Coelacanth (*Latimeria chalumnae* Smith, 1939) discoveries and conservation in Tanzania

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Prior to September 2003, coelacanths had not been officially recorded from waters off Tanzania. A sudden spate of coelacanth catches has resulted in 21 confirmed and several unconfirmed specimens being recorded. Nineteen specimens were caught in six months off Tanga, including six in one night. Nowhere else in the world have so many coelacanths been caught in such a short time. The reason for this sudden increase in catches is uncertain. There is concern that the impact of this fishing mortality might be threatening the population. Morphological and meristic data from Tanga specimens indicate that they are not notably different from those examined elsewhere in the western Indian Ocean. Tanzanian authorities plan to determine the size and conservation status of coelacanth populations so that informed conservation decisions might be made.

Introduction

Tanzania became the sixth country (Fig. 1a) to record the existence of the African coelacanth, *Latimeria chalumnae* Smith, 1939, in its waters on 6 September 2003, when a specimen caught off Songa Mnara Island was found in a market. Since then, a further 22 captures were reported by rural fishers, who were using deep-set shark gillnets (locally called *jarife*) at several localities along the coast. These catches from three widely separated localities (Fig. 1b) suggest that small colonies of coelacanth may be present in pockets of suitable habitat along the coast of Tanzania. Prior to this, there was an unconfirmed coelacanth sighting by a spear-fisherman at Mafia Island in 1953 and unconfirmed catches off Kigombe village near Tanga in both 1972 and 1994. The outer reefs south of Tanga (Fig. 1c) have been the site of 19 catches between 21 August 2004 and 12 January 2005.

A living coelacanth was first reported in South Africa in 1938, when a specimen was trawled off the Chalumna River near East London.[1] In 1952, a second identified specimen was caught by handline in the Comoros.[2] The Comoros archipelago was long assumed to be the 'home' of the coelacanth, with over 170[3–7] specimens caught there by deep hand-line fisheries (*mazé* fishing) since 1952. Until recently, coelacanths caught elsewhere were assumed to be hapless strays.[8] Submersible surveys in the Comoros have estimated population sizes of 150–650[9,10] individuals off Grand Comoro Island, with 300 or fewer individuals considered to comprise the total population; 68 live individuals were documented between 1989 and 1994.[10] One coelacanth was trawled off Mozambique in 1991,[11] five were caught in deep-set gillnets off southwest Madagascar since 1995,[12] one trawled off Kenya in 2001,[13] and now 21 reported from deep-set gillnets off Tanzania. Since the discovery of a population of coelacanths in Sodwana Bay, South Africa in 2000,[14] 26 individuals have been filmed by submersible, divers and remotely operated vehicles (ROVs).[15]

Coelacanths are considered to be rare fish and are listed in Appendix I (Endangered Species) of CITES, which prohibits international trade in specimens. Coelacanths are given additional protection in South Africa, Comoros and Indonesia by specific legislation.[16–18]

This paper reports morphometric and meristic data of available Tanzanian caught coelacanths, explores why so many coelacanths have been recently caught in Tanzania and confirms the importance of conservation.

Materials and methods

Twelve coelacanth specimens from Kigombe and Mwambani villages (Fig. 1c), currently held at the Tanga Coastal Zone Conservation and Development Programme (TCZCDP) and Tanga Sea Products Ltd (TSP), were measured in June 2005 and compared with earlier unpublished data on these specimens. Specimens from Lindi and Kilwa regions were not available for study. Of the specimens reported from the Tanga region, 11 whole specimens that had been previously dissected, and one head, were measured. Ten of those whole specimens were frozen, whilst one was preserved in formalin, as was the head. The system of measurements described by De Vos and Oyugi[13] was followed; however, in the absence of callipers large enough to measure point-to-point distances accurately, the straight-line distances between points perpendicular to the two points requiring measurement were taken. This is more consistent than distances following the contours of the body. Total length (TL) was measured between perpendicular lines extending from the tip of the snout and the end of the tail, and not along the length of the body. Given the motility of the lower jaw and its variable and inflexible gape in the specimens examined, this was the most consistent way of measuring TL. Standard length (SL) was also taken from the tip of the upper jaw. Additional measurements were also taken (see Tables 1, 2 as online supplements). Fin ray counts include every ray found on all fins.

