# Impact of fishing with *Tephrosia candida* (Fabaceae) on diversity and abundance of fish in the streams at the boundary of Sinharaja Man and Biosphere Forest Reserve, Sri Lanka

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**Abstract:** Local communities in some Asian, African and American countries, use plant toxins in fish poisoning for fishing activities; however, the effects of this practice on the particular wild fish assemblages is unknown. This study was conducted with the aim to investigate the effects of fish poisoning using *Tephrosia candida,* on freshwater fish diversity and abundance in streams at the boundary of the World Natural Heritage site, Sinharaja Forest Reserve, Sri Lanka. A total of seven field trips were undertaken on a bimonthly basis, from May 2013 to June 2014. We surveyed five streams with similar environmental and climatological conditions at the boundary of Sinharaja forest. We selected three streams with active fish poisoning practices as treatments, and two streams with no fish poisoning as controls. Physico-chemical parameters and flow rate of water in selected streams were also measured at bimonthly intervals. Fish were sampled by electrofishing and nets in three randomly selected confined locations (6 x 2 m stretch) along every stream. Fish species were identified, their abundances were recorded, and Shannon-Weiner diversity index was calculated for each stream. Streams were clustered based on the Bray-Curtis similarity matrix for fish composition and abundance. Physico-chemical parameters of water were not significantly different among streams (P > 0.05). A total of 15 fish species belonging to four different orders Cypriniformes, Cyprinodontiformes, Perciformes and Siluriformes were collected; nine species (60 %) were endemic, and six (40 %) were native species. From these, 13 fish species were recorded in streams with no poisoning, while five species were recorded in streams where poisoning was practiced. Four endemic and one native fish species were locally extinct in streams where fish poisoning was active. Fish abundance was significantly higher in control streams (32-39/m$^2$) when compared to treatment streams (5-9/m$^2$) (P < 0.05). We concluded that fish poisoning with *T. candida* may have resulted in a significant reduction in species richness, total abundance and Shannon-Weiner diversity index of fish species in the studied streams at the boundary of Sinharaja forest. We recommend that this fishing practice should be strictly regulated, and to inform local communities about the legal status of fish poisoning, its consequences and the importance of fish diversity for local livelihoods and conservation purposes. Rev. Biol. Trop. 64 (3): 1129-1141. Epub 2016 September 01.

**Key words:** exotic plant, *Tephrosia candida*, fish poisoning, Sinharaja forest.

Sri Lanka, a tropical island, boasts of the highest biodiversity per unit area of land for flowering plants and for all vertebrate groups except birds in Asia (Mahindapala, 2002). However, freshwater fish species richness of the country is in lower range with 91 indigenous, 50 endemic and 25 introduced species. The wet zone, which includes the Southwestern lowlands and the central highlands, provides habitats for most of the fresh water fish species (Senanayake & Moyle, 1982; Pethiyagoda, 2006). Nine new fish species have been discovered from stream and riverine habitats in this area during the period of 1998-2007 (Gunawardena et al., 2007). Two-thirds of the endemic fish species of the country were recorded from

rivers and streams, and they account for more than 90 % of threatened or vulnerable fish species (Wijeyaratne, 1993).

Major streams draining into Kalu Ganga and Gin Ganga rivers, originate from Sinharaja rain forest (Jayasuriya & Abayawardana, 2008). This has been designated by UNESCO as a Biosphere Reserve in 1978, and as a World Natural Heritage Site in 1988. Inhabitants of the 30 villages at the boundary of Sinharaja forest (Wijesooriya & Gunathilleke, 2003) receive a part of their daily protein requirement from freshwater fish, harvested from streams and rivers, as observed in Chalakudy River, Western Ghats, India (Raghavan, Prasad, Anvar Ali, & Pereira, 2008). Cast net and pole and line are the major fishing gears used by artisanal fishers living in villages. Use of plant toxins to catch freshwater fish is illegal in Sri Lanka, but low income groups in local communities still practice this fishing method, as they are unable to buy fish or fishing gears.

*T. candida* (Candolle, 1825) is an erect herb, shrub or small tree, up to 3.5 m tall, with straggling branches from the base (Hacker, 1990). The plants in this genus are widely distributed in tropical, sub-tropical and arid regions of the world. *T. candida* was locally introduced in 1970s as live legume mulch, for weed control in tea plantations (Wijewardene, 1984). Local communities accidentally discovered the ichthyotoxic effects of its smashed plant parts*,* and fishing using this plant is now widespread in areas where the plant is readily available, as it has paved a new way of easy fishing in streams at the boundary of Sinharaja forest. Villagers use plant poisons as it is an easy method to harvest fish from streams, a practice that has also been observed in other areas such as Guyana (Archer, 1934; Martyn & Follett-Smith, 1936; Forte, 1996; Andel, 2000), Papua and New Guinea (Barrau, 1955), Samoa (Cox, 1979), South and North America (Acevedo-Rodríguez, 1990; Kurup, Radhakrishnan, & Manojkumar, 2004; Bijukumar, Philip, Ali, Sushama, & Raghavan, 2013) and some African (Neuwinger, 2004) countries like Nigeria (Akpa, Ajima, Audu, & Labte, 2010).

