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Ethno-ichthyology and Diversity of Freshwater Fish in Malaysia

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Ikan dijaja berbau hanyir
Sarat seperahu di seberang sana
Sekilas saja ikan di air
Sudah tahu jantan betina

Literally translated, the popular Malay rhyme means that an expert knows whether a fish is a male or female with just a glimpse of it in the waters. For most of human history, peoples' livelihoods depend on their expertise on the behaviour and habitat of native fish species to provide food and other resources. Traditional ecological expertise is highly valued and consequently the modern Malay language is enriched with a number of fish-based words and sayings. Today, freshwater biodiversity is highly threatened on a global scale (WWF, 2020). At the same time, traditional ecological expertise and practices are declining as young Malaysians move away from rural areas. This article describes and highlights the importance of freshwater fish diversity in Malaysia, from both cultural and ecological perspectives.

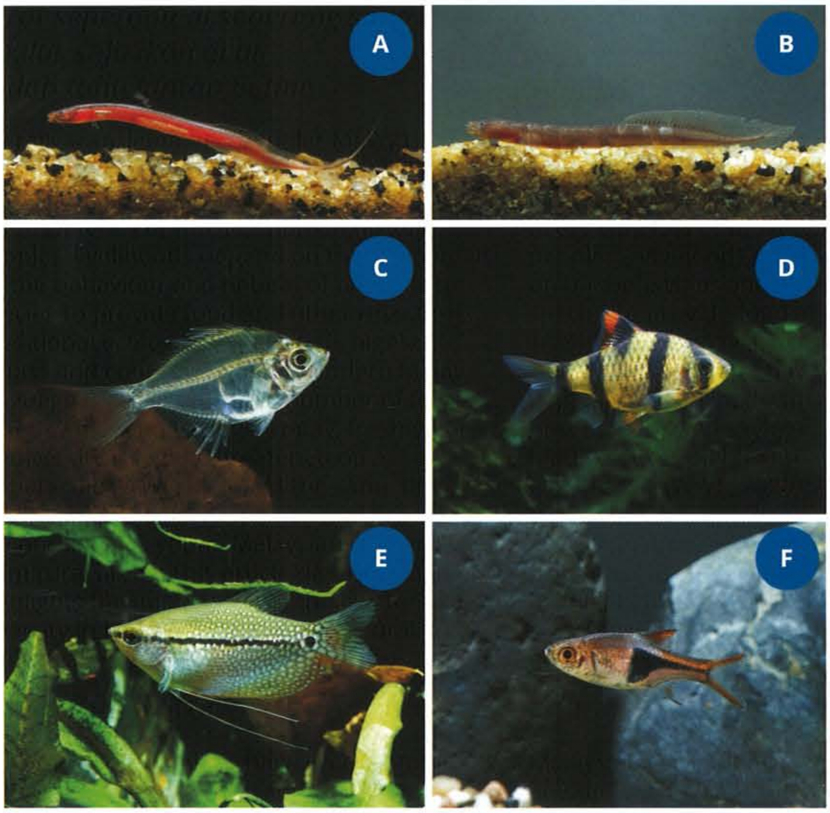


Fig. 1 Some of the diverse forms and colour patterns found in Malaysian freshwater fish: A) *Bihunichthys monopteroides* found in the North Selangor Peat Swamp Forest is named after *bihun*, a local rice noodle; B) Another blackwater swamp fish species has also been named after a local dessert dish: *Chendol keelini*; C) *Parambassis siamensis* is naturally translucent and invisible to predators; D) *Puntigrus partipentazona* is popularly known as 'tiger barb'; E) *Trichopodus leerii* is known as *sepat mutiara* due to the white spots resembling pearls on its body; F) *Trigonostigma heteromorpha* or harlequin rasbora has been collected and traded by the ornamental fish industry since the 1900s.

ETHNO-ICHTHYOLOGY

Malaysian communities have lived alongside aquatic habitats for thousands of years and as a consequence the communities have developed icons, metaphors and other references that illustrate the importance of fish in their daily conversations. In academic work, such interest is consolidated in a branch of anthropology known as ethno-ichthyology which explores and communicates the importance of fish in different human societies. The rhyme, or "*pantun empat kerat*", expressed above is one example. It means an expert always knows what he/she is doing. Another popular metaphor is *berpuyu-puyu*. *Puyu (Anabas testudineus;* Anabantidae) possesses a supra-branchial system that enables it to breathe air. During the monsoon season, groups of *puyu* are often seen crawling out of water and moving across land, searching for fresh puddles to inhabit. Thus, locals often use the expression *berpuyu-puyu* to describe a group of people making a beeline to special events.