Specimens were matched with earlier records by comparing the limited labelling remaining, the current location of specimens and by identification from the unique markings which had been recorded photographically at the time the fish were examined shortly after capture. As past and present measurements differed, they were not used to match up specimens. A photographic catalogue has been compiled to facilitate specimen identification and is available from the African Coelacanth Ecosystem Programme (ACEP), South Africa. Internal organs and stomach contents from each specimen were placed in plastic bags and frozen after dissection.

Samples of dorsal muscle tissue and scales were taken for stable isotope analysis from 10 frozen specimens. Dorsal muscle tissue is the standard material to extract for such analyses (S. Kaehler, pers. comm.).

Dorsal muscle, gill lamellae and pelvic muscle samples were

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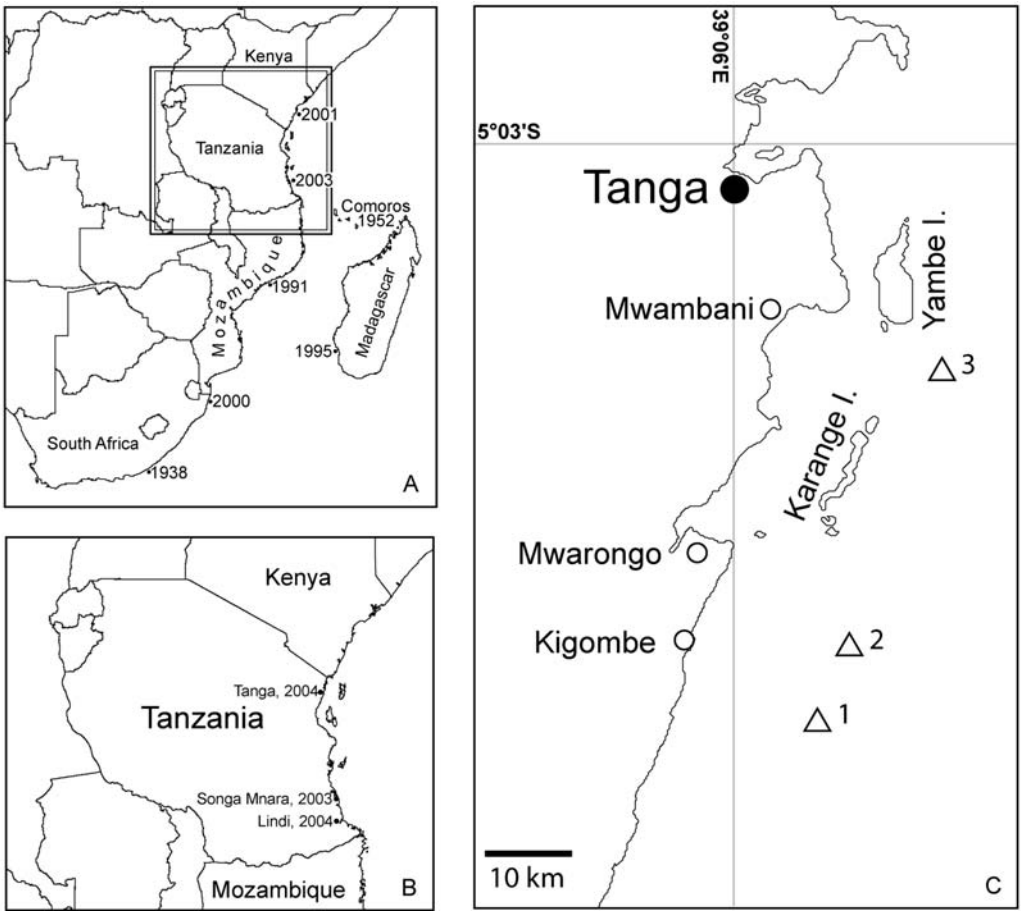