*Tephrosia* is well-known as a source of flavonoids, rotenoids, terpenoids, and sterols among their secondary metabolites (Dagne, Yenesew, & Waterman, 1989; Andrei et al., 2002; Olatayo, 2005; Touqeer, Muhammad, & Muhammad, 2013). Some of the ingredients isolated from *T. candida* are amorphispironone, tephrospirolactone, tephrospiroketone, deguelin, candidol (Dutt & Chibber, 1983), tephrosin (Morah, 1985), amorpholone (Kole, Satpathi, Chowdhury, Ghosh, & Adityachaudhury, 1992), candidone, rotenone and scillascillin (Stephen, Mckenzie, & Wayne, 2003; Dagne et al., 1989). Tephrosin ($C_{23}H_{22}O_7$) is closely related to the commercial insecticide rotenone ($C_{23}H_{22}O_6$) that is widely used in killing undesirable fish (Olatayo, 2005). The active ingredients of this plant are released by mashing and grinding the plant parts and then introduced to the water environment. Though *Tephrosia* is used in fish poisoning by local communities in all continents of the world, the effects of this fishing practice on wild fish assemblages are currently unknown. Therefore, we evaluated the effects of fish poisoning using *T. candida* on freshwater fish diversity and abundance in streams, at the unprotected boundary of Sinharaja forest. It was hypothesized that the frequent use of *T. candida* to poison fish would significantly reduce fish diversity and abundance, leading to their local extinctions in freshwater streams.

## MATERIAL AND METHODS

**Sampling sites:** The study was conducted at the unprotected boundary of Sinharaja forest reserve (with a total forest conservation area is 112 km²). Sinharaja is a lowland wet evergreen forest that is located in the Southwest area of Sri Lanka (6˚21'- 6˚26' N & 80˚21' - 80˚34' E). It lies between the tributaries of the Kalu Ganga and the Gin Ganga rivers, and extends within the administrative districts of Galle, Matara and Ratnapura, in the Southern and Sabaragamuwa provinces, Sri Lanka (Gunatilleke, Gunatlleke, Ethugala, & Esufali, 2004; Jayasinghe, Ekanayake, Bambaradeniya,

& Amarasinghe, 2005). A total of seven sampling field trips were undertaken on a bimonthly basis from May 2013 to June 2014.

A total of five streams were studied. Two streams were designated as control sites i.e. Ima ela (C1) and Katukandi ela (C2), where no *T. candida* fishing poisoning is practiced (NTF). Villagers living around these streams do not practice fish poisoning, as *T. candida* is not readily available in the area. Additionally, other three streams were selected as treatment sites ie. Hal dola (T1), Puwakgaha ela (T2) and Wadagaha hena ela (T3), and where *T. candida* fishing is frequently practiced (TF)

(Fig. 1). For this fishing practice, local villagers crush and ground around 3-5 kg of leaves and branches of *T. candida* with a wooden pestle and a natural rock mortar into a pulpy mass. The freshly prepared pulp is then simply thrown on the water surface in streams to poison the fish. The stunned, floating fish are then collected by hand or hand nets. They poison the streams 2-3 times a month, but fishing is not practiced on rainy days due to high flow rates in streams. *T. candida* is not cultivated for fishing purposes, but the plant is available in some tea plantations, abandoned agricultural lands and in some home gardens.
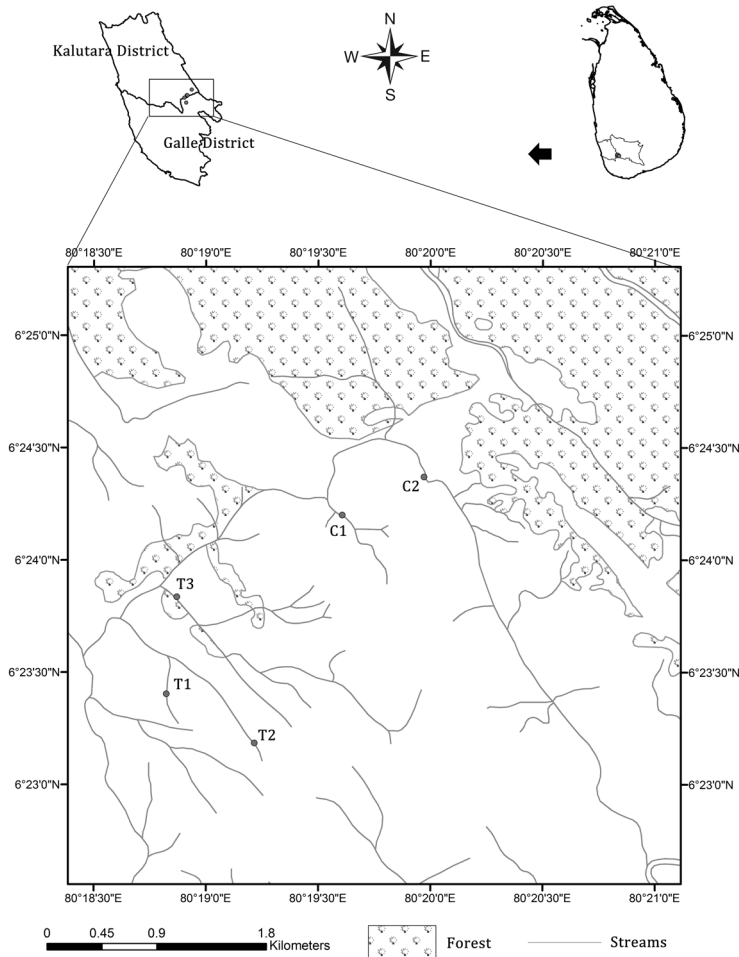