Traditional fish-based dishes have also been incorporated into Malaysian sayings. For example, native freshwater fish such as *lampam* (*Barbonymus schwanefeldii;* Cyprinidae) and *loma* (*Thynnichthys thynnoides;* Cyprinidae) are often scaly and bony and are therefore, difficult to eat. Rural societies have responded by storing a mixture of fish, cooked rice and herbs in clay urns to induce fermentation, which softens the bones and scales. This traditional dish is called *pekasam*, *bosou* or *kasam* in Peninsular Malaysia, Sabah and Sarawak respectively. Since the best *pekasam* is often located at the bottom of the urns, a stretched arm with considerable effort is necessary to reach the most fermented and flavourful pieces. Therefore, elders often advise the young ones "*alang alang menyeluk pekasam, biar sampai ke pangkal lengan*" which is a metaphor about perseverance and the necessity of going all out to achieve their dreams.

Aside from language, the cultural importance of fish to Malaysians is also reflected in traditional icons and practices. In fact, *semah* (*Tor tambra;* Cyprinidae) is the official state fish of Sarawak. In Sabah, locals have long recognised the perils of overfishing. Many villages in Sabah still use a traditional fish stock management system called *tagal*; also known as *managal* or *bombon* depending on the local dialect. *Tagal* only allows fish harvesting at certain times of the year or in certain areas (for example, away from fish spawning sites), approved by a committee of local community members. Anyone who violates a *tagal* pact can be tried in the Sabah Native Court. These traditional systems were developed long before "sustainability" and "food security" became popular buzzwords.

In Sarawak, *nubai* was a seasonal community event which used the milky white root sap of *Derris trifoliata* (Fabaceae), a climber plant species, which contains a bio-active compound called rotenone to stupefy fish. Fishes were traditionally harvested and shared in full view of everyone in the community. *Nubai* was overseen by village elders who used their traditional ecological knowledge to manage the dosing of sap so that enough fish were left to repopulate the rivers for future harvests. Groups or individuals who used this plant sap to catch fish without the community's consent could be tried and penalised by a local council of elders.

The use of toxicants for fishing, traditional or otherwise, has now been outlawed in Sarawak and *nubai* events are no longer permitted. This may be a rational directive as the younger generation has lost the traditional ecological knowledge needed to carry out *nubai* events responsibly. Consequently, the traditional ecological knowledge associated with *nubai* is now in decline, and the traditional view of freshwater fish as a community asset may also be lost in the future.

DIVERSITY AND TAXONOMY

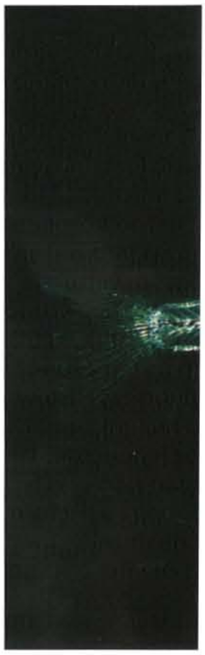
Malaysia is home to a wide range of freshwater ecosystems. The diversity of habitats and unique environmental conditions within each habitat help explain the high levels of fish diversity. There are 449 freshwater fish species

Fig.2 *Clarias leiacanthus* is called *keli dacing* because its slender body exhibits a series of vertical rows of spots that resemble the *dacing*, a traditional weighing scale.

recorded so far in Malaysia. At the time of writing, the Malaysian Biodiversity Information System (MyBIS) has recorded 289, 150 and 254 fish species in Peninsular Malaysia, Sabah and Sarawak respectively. These numbers are expected to increase as new species continue to be described every year. Some species such as *Bihunichthys monopteroides* (Chaudhuriidae; Figure 1A) and *Chendol keelini* (Chaudhuriidae; Figure 1B) are relatively rare in Malaysia as they can only be found in the peat swamps. Others such as *Parambassis siamensis* (Ambassidae; Figure 1C), *Puntigrus partipentazona* (Cyprinidae; Figure 1D), *Trichopodus leerii* (Osphronemidae; Figure 1E) and *Trigonostigma heteromorpha* (Danionidae; Figure 1F) are widely appreciated by aquarium hobbyists for their striking features.

