attached (**table 1, figure 2**). Anaesthetisation procedures were the same as for surgical implantation. The transmitter was attached to the fish below the dorsal fin with 0.5 mm steel wires inserted horizontally through the upper part of the musculature. The procedure lasted about 2 min.

After the transmitters were attached, the length, weight and sex were recorded before the fish were placed in a container with fresh water for recovery (2-5 min). Three fish (no. 4, 5 and 15) needed extra time for recovery and were placed in a keep-net and released after 1 to 2 hours. Five fish (two threespot tilapia and three pink happy) were released at the catch site (**table 1**). The remaining fish were released from 1000 m downstream to 350 m upstream of the catch site (**table 1**). The water temperatures in the river were 23.0-24.0 °C during catch and tagging. The anaesthetisation bath was changed when the temperature reached 28 °C.

Reduced activity levels were found during the first 12-24 hours after anaesthetisation and radio tagging of tilapia (*Oreochromis aureus* Steindachner, 1864) in a study of tagging effects (Thoreau & Baras 1997). They suggested that the tilapia need three to four days to completely compensate for the negative buoyancy resulting from anaesthesia and tagging (Thoreau & Baras 1997). To ensure that movements due to handling and tagging effects were not included in the statistical analyses, only results from 11 October (four days after the last fish was released) were included. This implies that 8 threespot tilapia and 6 pink happy were included in the habitat analyses (**table 1**). Two fish were tracked for the last time on 11 October, which implies that 7 threespot tilapia and 5 pink happy were included in analyses of movements (**table 1**)

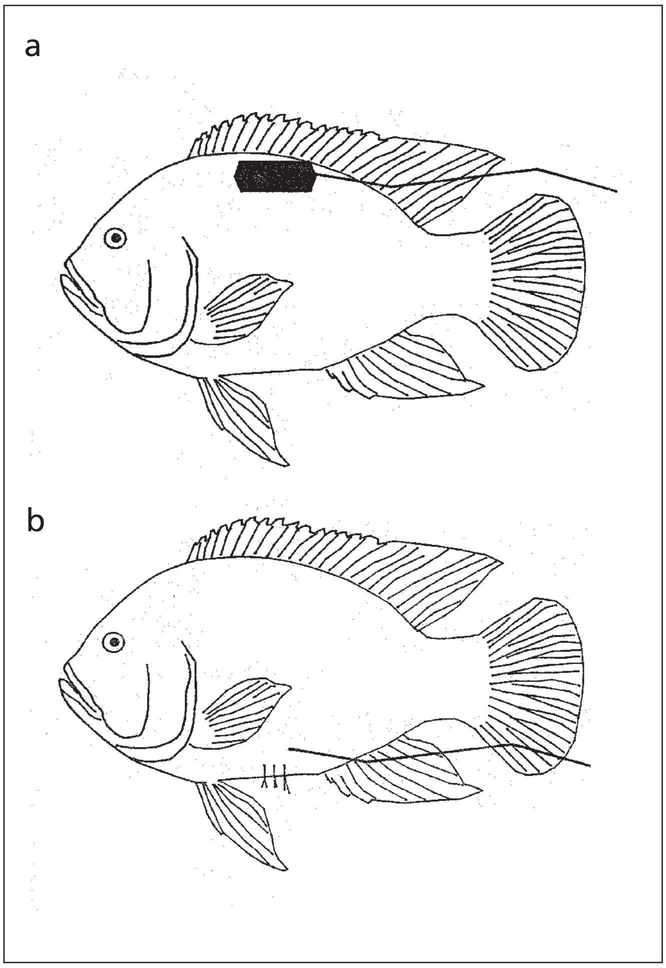



***Figure 2***
*Radio tagged pink happy a) with an externally attached radio transmitter, and b) with a transmitter surgically implanted into the body cavity, where three sutures and the trailing antenna are visible externally.*