Fig. 1. Maps showing catch localities. (**A**) Locations of known capture/confirmed sightings in the western Indian Ocean with date of first capture/sighting. (**B**) The three areas in Tanzania with confirmed catches. (**C**) Detail of the Tanga region, which is the focus of this paper. The capture localities are marked south to north with triangles: 1 is 'Between Maji Vike and Kange'; 2 is 'Kange Reef'; 3 is 'NE of Karange Island'.

collected for genetic analysis. One set is kept at the University of Dar es Salaam, whilst another is lodged at the South African Institute for Aquatic Biodiversity (SAIAB) in Grahamstown (SAIAB 76188–76199). One embryo (Fig. 2) from those found in the specimen designated Kigombe 10 (CCC 202) and several scales from Kigombe 1 (CCC 184) were also lodged at SAIAB (see Table 3 as online supplement) for specimen details; samples were taken from specimens allocated JRS numbers).

Results

Catches

Table 3 provides basic catch data for the 21 confirmed coelacanth catches in Tanzania from 6 September 2003 to July 2005. Specimens are listed by catch date. TCC is a sequential number for Tanzanian coelacanth catches. The CCC number is the Coelacanth Conservation Council reference assigned to that catch. The Verheij designation is used in this paper to refer to specimens from the Tanga region. JRS numbers are field numbers for specimens examined and samples taken in June 2005. Total mass ranged from 29 to 105 kg. The largest specimen, designated Kigombe 10 (CCC 202), probably had a mass of around 110 kg when caught, but is reported to have lost 10 eggs, expelled through the cloaca, before it was weighed. This would have increased its weight by an estimated five kilograms; the expelled eggs were not weighed. Eight females and three males are reported; the sex of the other specimens is unknown. Table 4 shows gear types responsible for coelacanth catches reported in the region. Figure 3 illustrates a close-up of coelacanth scales

Table 4. Accidental catch methods.

Method of capture	Date	Number of specimens
Handlining (*mazé* fishing) (Comoros)*	1952–Present	172
Shark gillnets (Tanzania, Madagascar)	1995–Present	30
Demersal trawling (South Africa, Mozambique, Kenya)	1938–Present	3

*Handlining in the Comoros has resulted in the largest number of coelacanth catches. Shark gillnets account for the second greatest number of catches. Trawling accounts for a minor number of the known catches.



Fig. 2. One of 36 coelacanth embryos from the large female (Kigombe 10) caught on 12 January 2005. This embryo was recovered from egg debris and is accessioned into the SAIAB collection as SAIAB 76199. Photograph: J. Stapley.

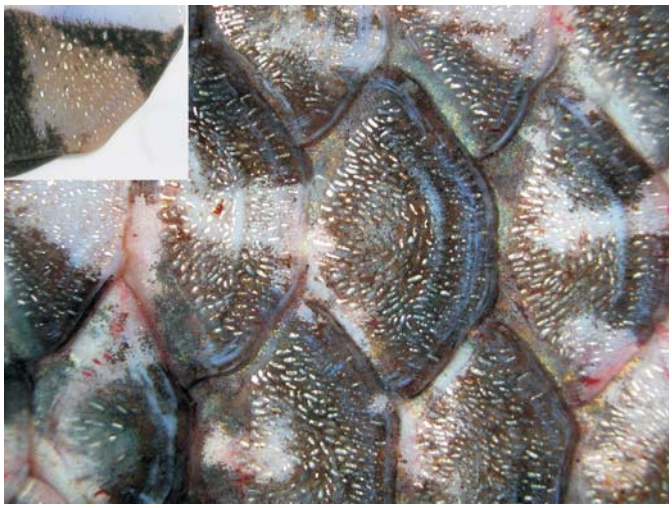


Fig. 3. Scales from a fresh coelacanth specimen from Tanga. Photograph: E. Verheij. Inset: scale from Sodwana coelacanth. Photograph: J. Stapley. Note the golden flecks on scales from both localities, possibly the result of the prismatic refraction of light. This effect is more pronounced than shown in the pictures; it is difficult to photograph.