**Fig. 1.** Sampling streams at the unprotected boundary of Sinharaja forest
(T1, T2, T3 - subjected to fish poisoning using *T. candida*; C1 & C2 - did not subject to fish poisoning).

**Water quality analysis:** Water quality was monitored with a 150 m gap in three locations in each selected stream. Water physico-chemical parameters such as temperature (Barannan 350 mm glass thermometer), pH (HACHE 10 portable pH meter), total dissolved solids (TDS) (SM 401 TDS meter), dissolved oxygen (DO) and five day biochemical oxygen demand (BOD) (APHA, 2007) were measured in each visit. The water flow velocity at each sampling site was measured using the floater drifting method (Bhat, 2004). Depth of selected streams varied from 0.5-0.6 m. Water quality parameters in streams were compared by one way ANOVA followed by Tukey's pair wise comparison.

**Fish sampling:** Fish were sampled from three selected locations in each stream. A 150 m gap was maintained between adjacent sampling locations, to avoid recording of the same individuals of different fish species. Fish were encircled (6 m long stretch of 2 m wide stream area) with minimum disturbance by fishing nets with a mesh size of 5 mm. Fish were captured using electro fishing gear [(Electrofisher, SAMUS 700 and collected by hand nets (mesh size 2 mm)] and cast nets (mesh size 5 mm). Fish were identified according to Mendis

and Fernando (1969); Goonathilake (2007); Silva, Maduwage and Pethiyagoda (2010); IUCN (2012); Pethiyagoda, Meegaskumbura and Maduwage (2012) and Froese and Pauly (2015). Fish were immediately released to their habitats after identification and enumeration.

Significant differences of total fish abundance and Shannon-Weiner diversity index of streams were obtained using Tukey's pairwise comparisons after two-way ANOVA. Five streams were clustered based on the Bray-Curtis similarity matrix of the fish composition and abundance using PRIMER version 5.2.9 software. Statistical differences of the major clusters of fish composition and abundance in the dendrogram were obtained using one-way ANOSIM.

## RESULTS

**Water quality in streams:** Temperature, pH, TDS, DO and BOD in water in five selected streams varied in a narrow range and were not significantly different (One way ANOVA, Tukey's; $P > 0.05$) (Table 1). The water flow rate recorded in the Wadagaha hena ela (T3) stream was significantly higher than the lowest flow rate recorded in the Katukandi ela (C2) stream. Flow rates in the other streams

TABLE 1

Physico-chemical parameters of water (mean±sd; range in parenthesis) in NTF (C1, C2) and TF (T1, T2, T3) streams at the unprotected boundary of Sinharaja forest, Sri Lanka

| Physico-chemical parameter | C1 | C2 | T1 | T2 | T3 |
|---|---|---|---|---|---|
| pH | 6.8±0.04 | 6.9±0.03 | 6.9±0.02 | 6.9±0.02 | 6.9±0.03 |
| | (6.6-7.1) | (6.7-7.1) | (6.7-7.1) | (6.7-7.1) | (6.7-7.1) |
| Temperature (°C) | 26.4±0.14 | 26.5±0.15 | 26.5±0.14 | 26.2±0.12 | 26.5±0.11 |
| | (26.8-27.3) | (26.1-27.6) | (26.2-27.4) | (26.1-27.6) | (26.3-27.5) |
| TDS (mg/L) | 20.4±0.24 | 20.1±0.22 | 19.8±0.13 | 20.5±0.21 | 20.4±0.11 |
| | (19.5-21.1) | (19.3-21.4) | (19.2-20.6) | (19.8-21.2) | (19.7-21.2) |
| Dissolved Oxygen (mg/L) | 8.7±0.07 | 8.8±0.04 | 8.8±0.05 | 8.9±0.04 | 8.8±0.05 |
| | (8.2-9.2) | (8.6-9.2) | (8.5-9.2) | (8.6-9.2) | (8.5-9.2) |
| $BOD_5$ (mg/L) | 0.9±0.0 | 1.0±0.0 | 1.0±0.0 | 1.0±0.0 | 0.9±0.0 |
| | (0.8-1.3) | (0.8-1.4) | (0.8-1.4) | (0.8-1.2) | (0.6-1.4) |
| Flow rate (cm/s) | 3.3±1.01[ab] | 2.1±1.02[b] | 4.2±1.04[ab] | 4.5±1.02[ab] | 5.1±1.01[a] |
| | (1.4-7.3) | (1.4-3.3) | (1.1-7.4) | (1.4-10.2) | (2.6-15.1) |