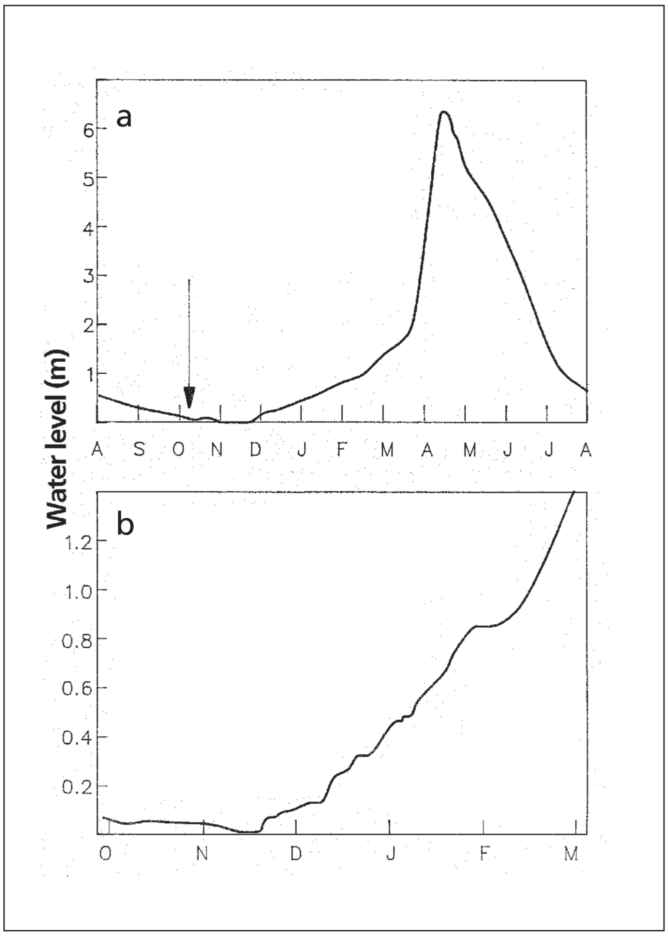



***Figure 3***
*a) The water level in the Zambezi River from August 1999 to August 2000. The arrow indicates the date of release of radio tagged fish in October 1999.*
*b) The water level in the Zambezi River during the period from when the radio tagged fish were released (5-7 October 1999) until the end of the tracking period (1 March 2000).*

## 3.4 Tracking

The fish were tracked daily to every third day until 22 October 1999. Then the fish were tracked daily to every eleventh day until 1 March 2000. In total, 39 tracking surveys were carried out, and the fish were tracked on average every fourth day. The fish were located with a precision of ± 10 m in the main river. Some of the backwaters were impossible to enter by boat, and the location had to be given based on the direction and signal strength. Some of the fish disappeared in periods. No areas of deep water existed, and it is likely that these fish had entered into backwaters where tracking was difficult. Since tracking is more efficient in the main river, the proportion of locations in the backwaters will be underestimated. When fish were stationary, the precision of the trackings was increased to ensure that the fish were moving and alive.

## 3.5 Water level

The water level was near its lowest when the fish were caught, tagged and released during 5-7 October (**figure 3**). During the following weeks, until the end of November, the water level was low and fairly stable. The water level started to rise 20 November 1999 and continued rising for the rest of the tracking period (**figure 3**).

# 4 Results

## 4.1 Range test

From 2.0 m depth, signals could be detected 700 - 800 m away, and from 1.5 m depth, signals could be detected 900 - 1100 m away. From 1.0 m depth, signals were still strong 1100 m away, the longest distance possible to record at that location.

## 4.2 Movements of the fish

Eleven of the 16 tagged fish were followed for 4 or 5 months, until the transmitters ran out of battery power. High precision trackings showed that all fish were alive as long as they were tracked. No transmitter-loss was recorded. At least three of the five fish that disappeared early in the tracking period were most likely caught in the local fishery. The transmitter attached to fish no. 10 was located inside a hut in a fishing village in Zambia. Fish no. 5 and 12 were located near a local net fishery before they disappeared.

Immediately after release, six of the eight threespot tilapia moved downriver (**figure 4**), whereas three of the seven pink happy showed a similar movement pattern (**figure 5**). The humpback largemouth also moved downriver immediately after release (**figure 6**). The length of this downriver displacement varied between small adjustments of less than 100 m up to 10 km (**figures 4, 5 and 6**). The downriver movements stopped after a few days. Two pink happy moved directly upriver after release (**figure 5**), and one threespot tilapia moved upriver the second day after release (**figure 4**). The remaining fish stayed in the release area in the days after tagging (**figures 4 and 5**).

From 11 October, only small movements were recorded for the threespot tilapia that could be followed (**figure 4**). A similar movement pattern was recorded for the pink happy (**figure 5**). The humpback largemouth was also recorded in the same area of the main river when found (**figure 6**). However, during the tracking period the humpback largemouth disappeared frequently. Since areas of deep water did not exist, it is likely that it had entered into backwaters where tracking was difficult. Average total distance moved from 11 October to 1 March was 375 m (range = 1-1150, SE = 142) for threespot tilapia and 1276 m (range = 540-1990, SE = 240) for pink happy. Total distance moved was longer for pink happy than for threespot tilapia (Mann-Whitney U-test, U = 2.0, P = 0.012). The farthest position recorded compared to the position held at 11 October was on average 220 m away (range = 0-500, SE = 90) for threespot tilapia and 538 m away (range = 20-1500, SE = 273) for pink happy, which was not different between the two