The anatomy of freshwater fish is shaped by the conditions in the rivers, lakes and swamps where they evolved. For example, the Borneo suckers or *Gastromyzon* spp. (Gastromyzontidae) are common in the hillsides of Sabah and Sarawak. These species are endemic to Borneo and possess pectoral and pelvic fins that resemble suction cups for latching on firmly to smooth rocks in torrential rivers. Ichthyologists use anatomical variations in size, shape, function and colouration to name a species based on the Linnean binomial system, which was popularised by the Swedish naturalist Carl Linnaeus in 1735. In accordance with the international scientific convention, the first of the two-part name indicates the genus or group which a species belongs to, and the second name distinguishes the species based on its unique characteristics.

Interestingly, a similar binomial nomenclature system for naming fish species existed in Malaysia long before the time of Linnaeus. In Malay, fish names are traditionally composed of two parts. For example, *Clarias leiacanthus* (Clariidae) is called *keli dacing* in Malay.



All species that look like catfish are given the first name *keli*. And because this species' elongated body displays vertical rows of spots that resemble *dacing*, a traditional weighing scale, *dacing* is the second name for this species (Figure 2). Similarly, *Mastacembelus erythrotaenia* (Mastacembelidae) is called *tilan bara* in Malay because *tilan* is the first name given to all spiny eels and *bara* refers to the fiery red body pigmentation that resembles *bara* or embers.

NATURAL AND MAN-MADE HABITATS

Most natural freshwater lakes in Malaysia are shallow (less than 5 m deep) and undergo seasonal fluctuations in water level that are linked to the flooding of major rivers. Examples of Malaysian floodplain lakes include Tasik Chini which is famous for the seasonal flowering of sacred lotus (*Nelumbo nucifera*; Nelumbonaceae), Tasek Bera which is home to over 100 species of freshwater fish including the arowana (*Scleropages formosus*; Osteoglossidae), and Loagan Bunut in Miri, Sarawak, which is an important cultural site of the Berawan community.

The majority of lakes in Malaysia are man-made, including reservoirs and tin-mine lakes. The deep lakes created by human activities establish different environmental conditions to those found in natural lakes. A number of fish species can establish naturalised populations in man-made lakes, including sport fishes such as *sebarau* (*Hampala macrolepidota*; Cyprinidae) and *belida* (*Chitala lopis*; Notopteridae). Another man-made habitat for fish found throughout Malaysia is rice paddy fields and their associated irrigation networks. Species inhabiting paddy fields include *temakang* (*Helostoma temminckii*; Helostomatidae), *haruan* (*Channa striata*; Channidae) and *belut* (*Monopterus javanensis*; Synbranchidae) which can survive in the poorly oxygenated waters. These fish are traditionally reported to help control insect pests. Paddy fishes also contribute to food security in rural areas where farmers consume them while waiting for the rice harvesting season.

Fig.3 The world's smallest fish *Paedocypris micromegethes*, reaching a maximum standard length of 10–12 mm, can be found in the central of Sarawak. To date, some *Paedocypris* spp. have also been recorded in the peat swamp habitats of Selangor, Terengganu, Pahang and Perak.

Freshwater fish can also be found living among the roots of a naturally occurring waterlogged forest that grows on peat soil. The soil releases organic contents that turn the water dark brown; similar to strong black tea. Hence, these habitats are also called blackwater swamps. The water in blackwater swamps is acidic, around pH 3-4 which is similar to the acidity of lemon juice. Despite these conditions, blackwater swamps are home to a range of freshwater fish, including species which are sought after by local and international aquarium hobbyists, such as *Betta* spp. (fighting fish) and *Parosphromenus* spp. (licorice gourami). Within the relatively small North Selangor Peat Swamp Forest (76,000 ha; about the size of Singapore), 114 fish species have been recorded (Amal *et al.*, 2020), including an undescribed species belonging to the genus *Paeocypris*—the smallest fish and inland vertebrate in the world (Figure 3). These findings highlight the importance of blackwater swamp forests for sustaining Malaysian fish diversity. However, most peat swamp habitats remain understudied and as a result their biodiversity is often underappreciated.