Note: Values are mean ± SE, range in parenthesis. Different superscript letters in a row denote significant differences (P < 0.05) compared by two way ANOVA followed by Tukey's pairwise test.

did not show a significant variation (One way ANOVA, Tukey's; P < 0.05).

**Fish species diversity and abundance:** A total of 15 fish species belonging to four different orders Cypriniformes, Cyprinodontiformes, Perciformes and Siluriformes were identified in the streams at the boundary of Sinharaja forest. Species richness of the streams ranged from 4-13, while the higher species richness was recorded in NTF streams and the lower in TF streams (Fig. 2).

Out of the 15 fish species recorded during the study, nine were endemic species (Table 2). *B. signata*, *P. nigrofasciatus* and *R. dandiya* were recorded in all TF and NTF streams. *A. dayi, C. brachysoma, D. malabaricus, G. ceylonensis, G. giuris P. bimaculatus, P. titteya, P. vittatus* and *S. notostigma* were only recorded in NTF streams. *S. notostigma* and *P. bimaculatus* were only found in Ima ela stream (C1), while *G. giuris* and *D. malabaricus* were only found in Katukambi ela stream (C2). Out of six species recorded in TF streams five were endemic to Sri Lanka.

*R. dandia* was the highest abundant fish in the streams at the boundary of Sinharaja forest (Table 3). Abundance of *R. dandia, P. nigrofasciatus, P. dorsalis, P. singhala, S. pleurotaenia,* and *B. signata* were significantly higher in NTF streams than TF streams (Two

way ANOVA, Tukey's, P < 0.05). The lowest abundance was recorded for *D. malabaricus, P. bimaculatus* and *G. giuris* followed by *G. ceylonensis, A. dayi* and *C. brachysoma*.

The total fish abundance in NTF streams was significantly higher than that of the TF streams (Table 4). The total fish abundance was very low in the Puwakgaha ela stream (T3) followed by Hal dola (T1) and Wadagahahena ela (T3) streams. The Shannon-Weiner diversity indices of the NTF streams were also higher than that of the TF streams. The Shannon-Weiner diversity index was significantly lower (Two way ANOVA, Tukey's; P < 0.05) in the Puwakgaha ela stream (T3) compared to NTF streams (Table 4).

According to the cluster analysis, based on the Bray-Curtis similarity matrix of the fish composition and abundance, mainly two clusters were formed (Fig. 3). These two clusters that represent TF and NTF streams were significantly different from each other (one way ANOSIM; P < 0.05). Absence of *A. dayi, C. brachysoma, D. malabaricus, G. ceylonensis, G. giuris, P. bimaculatus, P. titteya, P. vittatus* and *S. notostigma* in TF streams and higher abundance of *R. dandia, P. nigrofasciatus, P. dorsalis, P. singhala, S. pleurotaenia,* and *B. signata* in NTF streams separated TF and NTF streams into two clusters. Meanwhile, Cluster 1 was divided into two clusters (1a & 1b), since
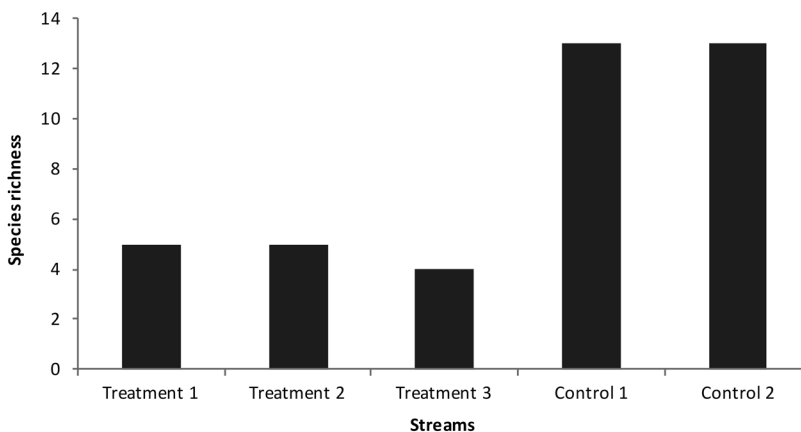


**Fig. 2.** Fish species richness (mean ±SD) in streams at the unprotected boundary of Sinharaja forest (Treatment 1, 2 & 3 - subjected to fish poisoning using *T. candida*; Control 1 & 2 - did not subject to fish poisoning).