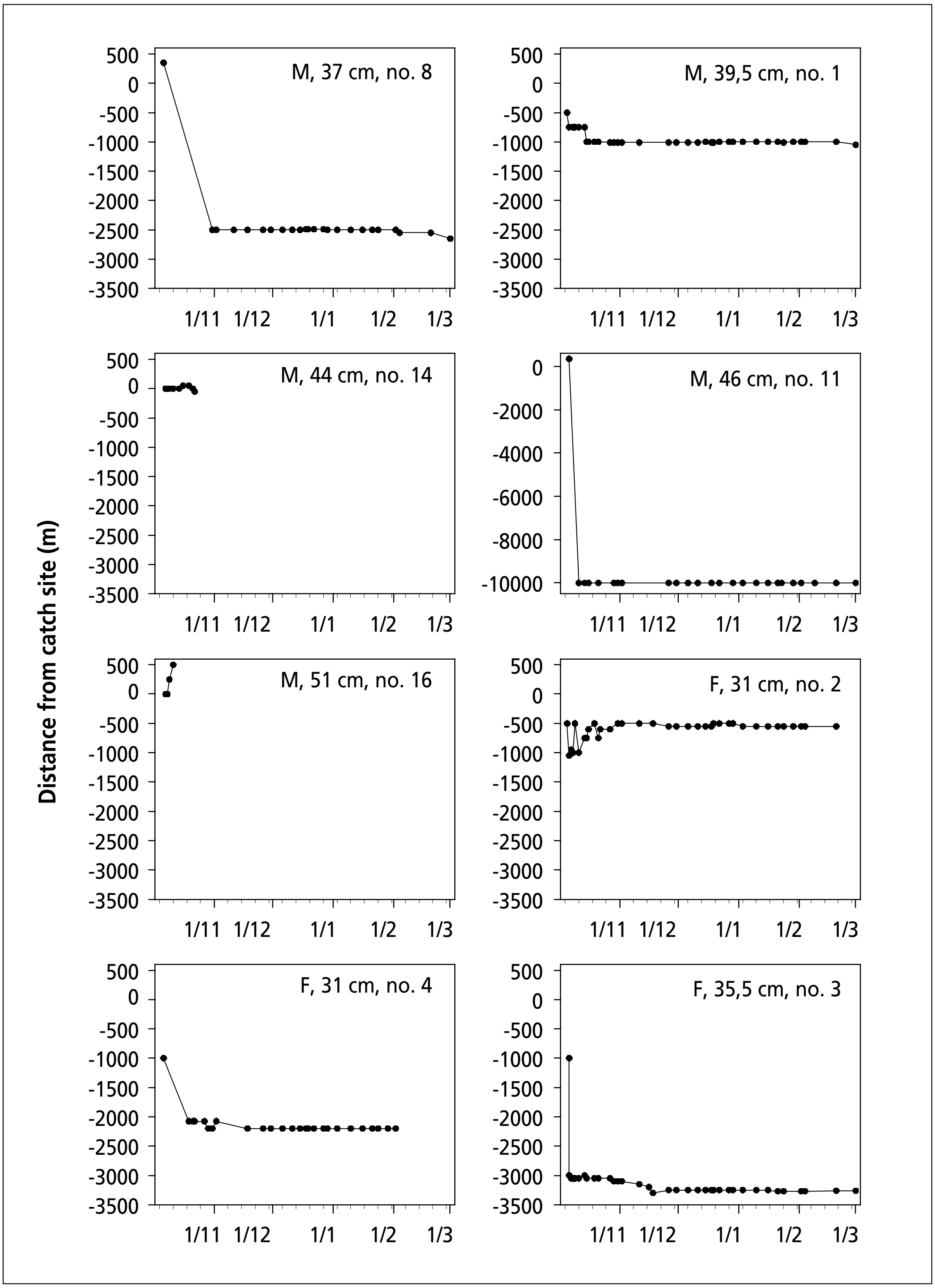



***Figure 4***

*Movements of radio tagged threespot tilapia near Kalimbeza Island in the Zambezi River in 1999-2000. Individual fish numbers correspond to the numbers given in **table 1**. Fish length and sex (F = female, M = male) are given for individual fish.*