VALUING TRADITIONAL KNOWLEDGE

The appreciation of Malaysia's freshwater fish diversity has been long recognised by local communities, from 'fish-like' cave paintings in Perak dating back 3,000 years or more, to modern day fishermen, aquarium hobbyists and anglers who spend hours waiting for a prize catch. There are many new discoveries still to be made about freshwater fish in Malaysia, including their taxonomy, ecology and the benefits they continue to provide for humans, such as biocontrol of rice pests. However, these discoveries will only be made if the next generation of fish taxonomists and ecologists are trained and supported to fill in these knowledge gaps. The traditional ecological knowledge curated by local communities who have managed freshwater fish stocks and their habitats over many generations can also provide us valuable information. We therefore call for the knowledge held by these communities to be recognised, recorded, and used to inform policies for conserving freshwater biodiversity.

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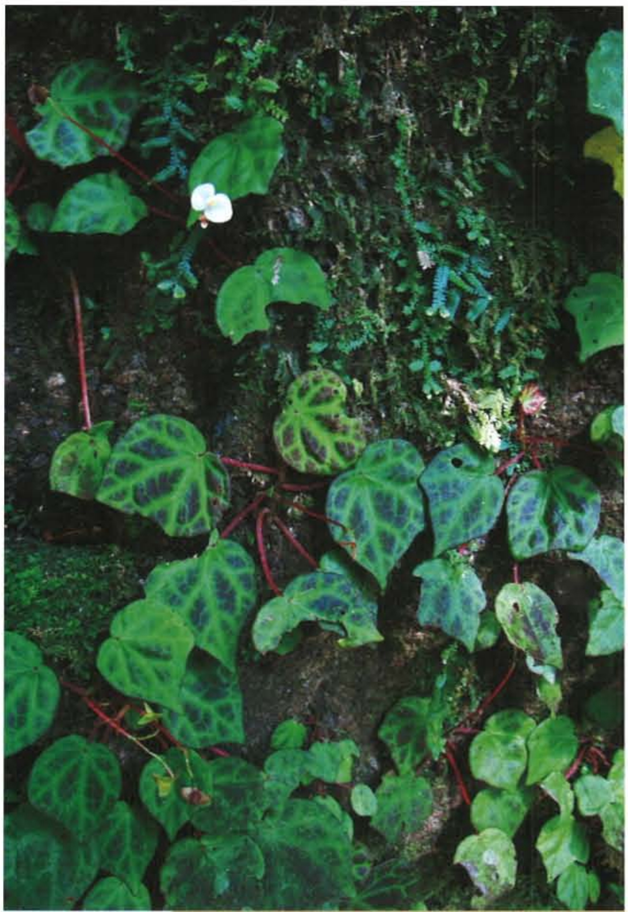

Begonia reginula at its natural habitat on stream boulders in a recreational forest. This regal and elegant Little Queen begonia captivates the heart of many.

Peeking into the sex lives of some indigenous Begonias of Peninsular Malaysia

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The study of floral biology or phenology is important for the prediction of flowering/fruiting and understanding pollination behaviour. To get a good glimpse of the flowering behaviour of *Begonia*, observations were made on 7 species that were cultivated at FRIM's nursery (Table 1). These endemic species are threatened in Peninsular Malaysia, and samples were limited to 1–8 flowering plants per species. The floral biology of *B. kingiana* has been reported in Chan & Tan (2021) and the data are incorporated in Table 1 for comparison and summary.

Male biased – *Begonia abdullahpieei* with unisexual inflorescence producing only male flowers.

In all species studied, inflorescences developed sequentially in a plant. Most inflorescences were bisexuals, bearing separate male and female buds/flowers. Unisexual inflorescences which produced male flowers only, became uncommon with increasing sampling size (Table 1). The number of male buds varied between 2 to 28 per inflorescence, whereas the number of female buds ranged from 1 to 7 per inflorescence.

Bisexual inflorescence of *Begonia reginula* with an open male flower and developing female buds (with green ovaries).

Records on early bud development were often incomplete because of intermittent or missed observations and some flowering events were not observed daily. Nevertheless, on average, the development of male bud to anthesis took about a week and up to 2 weeks (e.g. in *B. aequilateralis*). Female bud development took a slightly longer time than the male and usually began in the middle of the anthesis phase. All species observed were protandrous (meaning male flowers open first before female flowers), except *B. jiewhoei* where no female buds developed or the inflorescences aborted early. Flower sex ratios were biased to males, ranging 3–11 and was exceptionally high in *B. kingiana* (Table 1).

Flowers opened in the morning. Within a flower, on average, male anthesis was 2–5 days and female receptivity was 3–5 days. Within an inflorescence, the anthesis and the receptive phase normally did not coincide with each other. Time gap between them was common in *B. aequilateralis* and *B. rhoephila*, but not so in *B. kingiana* and *B. forbesii*. In some inflorescences of the latter two species, anthesis and receptivity overlapped 2–7 days, giving opportunities for self-fertilisation within the inflorescence. Additional details on the flowering behaviour are described below for selected species.