TABLE 2

Fish species recorded from NTF (C1 & C2) and TF (T1, T2 & T3) streams at the unprotected
boundary of Sinharaja forest, Sri Lanka

| Species name | Common name | Status | C1 | C2 | T1 | T2 | T3 |
|---|---|---|---|---|---|---|---|
| *Aplocheilus dayi* (Steindachner, 1892) | Sri Lanka day's killifish | Endemic | Ö | Ö | x | x | x |
| *Belontia signata* (Gunther, 1861) | Sri Lanka combtail | Endemic | Ö | Ö | Ö | Ö | Ö |
| *Clarias brachysoma* (Gunther, 1864) | Sri Lanka walking catfish | Endemic | Ö | Ö | x | x | x |
| *Devario malabaricus* (Jerdon, 1849) | Giant danio | Native | x | Ö | x | x | x |
| *Dawkinsia singhala* (Dunker, 1912) | Filamented barb | Endemic | Ö | Ö | Ö | Ö | x |
| *Garra ceylonensis* (Bleeker, 1863) | Sri Lanka stone sucker | Endemic | Ö | Ö | x | x | x |
| *Glossogibius giuris* (Hamilton, 1822) | Bar-eyed goby | Native | x | Ö | x | x | x |
| *Puntius bimaculatus* (Bleeker, 1863) | Redside barb | Native | Ö | x | x | x | x |
| *Puntius dorsalis* (Jerdon, 1849) | Long-snouted barb | Native | Ö | Ö | Ö | Ö | x |
| *Puntius titteya* (Deraniyagala, 1929) | Sri Lanka cherry barb | Endemic | Ö | Ö | x | x | x |
| *Puntius vittatus* (Day,1865) | Silver barb | Native | Ö | Ö | x | x | x |
| *Pethiya nigrofasciatus* [Gunther, 1868] | Sri Lanka black ruby barb | Endemic | Ö | Ö | Ö | Ö | Ö |
| *Rasbora dandiya* [Valenciennes, 1844] | Broad line strip rasbora | Native | Ö | Ö | Ö | Ö | Ö |
| *Schistura notostigma* (Bleeker, 1863) | Sri Lanka banded mountain loach | Endemic | Ö | x | x | x | x |
| *Systomus pleurotaenia* (Bleeker,1863) | Sri Lanka black-lined barb | Endemic | Ö | Ö | x | x | Ö |

Ö - species present, x - species absent.


TABLE 3

Fish abundance (mean ± sd/m$^2$; conservation status in parenthesis) in NTF and TF streams
at the boundary of Sinharaja forest, Sri Lanka

| Order | Family | Species | Control 1 | Control 2 | Treatment 1 | Treatment 2 | Treatment 3 |
|---|---|---|---|---|---|---|---|
| Cypriniformes | Cyprinidae | *R. dandiya* (LC) | 11±1.33 | 12±0.46 | 2±1.92 | 4±0.98 | 2±0.11 |
| | | *P. nigrofasciatus* (EN) | 2±0.35 | 4±2.35 | 1±0.93 | 1±0.18 | 1±0.30 |
| | | *P. dorsalis* (LC) | 2±0.35 | 5±4.47 | 1±0.39 | 2±0.47 | |
| | | *D. singhala* (LC) | 2±1.04 | 5±0.88 | 2±0.29 | 1±0.27 | |
| | | *S. pleurotaenia* (EN) | 2±0.21 | 3±1.7 | | | 1±0.12 |
| | | *P. vittatus* (LC) | 2±0.12 | 1±0.23 | | | |
| | | *P. titteya* (EN) | 2±0.55 | 1±0.09 | | | |
| | | *G. ceylonensis* (VU) | 1±0.02 | 1±0.18 | | | |
| | | *D. malabaricus* (LC) | | 1±1.41 | | | |
| | | *P. bimaculatus* (LC) | 1±0.16 | | | | |
| | Balitoridae | *S. notostigma* (NT) | 3±1.20 | | | | |
| Perciformes | Osphronemidae | *B. signata* (NT) | 2±1.04 | 3±0.44 | 1±0.26 | 1±0.18 | 1±0.20 |
| | Gobiidae | *G. giuris* (LC) | | 1±0.10 | | | |
| Cyprinodontiformes | Aplocheilidae | *A. dayi* (EN) | 1±0.09 | 1±0.15 | | | |
| Siluriformes | Claridae | *C. brachysoma* (NT) | 1±0.47 | 1±0.0 | | | |

Conservation status of fish species are given in the parenthesis. **EN** - endangered, **LC** - least concern, **NT** - near threatened, **VU** - vulnerable (IUCN, 2012; MOE, 2012).