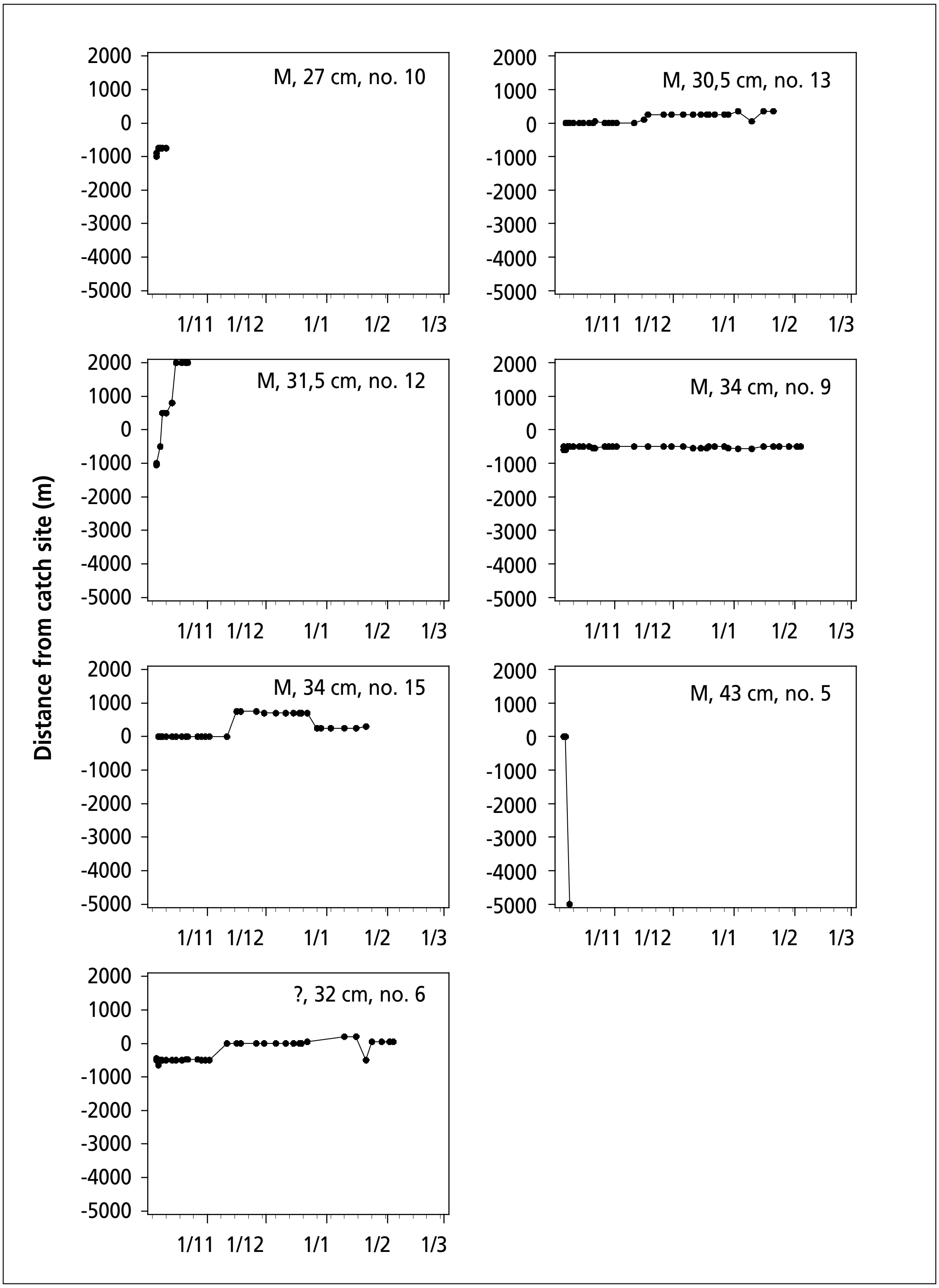



***Figure 5***

*Movements of radio tagged pink happy near Kalimbeza Island in the Zambezi River in 1999-2000. Individual fish numbers correspond to the numbers given in* ***table 1****. Fish length and sex (F = female, M = male) are given for individual fish.*

species (Mann-Whitney U-test, U = 8.0, P = 0.35). Average number of movements shorter than 200 m was 4.8 (range = 0-9, SE = 1.1) for threespot tilapia and 2.8 (range = 0-7, SE = 1.1) for pink happy from 11 October to 1 March. Average number of movements longer than 200 m was 0.5 (range = 0-2, SE = 0.3) for threespot tilapia and 1.7 (range = 0-4, SE = 0.6) for pink happy. There were no differences in number of movements shorter or longer than 200 m between the two species (Mann-Whitney U-tests, < 200 m: U = 15.0, P = 0.28; > 200 m: U = 12.5, P = 0.14).

Of the five fish released at the catch site (**table 1**), four fish (80%) were later recorded at the catch site (**figure 4 and 5**). Of the 11 fish released 350-1000 m from the catch site (**table 1**), only one (9%) was later recorded at the catch site (**figure 5**).

## 4.3 Habitat utilisation

The threespot tilapia were located in the main river on average 67%, backwaters 13% and mouth of backwaters 20% of the trackings (**figure 7**). Five individuals were only or most frequently located in the main river, two in the mouth of backwaters and one in backwaters (**figure 8**). The pink happy were located in the main river on average 71%, backwaters 25% and mouth of backwaters 4% of the trackings (**figure 7**). Five pink happy were only or most frequently located in the main river, and one in backwaters (**figure 9**). The humpback largemouth was only located in the main river, but was frequently impossible to record (**figure 10**).