Fig. 4. Kigombe 2 with fishers, Tuwe Saidi and Jumbe Kombo. Note damage to fins. Damage was more extensive when examined, after storage, in June 2005. Photograph: E. Verheij.

from Tanga and the inset, a scale a from Sodwana Bay specimen. Colouration of specimens did not appear different from that reported elsewhere in the region.

Several other catches have been reported from the Songa Mnara region, but as we were unable to track down physical specimens or any data for these, they have not been assigned CCC numbers or included in the tables.

All of these coelacanths were caught in bottom-set shark gill nets (*jarife*) with a mesh size of approximately 150 mm. The fishers estimated the depths of capture to be between 40 and 200 m.

Preliminary analyses of stomach contents of the Tanga specimens found that crustaceans and a deep-water apogonid fish, *Coranthus polyacanthus,* had been eaten.

Morphometrics and meristics

Morphometric and meristic data for specimens examined in June 2005 are shown in Tables 1 and 2. Data marked by a superscript [d] indicate measurements which could not be recorded with accuracy due to damage, particularly to fins. Differences were noted between measurements of specimens in July 2005 and earlier measurements made shortly after each catch.

Dentition

Coelacanths have a large number of small coniform teeth in addition to the principal canine-type (length over three times basal width) teeth. Teeth were variable, with only a few specimens having a fairly symmetrical arrangement of teeth within their jaws. No definitive characteristic pattern for the arrangement of teeth in the upper or lower jaw was apparent. Patterns of dentition are, therefore, of little value for taxonomic characterization.

In the absence of larger canine teeth, assuming they were lost, replacement teeth seemed to be growing. The anterior of the gill arches were also covered by teeth; the patches which appeared to comprise larger bi- and tricuspid teeth were counted as 'gill rakers'.

Condition of specimens

When examined in June 2005, specimens kept at TSP had badly damaged fin rays, particularly on the caudal fin, making accurate counts difficult; a truly accurate count can probably only be made with X-rays. Large numbers of scales were missing from many specimens, again making counts a problem and potentially inaccurate (LL scale counts lower than those when examined fresh; scale insertion points which would enable more accurate counts were difficult to detect, thus only pored scales present on the specimen were counted). The left pectoral and caudal fins on Kigombe 2 (Fig. 4) were particularly badly damaged. The left pectoral fin of Mwambani 1 was missing, but this appeared to be an old injury that was recovering, as darker, tough tissue covered the wound. The current state of preservation and location of specimens are listed in Table 3.

Discussion

Catches

The 19 coelacanths caught in the Tanga region between August 2004 and January 2005 represent the largest number of these fish caught in an area anywhere in the world in a six-month period. The removal of females carrying large numbers of eggs and developing embryos compounds the potential threat to the population. Of the 11 fish for which sex determinations were made, eight were females and the rest males; given that the recovery of populations will depend more on females than males, the high proportion of captured females is a concern.

The 110-kg specimen designated Kigombe 10 (CCC 202) represents the heaviest coelacanth yet landed; the previous record was for a 98 kg female caught off Mozambique, carrying 26 near-term pups.[11] The two largest-known coelacanth specimens were both pregnant females.