| Stream | Fish abundance (/m$^2$) | Shannon-Weiner diversity index |
|---|---|---|
| Treatment 1 | 7±0.5[a] | 1.52±0.0[ab] |
| Treatment 2 | 9±0.5[a] | 1.26±0.0[ab] |
| Treatment 3 | 4±1.0[a] | 0.99±0.3[b] |
| Control 1 | 32±0.0[b] | 2.04±0.0[a] |
| Control 2 | 39±5.5[b] | 1.98±0.1[a] |

Values are mean ± SE. Different superscript letters in a column denote significant differences (Two way ANOVA, Tukey's, P < 0.05).
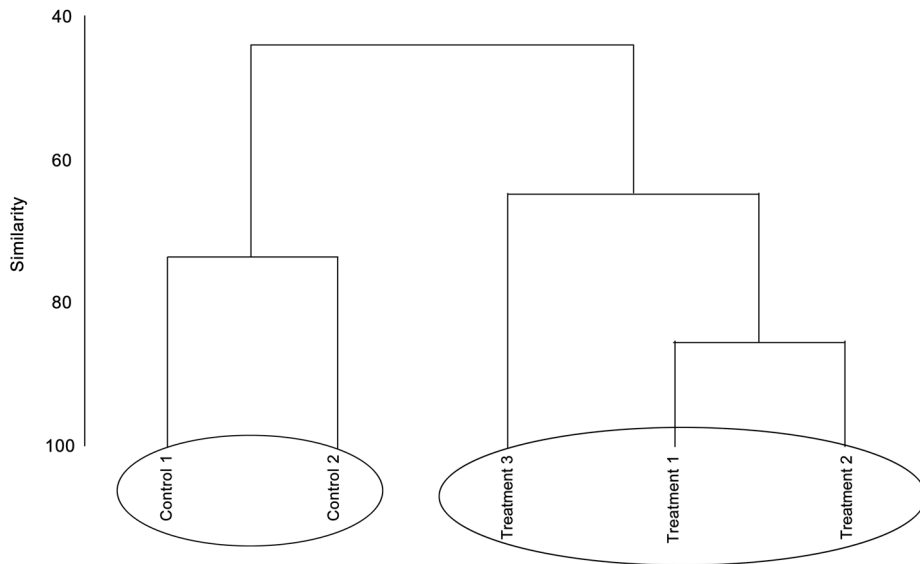


**Fig. 3.** Dendrogram of streams resulting from a hierarchical cluster analysis of fish abundance and composition data. (Treatment 1, 2 & 3 - streams subjected to fish poisoning using *T. candida*; Control 1 & 2 - streams that did not subject to fish poisoning).

there were two species only for the cluster of control stream 1, but not for control stream 2; besides, other two species were only distributed in the cluster of control 2 but not in control 1 cluster. Six species were only present in cluster II, four species in cluster of treatment 3 (2a), and five species in cluster for both treatments 1 and 2 (2b). Use of *T. candida* to poison fish by local communities has changed fish diversity and abundance in streams at the boundary of Sinharaja forest.

## DISCUSSION

Variation of physico-chemical parameters of water in streams in a narrow range without significant differences may be due to similar geographical and climatic conditions shared by all the treatment and control streams. Among the 15 species that inhabit the streams, nine species (60 %) were endemic, and six (40 %) were native species (IUCN, 2012; MOE, 2012). Galle and Matara districts, that share larger part

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of Sinharaja forest, harbor 64 and 57 fresh-water fish species, respectively (De Silva et al., 2009). Stream and riverine habitats of unprotected boundary of Western Ghats, India, provide habitats for 32 fish species (Abraham & Kelkar, 2012). The comparatively lower fish diversity observed in the present study may be attributed to the low habitat heterogeneity of the sampling area. However, the conservational importance of stream habitats at the unprotect-ed boundary of Sinharaja forest is highlighted by recording four endangered, one vulnerable and three near threatened endemic fish species in the respective streams. This is in agreement with Goonatilake (2012), who indicated that the majority of threatened and endemic fresh-water species, inhabit in streams that are lying outside the protected area of the country.

According to differences in diversity and abundance of fish in TF and NTF streams, they were classified into two clusters through Bay Curtis similarity matrix. The presence of *B. signata, D. singhala*, *P. dorsalis, P. nigro-fasciatus* and *R. dandiya* in all the streams, except in Wadagaha hena ela stream (T3) (where *D. singhala, P. dorsalis* were absent), exhibits the ability of these fish species to resist fishing induced local extinctions and/or their ability to recolonize within a short period of time. Here, local extinction refers to the loss of the entire population of particular fish species from all the sampling locations in a stream. Lower number of individuals of these species recorded in streams subjected to fish poisoning compared to their numbers in NTF streams suggests their inability to further resist the pressure imposed by plant toxins. Shannon-Weiner diversity index was also lower in the TF sites than the NTF sites. The lowest value for Shannon-Weiner diversity index was recorded for TF stream three (0.99±0.3), while the high-est value (2.04±0.0) was recorded for the NTF stream one. If this fishing practice continues into other streams, these fish species may face a threat of local extinction as there is less chance of recovery and recolonization in freshwater ecosystems compared to other aquatic ecosys-tems (Pullin, 1990).