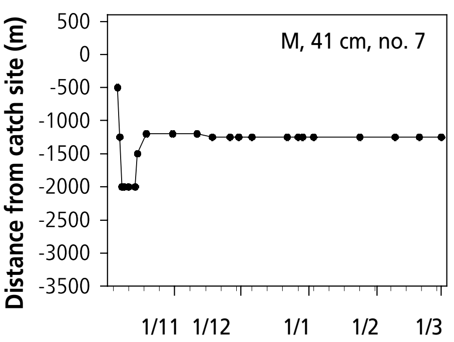



*Figure 6*
*Movements of a radio tagged humpback largemouth near Kalimbeza Island in the Zambezi River in 1999-2000. Individual fish number corresponds to the number given in **table 1**. Fish length and sex (M = male) are given.*

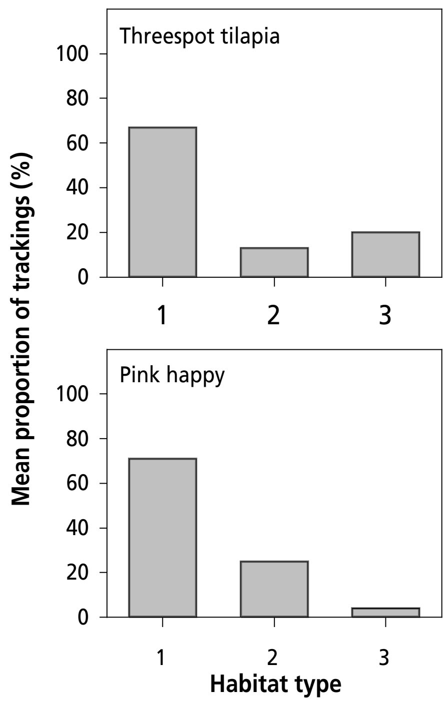



*Figure 7*
*Habitat utilisation for threespot tilapia (n = 8) and pink happy (n = 6) radio tagged near Kalimbeza Island in the Zambezi River in 1999-2000. Habitat type: 1 = main river, 2 = backwater, and 3 = mouth of backwater.*