B. aequilateralis

Male anthesis began in the morning with tepals fully opened around 8.30–8.50 am. Stamen matured from centre to periphery. In the evening at about 4.30 pm, the flower closed its 2 lateral tepals (another 2 vertical tepals remained open). The lateral tepals opened again in the next morning around the same time. Anthesis ended when the flower dropped after about 4 days, in the evening. Female buds started to appear in the middle of the anthesis phase.

Table 1. Floral behaviour of *Begonia* species.

	Parameters	*B. abdullahpieei*	*B. aequilateralis*	*B. orbesii*	*B. jiewhoei*	*B. kingiana*	*B. reginula*	*B. rhoephila*
1	N plant	2	2	3	2	8	1	8
2	N inflorescence	2	3	7	3	13	2	14
3	N unisexual (male only) inflorescence	1	1	1	ND	2	1	2
4	N male bud per inflorescence	3	8-14	2-3	5-6	6-28	3	3-7
5	N female bud per inflorescence	1	3	1-2	ND	1-7	1	1-2
6	Development of male bud, mean (range), in days	8.5 (7-10)	16 (10-22)	ND	9 (7-10)	12 (9-15)	6	8 (5-16)
7	Anthesis duration within the flower, mean (range), in days	4.3 (1-5)	3.6 (1-6)	2	3.4 (2-4)	3 (1-7)	4.7 (3-6)	3.4 (1-6)
8	Anthesis duration within inflorescence (day)	5-14	11-14	ND	3-17	8-33	6-10	6-17
9	Development of female bud, mean (range), in days	at least 10	at least 16	8	ND	15 (7-32)	ND	16 (14-21)
10	Female receptivity, mean (range), in days	ND	ND	3.6 (2-14)	ND	5 (3-6)	ND	5.2 (3-7)
11	Time gap between anthesis and receptivity within inflorescence (day)	ND	7	1	ND	6	ND	12
12	Male to female sex ratio, mean	3	4.0	ND	ND	10.9	ND	3.7

ND - no data.

After you – Within an inflorescence, male flowers of *B. forbesii* developed before female flowers, forming a temporal gap between anthesis and receptivity, and hence, avoiding self-pollination. Pictured here are opened male flowers and female buds (with red ovaries).

Soul-mate? *B. rhoephila* with male flower (above) and female flower (below) on separate inflorescences but opened at the same time, allowing self-pollination to occur.

B. rhoephila

Male flowers opened at 5–6 am and closed in the evening around 4–5 pm, but a few remained open throughout the day. In a same inflorescence, female buds developed during male anthesis phase, and female receptivity did not coincide with anthesis. Female flowers opened 11–13 days after the end of anthesis. Of the total 15 female buds, 33% aborted prematurely after 5–9 days of development.

When a single plant produced 2 or more inflorescences successively, there was a temporal gap of at least 1 week between the female receptivity of the first inflorescence and the male anthesis of the subsequent inflorescence. In one particular observation, the two phases overlapped for 7 days, enabling possible self-fertilisation within plant via pollinators or hand pollination.

In summary, begonia flowers open in the morning, and temporal gap between anthesis and receptivity in *Begonia* species indicates preference for outcrossing. For hand pollination studies, the best time frame for pollination of flowers should be within the first 3 days of floral bloom for both sexes.

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Is *ex situ* relocation or introduction of threatened species workable? Preliminary results of seeding and transplanting of begonias into a similar natural habitat

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Pretty alone out there - The serene and tranquil *ex situ* stream habitat of *B. abdullahpieei.* The plant flowered and fruited a few times after transplanting.

To a nature lover who has deep respect and appreciation of Mother Nature, scenes of beautiful pristine forests being bulldozed for logging or stripped bare for land development, leaving behind disfigured landscapes of bald patches or forest fragments with damaged trees slowly bleeding to death, is indeed disturbing and heart-wrenching. Many rare endemic species are often hapless victims of such destructive activities, and those that cheated death are left to fend for themselves in the detrimental and badly degenerated habitats. For some, the population may drastically decline because of habitat loss. Begonias are such a group of plants that have had such a similar fate and, regrettably, infamous as one of the most threatened families in Peninsular Malaysia (Lillian Chua SL, FRIM, pers.comm.). To safeguard species from extinction, *ex situ* conservation is often required, by duplicating the population elsewhere, if the original population ever perishes in the future.