Though *B. signata* and *P. nigrofasciatus* were recorded in all the streams in the present study, their population sizes have noticeably reduced in other areas of the country, mainly because of over exploitation for aquarium trade (Goonathilake, 2012). However, the abundance of *B. signata* was very low in TF streams and it may face high risk of elimination/disappear-ance from these streams in future. This situa-tion may be further aggravated by their solitary and territorial behavioral traits that make them poor colonizers. Colonization abilities of fish species mainly regulate local recurrence of regional species (Angermeier & Winston, 1998). Also, *S. pleurotaenia* was recorded in only one TF stream while it was recorded in higher numbers in both NTF streams. This species may be highly vulnerable to fish poi-soning, as it inhabits in the middle of the water column and form small schools. Some of the traits of individual fish species make them more vulnerable to environmental perturba-tions, and these traits increase the probability of their local extinctions (Angermeier, 1995; Bergerot, Hugueny, & Belliard, 2015).

The response of fish assemblages to fre-quent poisoning was the extinction of five fish species including, *A. dayi, C. brachysoma, G. ceylonensis, P. vittatus* and *P. titteya* from TF streams. This highlights the suitability of fish assemblages as sensitive and reliable indicators of aquatic ecosystems health (Ibarra, Gevrey, Park, Lim, & Lek, 2003; Rashleigh, 2004). These extinctions deserve priority in conserva-tion activities because they are the first steps towards extinctions at larger spatial scales (Pitcher, 2001; Dulvy, Sadovy, & Reynolds, 2003). Out of five species extinct from TF streams only two species, *C. brachysoma* and *G. ceylonensis* are considered as food fishes in Sri Lanka. The extinction of other smaller fish species (*A. dayi, P. vittatus* and *P. titteya*) from TF streams, showed the negative impact of fish poisoning on non-target species. Fish poison-ing plants are even toxic to non-target aquatic macro invertebrates, Baetidae (Mayflies) and Hydropsychidae (Caddisflies) (Karunamoorthi, Bishaw, & Mulat, 2009). *A. dayi, P. vittatus*

and *P. titteya* are small fish, and small-bodied freshwater fish species are more vulnerable to extinction, due to their naturally small ranges (Gaston, 1994), which may put them in a more precarious position when their habitats are impacted by humans (Reynolds, Webb, & Lorraine 2005). Decline of endemic fish species populations in the wild have been already observed in some other areas of the country due to habitat alteration, invasive species, ornamental fish trade, food fishery, heavy use of agrochemicals, gem mining and large and small scale hydropower projects (Wijeyaratne, 1993; Pethiyagoda, 1994; Pethiyagoda, 2006; Goonatilake, 2007; Goonatilake, 2012). Fish poisoning by *T. candida* has further intensified the threats faced by endemic fish species in the country, and currently, the endemic freshwater fish of Sri Lanka are classified in a highly vulnerable state (Goonatilake, 2012).

*D. malabaricus, G. giuris*, *P. bimaculatus* and *S. notostigma* were only recorded in one stream out of five streams studied. With the exception of *S. notostigma,* that is endemic and considered as vulnerable, the other three species were considered as least concern according to IUCN threatened species classification (IUCN, 2012; MOE, 2012). Significantly lower distribution and abundance of these species in streams at the boundary of Sinharaja forest may be due to their need for special habitat requirements. There is a greater risk of local extinction of these species mainly because of their rarity. *D. malabaricus, G. giuris* and *P. bimaculatus* are ubiquitous in other areas of the country, and its lower abundance in the streams at the boundary of Sinharaja forest, need to be further studied. *D. malabaricus* was highly abundant from upstream to downstream in Chalakudy River, Western Ghats, India (Raghavan et al., 2008).

Periodical killing of fish without any size disparity and indiscriminate removal may have led to permanent changes in fish diversity and abundance in streams at the boundary of Sinharaja forest. Fish poisoning in streams causes incalculable loss of juveniles and small fishes other than the target species (Ekanem, Meinelt, Kloas, & Knopf 2004; Akinbulumo, Fagbenro, & Fasakin, 2005). Poison may easily flow downstream over a long distance exposing fry and fingerlings for lethal and sublethal concentrations. Ekanem et al. (2004) and Akpa et al. (2010) suggested discouraging the use of *T. vogelii* as a fish poison due to its high toxicity to fish larvae in freshwaters. When fish species eliminated completely from their native habitats there is a lower chance for quick re-colonization (Pethiyagoda, 1991). A similar fish population reduction caused by indiscriminate poisoning of streams and ponds was observed around Amerindian settlements in Guyana (Forte, 1996). Fishing-induced extinctions (Dulvy et al., 2003; Darwell et al., 2008; Chong, Lee, & Lau, 2010) as observed in the present study, endanger biodiversity and affect ecosystem functioning. Such extinctions are probably going unnoticed, because of high levels of illegal fishing, geographic heterogeneity, and data scarcity (Castello, Arantes, Mcgrath, Stewart, & De Sousa 2014).