Habitat

The habitats in which the Tanzanian coelacanths were caught are ill-defined. Charts of the region have very low resolution and are of little value in determining the bottom composition or topography. Simple point-based echosounding transects taken from a small boat using handheld GPS and simple 'fishfinder' type echosounder after the catches suggest that the bottom profile in the Tanga region consists of a series of 10–15-m-high terraces between 70–140 m depth. Some of these may represent fossil coastlines from previous glaciations, analogous to coelacanth habitats at Sodwana Bay.[19–21] Higher resolution surveys, including visual ground-truthing, are necessary to define the habitats.

The estimated surface currents, between 1–3 knots off Tanga, are similar to those off Sodwana and the Comoros.[15,21] Current at depth is unknown.

Water temperatures at the catch depths are unknown; surface temperatures were approximately 26°C, which is higher than the reported temperature tolerance range of coelacanths.[9,22,23] Divers at 30 m depth in late August 2004, near to the 70 m catch locality, recorded a bottom temperature of 23.5°C, which suggests that temperatures in deeper water are likely to be cooler than this, corresponding to those where coelacanths have been studied *in situ* elsewhere in the Western Indian Ocean (WIO).

A coelacanth was caught in shallow depths (40–44 m) by a trawler near Pebane, Mozambique[11] over what is believed to be an open, sandy bottom. The captures in Tanga at an estimated depth of approximately 40–60 m do not represent the shallowest known catches, but are shallower than the known depth range in the Comoros.[22] A coelacanth sighted by divers at approximately 54 m near Diepgat Canyon, Sodwana Bay, was associated with an upwelling of colder water, which suggests that coelacanths extend their depth range into shallower water than might be expected during environmental perturbations.

A limited, short tracking study of one animal in Sodwana Bay indicated nocturnal movements into shallower water than that occupied in the caves during daytime.[15] Conversely, in the Comoros, nocturnal foraging behaviour is into deeper water; this behaviour is thought to reflect the position of suitable cave shelters and where food is most abundant (at and above caves at Sodwana, below caves at Grand Comoro).[15,22,23] The habitat in Tanzania is more similar to that in Sodwana than the volcanic Comoros.

The declining[24] hand-lining fishery in the Comoros (*mazé* fishing) accounts for the greatest number of coelacanth catches in the WIO, but shark gillnets are a much more widespread fishing gear in the region, which is increasingly used in remote locations around the WIO (Table 4). Trawling accounts for a small number of catches, presumably due to coelacanths generally remaining over rocky or otherwise unsuitable trawl-fishing terrain.

Morphometrics and meristics: comparisons with other catches

Limited data are available in the literature for comparison with measurements presented in this paper. Some length–weight data can be found in Bruton and Coutouvidis.[3] Froese and Palomares[25] have attempted to analyse various life-history parameters from previously published data, and have estimates of growth, natural mortality, length–weight relationship, maximum length and length at first maturity, primarily from Bruton and Coutouvidis[3] and subsequent updates by Bruton.[4–7] Bruton and Armstrong[26] have explored the limited data available and described some preliminary size frequencies, length–weight relationships, sex ratios, growth rates and population estimates for coelacanths from Ngazidja (Grand Comoro) and Anjouan. More comparable are the data in De Vos and Oyugi,[13] but these are drawn from a single fish. Limited data are available in Bruton *et al.*[11] and Heemstra *et al.*[12]

Measurements of biological specimens are known to vary between workers, particularly where obvious, consistent 'landmarks' are absent; such differences make statistical comparison of data gathered by different workers questionable unless steps are taken to quantify this error. Given that the magnitude of any differences can likely be accounted for by the measurement error between investigators, and the differences in method between the available records, any apparent differences could be statistically meaningless until those factors can be ruled out. More rigorous morphometric analysis on larger sample sizes by a single investigator using a standard technique is required to detect differences among the various catch localities.