Ex situ conservation in nurseries is a common practice but not without teething problems. Species that require very specific habitat and conditions to grow, such as endemic begonias, are 'fussy' or sensitive to environmental changes and are often difficult to maintain in nurseries. Furthermore, in a well-equipped nursery facility with controlled environment, long term maintenance of living collection is costly and space is limited.

A good alternative to keeping species in a nursery is the translocation or introduction of targeted populations to another similar habitat. To succeed, sufficient understanding of the natural history and ecological requirements is much needed. Fortunately for begonias, such information is available (Kiew 2005, Chan 2018).

Planting trials are important tests to conditions for *ex situ* establishment and maximum survival of a new population. This pilot study was a test bed for seeding and transplanting of various species of native begonias into an *ex situ* natural habitat, and served as an investigation into the future work on population relocation, when the need arises.

Suitable planting sites in FRIM were identified, i.e., 2 small natural streams at the Rover forest trail, at selected microsites with moist rocks of little vegetation, high humidity and shade under the forest canopy. The mean temperature and relative humidity across 11 microsites in August 2010, was 25.7 °C and 90.2 %, respectively. The canopy gap index was measured once in 2013, 2015, 2017 and 2019 using a canopy scope (Brown et al., 2000), and the mean index was 2.8 (ranged 1–20, 13 microsites) or 11% of gap exposure, indicating low light environment. Planting in natural streams allowed us to further understand the plant behaviour such as growth, response to environment stochasticity or reproductive patterns in a more natural setting.

Transplanting Pilot Test

The first trial began in July 2009 using 21 plants of 3 rare species i.e. *Begonia abdullahpieei*, *B. aequilateralis* and *B. herveyana*. These species are rhizomatous and grow on rocks in streams. I used 2-year-old seedlings of *B. aequilateralis* and *B. herveyana* and half-year-old clones of *B. abdullahpieei* (propagated via leaf cuttings) as transplants.

Leaving their comfort cocoons in the nursery, the plants were transplanted to 18 microsites and placed on top, sides or crevices of rocks, facing away from direct streamflow. They were closely monitored for 2–3 days in the first week as the plants adapted to the unpredictable environment. After several weeks, 2 plants were dislodged or washed away while the rest performed relatively well. After 6 weeks, some plants secured anchorage onto rocks.

The plants were unfortunately short-lived. In the first 3 months, 76% of the plants were still alive while the rest disappeared, most likely being washed away by heavy rains. After 6 months, the percentage dwindled to 19%. A few plants were smothered by leaf litter cast by the large leaves of *Artocarpus* sp. Only 4 plants survived the first year and those planted in rock crevices had a better survival rate. After 3 years, only 2 plants remained. The last survivor, *B. abdullahpieei,* mysteriously disappeared in the 5th year (2014).

Second Transplant

After testing the ground and learning from the first trial, I proceeded with the second trial using clones (with 2–7 leaves) propagated from leaves. These clones had well-established roots and required gentle handling when removing the soil. A total of 24 transplants comprising *Begonia abdullahpieei, B. holttumii, B. kingiana, B. maxwelliana, B. rhoephila* and *B. yenyeniae* were planted at 8 microsites during wet seasons in March, October and December 2013. The plants were tied with cloth ribbons onto damp, vertical rock faces or in crevices, away from direct streamflow and was neither inundated by water nor too dry. The roots more or less touched the ground and were covered with some leaf litter to avoid dehydration. After 3 years, only 5 plants remained and until now in 2021 after 8 years, 2 plants, namely *B. rhoephila* and *B. kingiana*, are

Mistake me not! Pollinators such as stingless bees are often hoodwinked to pollinate the rewardless female flowers (left) that resemble male (right) flowers that carry pollen. Such ingenuity and craftiness of begonias in devising pollination by deceit.

still growing peacefully and contented in their new-found home.

In both trials, at least 1 month was needed for transplants to anchor firmly onto rocks. Possible causes of mortality included root damage when transplanting, planting site too wet causing root rot, physiological stress or failure to adapt to a new environment, dislodgement by downpours or stream floods and smothering by leaf litter. At times, some plants were miserably bare of leaves (could be a sign of physiological stress), leaving the rhizome behind as if dead. They sprang back to life when new leaves eventually grew again but in much smaller sizes.