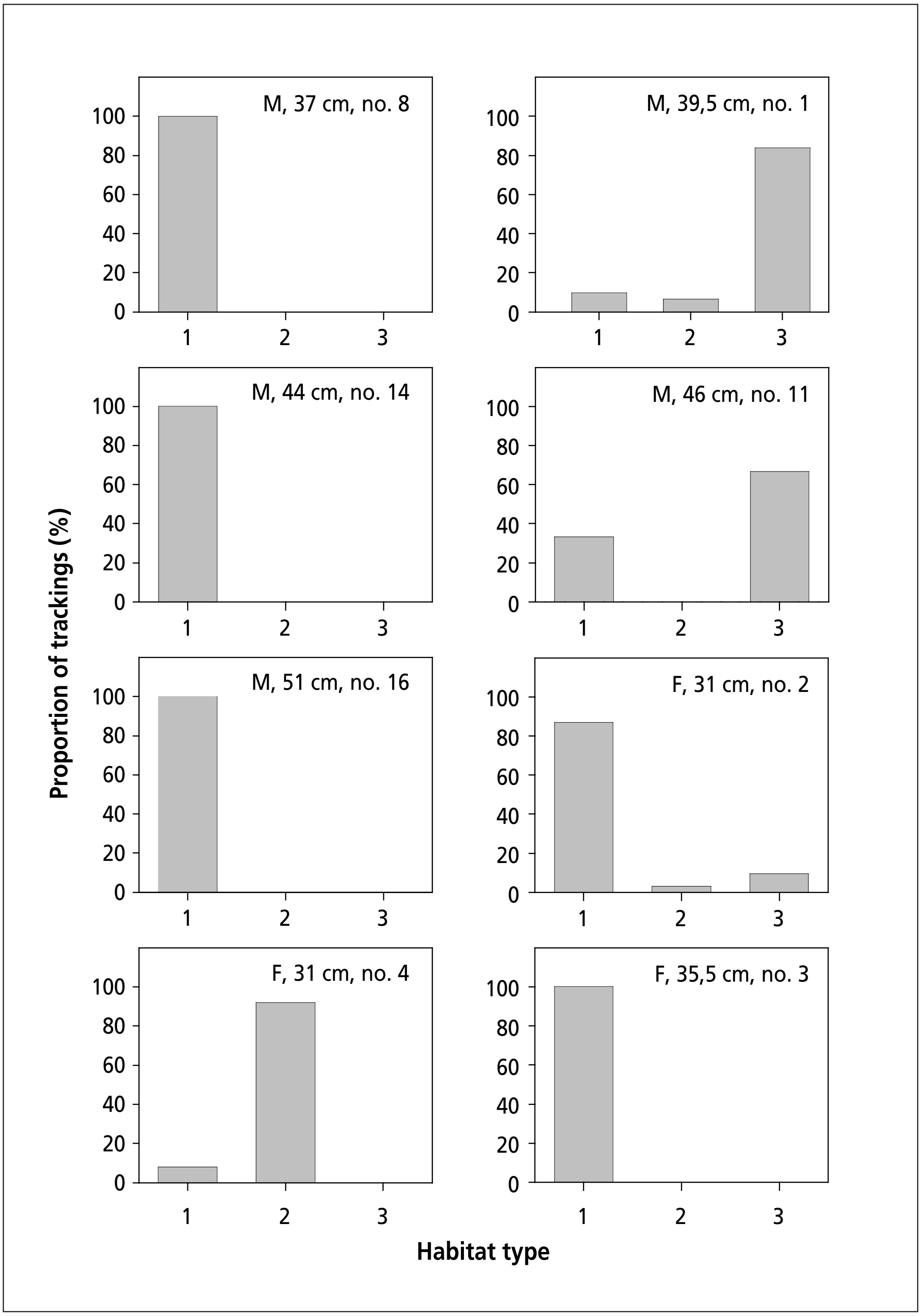



***Figure 8***
*Habitat utilisation for individual threespot tilapia radio tagged near Kalimbeza Island in the Zambezi River in 1999-2000. Habitat type: 1 = main river, 2 = backwater, and 3 = mouth of backwater. Individual fish numbers correspond to the numbers given in **table 1**. Fish length and sex (F = female, M = male) also are given.*