Condition of specimens

Differences between the measurements made in July 2005 and earlier ones might in part be explained by deterioration of specimens in storage over the 6–10 month time interval, or by distortion of the bodies by dissection along the ventral midline and the removal of internal organs; differences in method are also a possibility. Later measurements and counts were generally shorter or fewer. Whilst freezer shrinkage may play a role, it is likely to be minor relative to that of damage to specimens. Total length, standard length and certain fin dimensions were not always possible to measure accurately as the ends of the fins were often damaged or entirely missing. Missing scales, particularly on the caudal peduncle, often made accurate scale counts impossible.

The two frozen specimens at TCZCDP were in much better condition, as they had evidently been handled less, being in a dedicated chest freezer. However, the specimen designated Kigombe 1 (CCC 184) was found to have been only partly immersed in preserving fluid and was drying out, probably due to evaporative losses.

Proper preservation and curation of coelacanth specimens is imperative. Photographic comparison of the specimens in a relatively fresh state with their appearance in July 2005 showed that extensive damage had taken place whilst in storage. Given the uncertainty of power supplies in remote areas and the fragile nature of large, frozen specimens, formalin fixation and storage in alcohol in a museum collection is the most effective method of long-term preservation. Considerable care must be taken when handling heavy, bulky fish as scales are easily torn loose in an effort to obtain a good grip.

Coelacanth specimens are national treasures which need to be treated with extraordinary care and should be deposited in a museum where they can be viewed by the public and properly curated. The first specimen from Songa Mnara in 2003 (CCC 181) is in the National Museum in Dar es Salaam; this specimen is of interest as it was butterfly cut and dried for market prior to fixation.

Colouration

Erdmann, Caldwell and Moosa[27] describe the Indonesian coelacanth (*Latimeria menadoensis* Pouyaud *et al.*, 1999)[28] as being brown rather than 'steel blue', and indicate that the most distinctive feature is the golden flecks on the scales. These are believed to be a consequence of a prismatic effect of light reflecting off denticles on the scales. This same phenomenon has been noted on fresh scales sampled from coelacanths in Sodwana Bay, and on fresh specimens from Tanga, so the diagnostic value of this particular character requires assessment (Fig. 3).

Explaining the sudden appearance of coelacanths in the catches

In Tanzania, a correlation between the activities of prawn trawlers in the Tanga and Kilwa (Songa Mnara) regions and catches of coelacanths in *jarife* nets might exist. Reports suggest that coelacanths are caught when trawlers are active, but they are not taken when trawlers are absent (S. Makoloweka, pers. comm.). Prawn trawlers became active in the region relatively recently, whilst deep-set shark nets have been in use since 2001 (S. Makoloweka, pers. comm.). More rigorous observations of the trawlers and incidental catches, if any, and a detailed under-

standing of the fishing methods of the *jarife* fishermen would be worthwhile; an appreciation of the needs of the resource users in the region will prove invaluable to planning marine protected areas.

Prawn trawlers have operated in the Rufiji River delta area but are now trawling farther south, close to Kilwa (Songa Mnara), where coelacanths have also been caught. Trawlers operating relatively close inshore may cause coelacanths to move into shallower water than they habitually frequent, perhaps due to disturbances caused by the net or noises produced by the fishing gear or boats themselves. This is puzzling because there is minimal reaction to a relatively noisy submersible operating in close proximity.[15]

In situ observation (extended tracking studies) of coelacanths with and without the presence of active prawn trawlers, together with detailed measurements of oceanographic parameters and close monitoring of *jarife* fishing would show whether trawlers do affect coelacanth behaviour. Until such studies have been completed, the moratorium on trawling activities in the region should continue.

Recommendations

The high catch rate of coelacanths in Tanga is of great concern and highlights the urgency with which conservation measures should be enacted. Creation of an effectively managed MPA protecting an area occupied by coelacanths is being considered by Marine Parks and Reserves, Tanzania. The Tanzanian authorities are planning a research project with ACEP to determine the size and extent of coelacanth populations with a view to developing the most appropriate management and conservation strategy.

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