Some Success Story

Despite the high failure rate of transplants, 2 species grew well and successfully flowered or fruited after transplant:

a) *Begonia abdullahpieei*

Transplanted in July 2009, I was delighted to see the plant sweetly blossomed from December 2011 to February 2012, with 3 inflorescences flaunting the unblemished white pinkish flowers adorned with yellow stamen or stigma in the middle. During this period, the plant had 11 leaves and the biggest leaf was 7 cm in width. Only 1 mature fruit was produced and it contained a lot of undeveloped seeds. Viable seeds were estimated at c. 856 and from these, 34 seeds (c. 4%) germinated on sphagnum moss in a petri dish. Only 8 seedlings (0.9%) remained after 1 year and sadly, none survived the second year. The same plant again flowered and set fruits in August 2012. Two months later, 1 of the 2 mature fruits containing about 20 seeds was collected. Only 6 (30%) seeds germinated and 3 (15%) seedlings remained after 1 year. None survived after 2 years. Successful fruiting and seed germination indicate that the species is self-compatible.

Growing stronger, the plant flowered once more in July 2013 (5th year) and later branched into 2 ramets in December 2013. Subsequently in April 2014, an inflorescence was produced but no fruit was observed in June. To my dismay, the plant lost all its leaves except one tiny leaf in July. Hanging on, it regrew 7 leaves of juvenile-sized in November but sadly, it vanished in the 6th year in September 2015, and the cause of mortality is unknown.

b) *Begonia rhoephila*

The plant possessed 8 leaves (the widest leaf was 8.5 cm) and flower buds when transplanted in March 2013. It flowered 2 weeks later but no fruit was set. In 2016, it branched and formed 2 ramets and a year later, the biggest leaf size was 18 cm long x 7 cm wide. No flowering/fruiting was observed since 2013 until finally in April 2022, a dried fruit capsule and a flower bud were seen.

Seed Planting Trial

In June 2010, seeds of *Begonia aequilateralis* and *B. herveyana* were sown at 20 microsites of both streams, on vertical rock faces, mostly with some moss cover. Germination occurred at 12 microsites. Possible reasons for the failed establishment of seedlings at some microsites could be: seedlings died at the initial stage, microsites were unsuitable (too dry or too wet) or seeds were not viable.

At one particular microsite where seeds of *B. herveyana* were sown, ample seedlings germinated and survived (this microsite had the most number of seedlings among all microsites). The microsite was sheltered from direct rain pours, humid and exposed to little sunlight. The mean daylight intensity was 2,291 lx, the mean temperature was 25.2 °C and the mean relative humidity was 98 % (sampled in January, May and July 2012 and June 2013 with a total of 86 days of hourly records for 24 hrs). About 30 seedlings emerged after 1 mo. Subsequently, the number decreased to 17 after 1 year (the plants had 2–3 leaves of c. 1 cm wide), 9 in the 3rd year and finally 5 juveniles remained in the 9th year (leaf sizes: 2–4 cm wide x 3–8 cm long) and are still alive until today. The largest leaf size recorded was in the 4th year i.e., 8.5 x 14.4 cm.

Begonia aequilateralis also grew quite well from seeds at another microsite, with 19 seedlings (biggest leaf width = 1.6 cm) after 1 year. In the 3rd yr, 5 seedlings were left with each plant having 6–14 leaves (leaf width 2–5 cm). In the 7th year, 2 survived (biggest leaf: 7.9 cm width x 22.2 cm long) and finally only 1 juvenile left after 11 years in 2021.

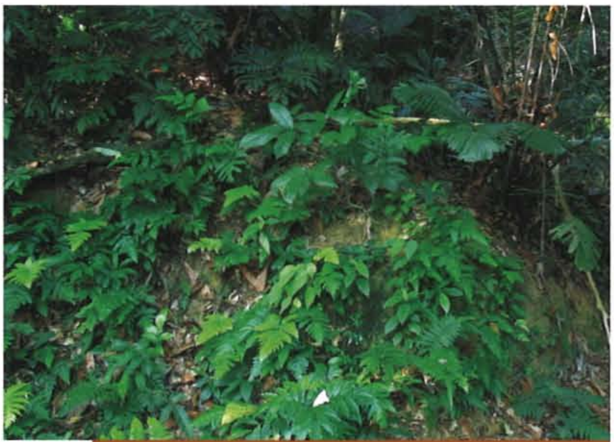
Another species, *B. holttumii* was sown later in August 2010 at microsites similar to its natural habitat, i.e., earth-covered rocky stream banks. Some were sown on vertical rock surfaces. On one particular earth bank next to the Rover trail, after 1 month, numerous tiny seedlings emerged and after 6 mo, there were about 140 seedlings. After 1 year, the number reduced to c. 50 plants (leaf width 1–2.5 cm) and after 1.5 year, 30 plants left (leaf width 4.5–9.5 cm). In 2014, 2 adults remained and none survived by 2017, overgrown by bushes.