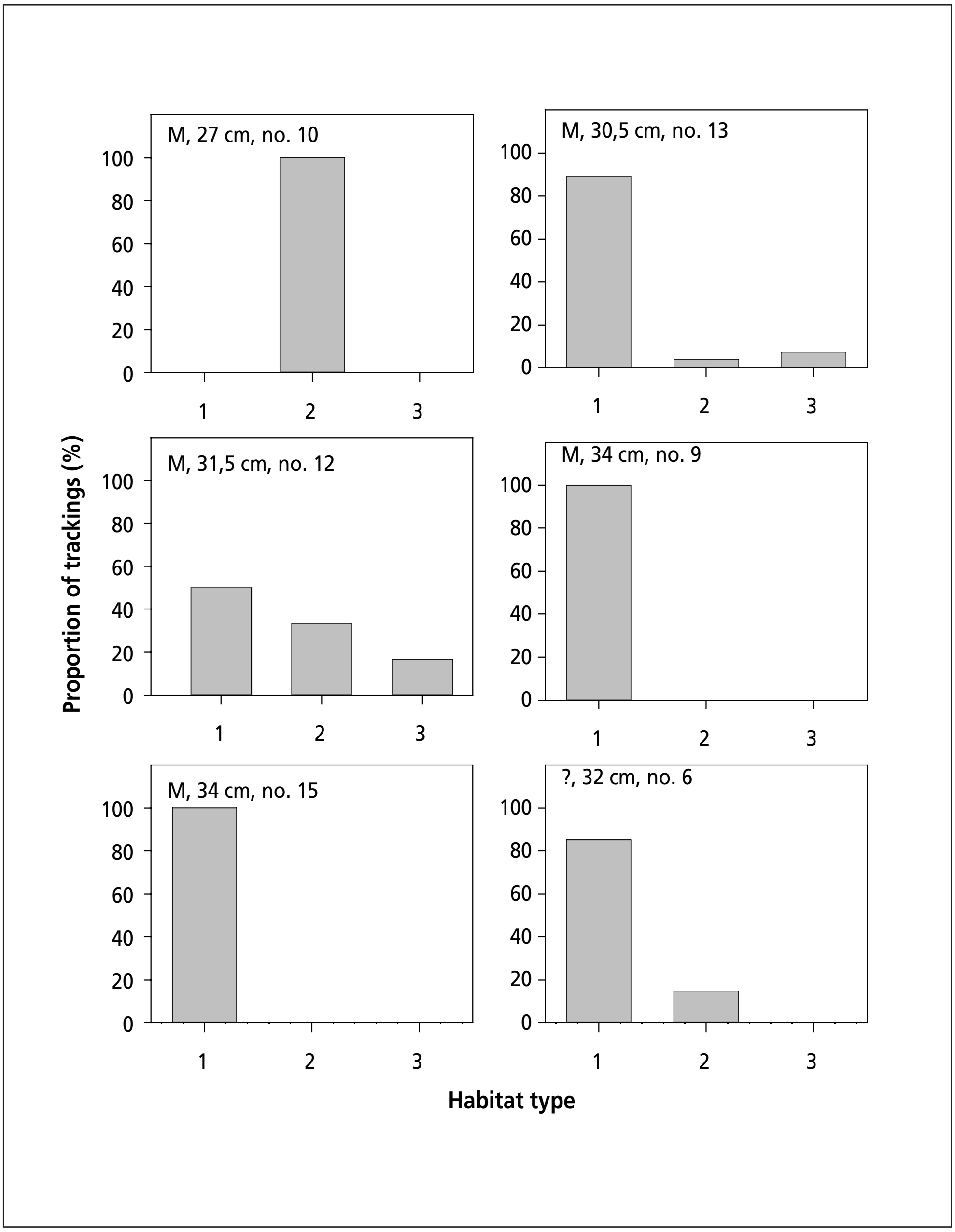



***Figure 9***
*Habitat utilisation for individual pink happy radio tagged near Kalimbeza Island in the Zambezi River in 1999-2000. Habitat type: 1 = main river, 2 = backwater, and 3 = mouth of backwater. Individual fish numbers correspond to the numbers given in **table 1**. Fish length and sex (F = female, M = male) also are given.*

***Photos opposite page:***
*Radio tagging of threespot tilapia.* ***Upper left:*** *Transmitter being surgically implanted into the body cavity through an incision in the ventral skin. The antenna was pulled through the body wall with a hollow needle.* ***Upper right:*** *Fish with an externally attached transmitter.* ***Middle:*** *The fish were placed on their dorsum on the surgical table during the surgical procedure.* ***Lower left:*** *Release of tagged fish.* ***Lower right:*** *The incision was closed with independent permanent silk sutures.*

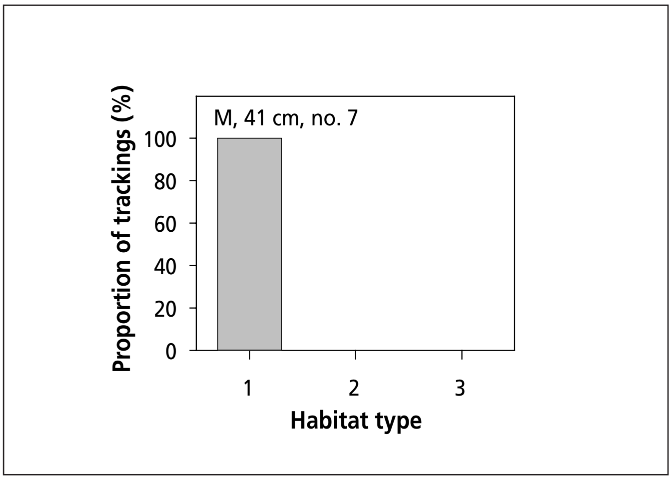
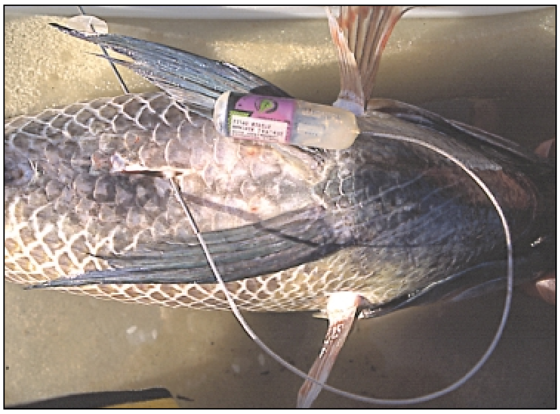



***Figure 10***
*Habitat utilisation for a humpback largemouth radio tagged near Kalimbeza Island in the Zambezi River in 1999-2000. Habitat type: 1 = main river, 2 = backwater, and 3 = mouth of backwater. Individual fish number corresponds to the number given in **table 1**. Fish length and sex (M = male) also are given.*





# 5 Discussion

Fishing intensity in the Zambezi River is increasing, and overexploitation of fish populations is of great concern. Implementation of fishing regulations is required to successfully secure a sustainable utilisation of these resources. Information on migrations and habitat preferences of important fish species in this region is essential for the development of local, national and international management regulations. This study showed that telemetry is a suitable method for collecting information about movements and habitat utilisation in this river system.