Freshwater fish are highly vulnerable to human induced extinctions than their marine and terrestrial counterparts (Riccardi & Rasmussen, 1999; Dudgeon et al., 2006; Strayer & Dudgeon, 2010; Vaughn, 2010). However, the scientific community attention on the overexploitation of freshwater ecosystems is weaker than the attention on terrestrial (Myers, Mittermeier, Mittermeier, Dafonseca, & Kent, 2000; Revenga & Kura, 2003; Linke, Turak, & Nel, 2011) and marine ecosystems, although the loss consequences could be similar if not worse (Allan et al., 2005). Illegal and unauthorized fishing practices are responsible for the collapse of fish stocks and destruction or alteration of important freshwater habitats all over the world (Mota, Sousa, Araujo, Braga, & Antunes, 2014). Scientific information on these fishing practices is required in future planning and for the implementation of appropriate conservation and management strategies of aquatic species (Angermeier & Winston, 1998; Dudgeon et al., 2006), especially in tropical countries, where law enforcement is comparatively weak. The findings of the present study can be used in

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policy development and planning in aquatic ecosystem conservation in Sri Lanka as well as in other countries where plant poisons are still used as a fish catching technique. The use of *T. candida* as a fishing practice should be strictly regulated, as plant poisons cause local extinctions and population reductions of fish in freshwater streams. The village communities need to be educated on the drawbacks of this fishing practice and conservational importance of freshwater fish species richness in the area.

## ACKNOWLEDGMENTS

## RESUMEN

**Impacto en la diversidad y abundancia de peces en riachuelos de la frontera de la Reserva Forestal de Sinharaja, Sri Lanka al pescar con *Tephrosia candida* (Fabaceae).** Las comunidades de algunos países asiáticos, africanos y americanos utilizan las toxinas de las plantas para pescar, sin embargo, los efectos de esta práctica en grupos de peces silvestres son desconocidos. Este estudio se llevó acabo con el objetivo de investigar los efectos del envenenamiento de peces con *Tephrosia candida* en la diversidad y abundancia de peces de agua dulce en riachuelos de la frontera la Reserva Sinharaja en Sri Lanka. En total se realizaron siete giras bimensuales al campo de mayo 2013 a junio 2014. Se muestrearon cinco riachuelos con condiciones ambientales y climáticas similares en la frontera de la reserva de Sinharaja. Como tratamientos se seleccionaron tres riachuelos con práctica activa de envenenamiento de peces y dos riachuelos sin envenenamiento de peces como controles. También, en intervalos bimensuales, se midieron los parámetros físico-químicos y de corriente del agua en riachuelos seleccionados. Se utilizó la electropesca y redes en tres sitios (6 x 2 m) seleccionados al azar a lo largo de cada riachuelo para el muestreo de peces. Se identificaron los peces a nivel de especie, se anotó su abundancia y se calculó el índice de diversidad de Shannon-Weiner para cada riachuelo. Con base en la matriz de similitud de Bray-Curtis se agruparon los riachuelos para composición y abundancia de peces. Los parámetros físico-químicos del agua fueron no significativamente distintos entre los riachuelos (P > 0.05). Se recolectó un total de 15 especies de peces que pertenecen a cuatro órdenes: Cypriniformes, Cyprinodontiformes, Perciformes y Siluriformes; nueve especies (60 %) fueron endémicas y seis (40 %) nativas. Trece especies se encontraron en riachuelos donde no se practica el envenenamiento mientras que cinco especies se encontraron en riachuelos donde sí se daba esta práctica. Cuatro especies endémicas y una nativa estaban extintas en riachuelos donde la práctica del envenenamiento era activa. La abundancia de peces fue significativamente alta en los riachuelos control (32-39/m$^2$) al compararse con los tratamientos (5-9/m$^2$) (P < 0.05). Se concluye que el envenenamiento de peces con *T. candida* puede haber resultado en una reducción significativa de la riqueza de especies, la abundancia total y el índice de diversidad de Shannon-Weiner de las especies de peces en los riachuelos estudiados en la frontera de la reserva Sinharaja. Se recomienda que esta práctica de pesca sea estrictamente regulada y que se informe a las comunidades locales acerca del estado legal del envenenamiento de peces, sus consecuencias y de la importancia de la diversidad de peces para el sustento local y para propósitos de conservación.

**Palabras clave:** planta exótica, *Tephrosia candida*, envenenamiento de peces, Reserva Sinharaja.

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