Begonia holttumii was much faster-growing than *B. aequilateralis* and *B. herveyana*. Plants that grew on earth banks were much larger than those on vertical rock faces. The largest plant had leaf width up to 4.5 cm after 1 year and the size doubled after 2 years.

Tying the knot and till death do us part - *Begonia rhoephila* comfortably settling down at a sheltered microsite.

Welcome on board! Microsite with most seedlings of *Begonia herveyana*. Inset: One-year-old seedlings in August 2011.

Patience is needed for slow growing *B. herveyana*. Fit and healthy plants after a decade in September 2021.



Spot me if you can - *Begonia holttumii* (centre) growing among weeds next to the forest trail. All died in 2018 because covered by fallen giant aroid.

Just in 2 years, *B. holttumii* successfully reproduced with a total of 5 plants flowering from 2012 to 2016. Three plants on the earth bank next to the trail, started flowering and fruiting from December 2012 until March 2013 and subsequently flowered in June 2013. The biggest leaves were 8–11 cm in width. This site was more exposed to the sun and surrounded by weeds and small shrubs. At another shady microsite next to the stream, one particular plant grew very well and branched into 2 ramets (c. 12 leaves per ramet). It flowered and fruited every year from February 2014 until June 2016, producing up to 4 inflorescences and 6 fruits in a single flowering season. The biggest leaf size was 12 cm wide x 21 cm long at reproductive stage. This plant was last seen in 2017 and no longer found in 2018.

Begonia holttumii has an erect stem, and in this study, one mature plant grew up to 20 cm in height. It is also able to regenerate easily from broken leaves or stems and form clones. These salient features enable the species, to some extent, to survive and compete with weeds. In 2014, weed clearing was carried out as part of the trail maintenance, and 7 out of 10 plants growing next to the trail were damaged. Fortunately, most survived and regenerated. However, in 2018, all plants disappeared after further disturbances i.e., being covered by fallen plants or overgrown by weeds. Such catastrophic events by chance demonstrate the high vulnerability of very narrowly distributed species to local extinction. During the last visit in September 2021, only one juvenile surviving well on a big boulder, overshadowed by weeds.

Summary

This preliminary study showcased a viable option or workable solution to implement *ex situ* conservation of rare and threatened begonias in a non-native natural environment. It convinced us that conservation of such begonias can be strengthened through establishing or duplicating more populations into similar natural habitats. Nevertheless, the planting methodology and microsite selection may need fine-tuning to increase the survival rate of transplants or seedlings. Ideal conditions would be of high humidity, low light intensity, well-drained and free from heavy leaf litter or weeds. Many a time we have to try by trials and errors as it is difficult to experiment *in situ* because of so many uncontrollable factors interacting in the wild. Seed propagation is suitable for fast-growing species such as *B. holttumii* or *B. maxwelliana* whereas for very slow-growing species (e.g. *B. aequilateralis, B. herveyana* and *B. tampinica*), clonal propagation is recommended.

After transplanting, many of the plants dropped their leaves, perhaps sensitive to stress and changes in a new environment. Hence, acclimatisation of transplants to a new environment may be needed. Another method worth trying in future is to attach leaf cuttings directly onto rocks to grow by themselves without the need for acclimatisation. A much more important consideration is the careful selection of planting microsites suitable to the targeted species.

Proud of you – *Begonia holttumii* grown from seeds, first flowered and fruited just after 2 years.

This plant of *B. holttumii* without fail, flowered and fruited annually from 2014 to 2016.

Planting should be followed up by regular monitoring and tending or weeding if necessary.

A newly introduced population may take years for it to flourish, reproduce and viable on its own and may not fully substitute or replicate the original population. Hence, *in situ* conservation still deserves the utmost priority and should not be compromised. *Ex situ* conservation is an added bonus that serves as a backup. In summary, effective *ex situ* conservation of threatened species with minimal cost and effort is possible through the introduction of populations into similar natural habitats.

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