Although telemetry has been used extensively in fishery research during the last decade, few studies have been conducted in tropical rivers. Even fewer in large rivers like the Zambezi. To be able to record signals from a transmitter, the receiver antenna needs to be within detection range for signals from the transmitter. The detection range varies with depth and with conductivity of the water. The range test conducted in the channel around the Kalimbeza Island indicated that the conductivity was low, as transmitters could be located on the bottom at 2 m depth from 700-800 m distance. The width of the main river where the fish were recorded was less than the range during this project, making manual tracking reliable and fast. Several fish were located in backwaters. Some of the backwaters were impossible to enter by boat, making tracking more time consuming. Some individuals disappeared frequently, and since no areas of deep water existed in the main river it is likely that these fish had entered into backwaters. The proportion of lokalizations in backwaters, therefore, may have been underestimated.

Nine of the tagged fish showed a downriver movement immediately after release, whereas the fish were mostly stationary and showed only smaller movements later during the tracking period. We, therefore, believe that these downstream movements were a behavioural reaction to handling and tagging. Downstream movements immediately after release are also regarded in other studies as abnormal behaviour due to handling and tagging (e.g. Mäkinen *et al*. 2000). However, anaesthetisation and tagging procedures seemed to be acceptable. All fish were alive as long as they were tracked, and no transmitter-loss was recorded.

Eleven fish were released 350 to 1000 m from the catch site. Only one was recorded later at the catch site, indicating that displaced individuals of threespot tilapia and pink happy did not show a homing behaviour to the catch site. Such homing behaviour has been demonstrated, for example, for displaced Atlantic salmon spawners (*Salmo salar* L.) (Heggberget *et al*. 1988) and dusky grouper (*Epinephelus marginatus* Lowe, 1834) (Lembo *et al*. 1999).

The results from this study showed that adults of threespot tilapia and pink happy were stationary with only small movements during the period with increasing water flow towards the rainy period. However, the number of tagged and tracked individuals were small in this study, and a larger number of fish of both sexes and varying sizes should be studied before making conclusive statements.

The fish were tracked in three different main habitats; main river, backwater and mouth of backwater. The threespot tilapia were located in the main river on average 67%, backwaters 13% and mouth of backwaters 20% of the trackings. According to Skelton (1993), this species prefers slow-flowing or standing water such as in pools, backwaters and floodplain lagoons. Adults occupy deep open waters, whereas juveniles remain inshore among vegetation (Skelton 1993). The pink happy were located in the main river on average 71%, backwaters 25% and mouth of backwaters 4% of the trackings. According to Skelton (1993), this species prefers deep main river channels and floodplain lagoons with sandy bottoms. The humpback largemouth was only located in the mainstream, but was frequently not recorded, indicating that it stayed in backwaters during these periods. This species is usually found inshore off marginal vegetation of main river channels or deep connected lagoons (Skelton 1993).

The fish were probably tracked during their spawning period. Threespot tilapia raise multiple broods during the warmer months (Skelton 1993). Both pink happy and humphback largemouth breed in early summer (Skelton 1993). Threespot tilapia and pink happy are female mouthbrooders (Skelton 1993).

## 5.1 Recommendations

In eastern Caprivi, a plan for sustainable management of the fish resources must take into consideration that the river system is shared by several countries (Namibia, Zambia, Botswana and Zimbabwe), and that the fish stocks may be influenced by subsistence fishing, commercial fishing, and recreational fishing (trophy fishing, fishing competitions). Basic information about annual movements, habitat preferences and habitat utilisation of target species is needed to regulate the fishery among the different countries and exploitation types.

Fishes use the dimensions of time and space in many ways. The individuals of some species spend all their lives close to where they were spawned and hatched. Other species, however, perform long migrations covering perhaps thousands of kilometres. Migrations are usually defined as the movements that result in an alternation between two or more separate habitats, occur with a regular periodicity, and involve a large part of the population (Northcote 1978, 1984). Individual fish may maximise their fitness by moving between habitats suitable for reproduction, feeding and shelter at the appropriate times in their life span.

In the Zambezi River, fish migrations probably are linked closely to the annual flood cycle. This may concern both horizontal migrations (between the main channel and floodplains) and longitudinal migrations (along the main channel of the river). Both types of migration may bring the fish across national borders or from protected to exploited areas. The fish often become more vulnerable to fishing during migration. We, therefore, recommend to continue the work on describing the annual movements, migration and habitat utilisation of selected fish species in the Zambezi River in eastern Caprivi, and to investigate the effects of variations in water level on migration and habitat utilisation. This is basic information needed for solving the transboundary management issues for the Caprivi. Such studies should preferably be carried out in collaboration with Zambia.

Experiences from the present study show that during periods of low flow, the fish in this area can be effectively tracked by boat. However, during periods of flooding, the tracking may be more complicated and hence, may be carried out by plane. When tagging a high number of fish, tracking of fish with transmitters on different frequencies similar to this study will be almost impossible, because the receiver only listens to one frequency at a time. Therefore, when tagging a high number of fish, coded transmitters allowing for a high number of transmitters on each frequency will be needed.

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