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Global extinctions of freshwater fishes follow peatland conversion in Sundaland

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The peat swamp forests (PSFs) of Sundaland, in Southeast Asia, support many endemic freshwater fish species. However, the future of these species is in doubt, owing to ongoing PSF deforestation. Here, we show that, if current rates of PSF conversion to a predominantly agricultural mosaic landscape continue through 2050, 16 fish species may become globally extinct. In the worst-case scenario, where the rate of conversion across the region matches that of the most rapidly deforested river basin, 77% (79 of 102 species) of the narrowly adapted (stenotopic) fish species are likely to become extinct, a figure that would more than double known extinctions of the world's freshwater fishes. As indicated by our analysis, the PSFs of Indonesia's Central Kalimantan region would be most severely impacted.

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Peatlands in the Sundaland biodiversity hotspot, which includes the Malay Peninsula and the islands of Borneo, Java, and Sumatra, constitute 36% (160 000 km^2) of the global tropical peatland area (Miettinen and Liew 2010; Page *et al.* 2011). Peat swamp forest (PSF) – a lowland forest ecosystem characterized by restricted and distinctive floristic communities – forms atop peat soils derived from woody plant debris (Figure 1, a–c; Posa *et al.* 2011). PSFs were long assumed to be biologically impoverished (Janzen 1974), as the swampy terrain, dense spiny undergrowth, and highly acidic water (~ pH 3) combine to impede field research (Posa *et al.* 2011). In recent years, however, surveys have uncovered numerous freshwater fish species that are narrowly adapted (stenotopic) to the highly acidic blackwater streams in Sundaland's PSFs (Figure 1, d–m; eg Ng *et al.* 1994; Kottelat *et al.* 2006).

The future of these stenotopic fish species is threatened by the unabated conversion of Sundaland's PSFs to industrial-scale forestry and monoculture plantations (Figure 1, b and c; Koh *et al.* 2011). By 2010, more than 60% of Sundaland's PSFs have already been lost (Miettinen *et al.* 2012), yet few studies have assessed the threat to biodiversity from PSF conversion, particularly in terms of the risk and likely magnitude of species extinctions. Here, we forecast the magnitude and geography of fish species extinctions in Sundaland under alternative land-use change scenarios, to inform conservation policy in the region. Specifically we ask the following three questions: (1) how many fish species will likely become extinct if the current trajectory of land-use change continues to 2050? (2) Which fish species are the most vulnerable? (3) Which river basin is likely to lose the greatest number of fish species?

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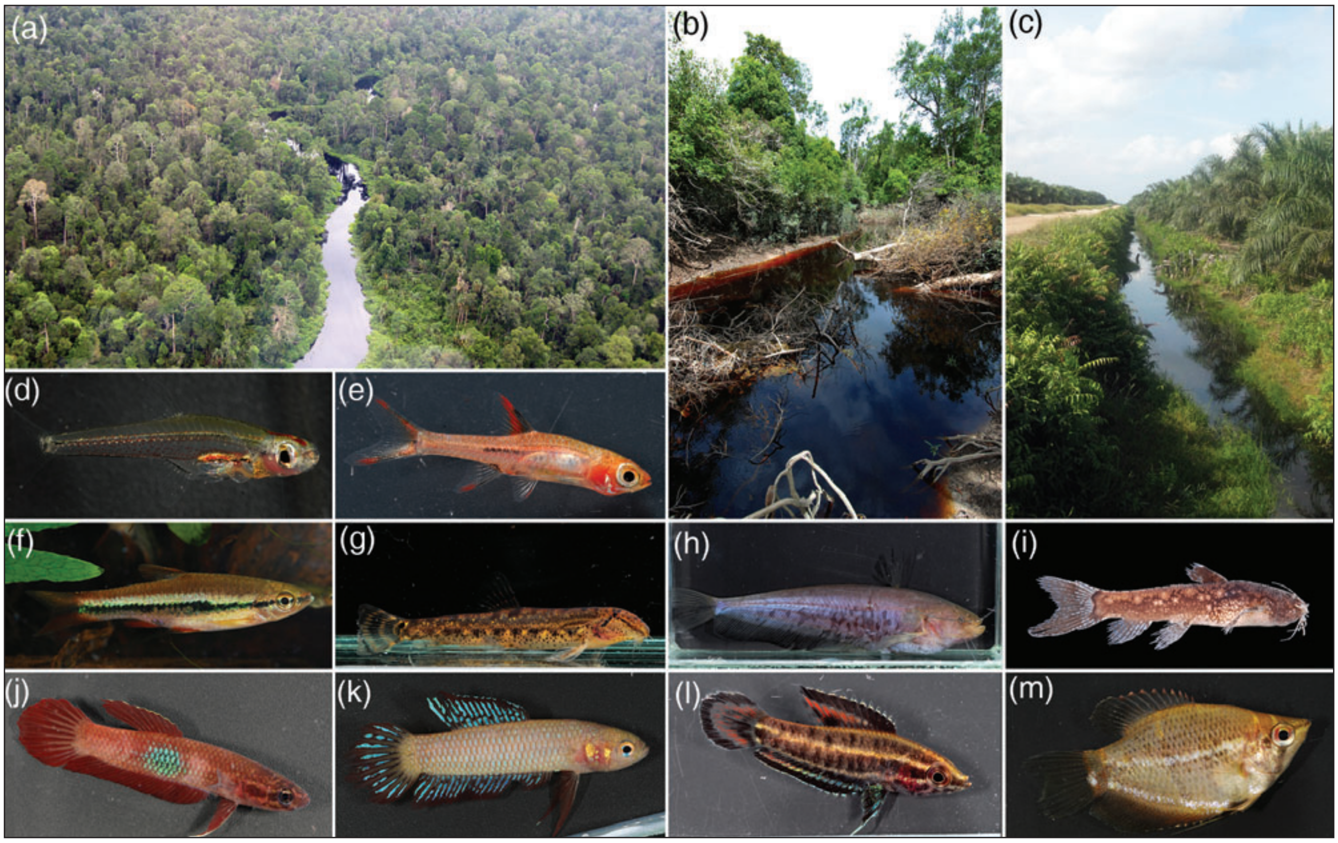
Methods

Delineation of basins and species dataset

Sundaland is a biogeographical region in Southeast Asia that includes the Malay Peninsula on the Asian mainland and the large islands of Borneo, Java, and Sumatra and their surrounding smaller islands. We identified independent PSF river basins by combining a map of river basins (FAO 2005) with a peatland land-cover map (Miettinen *et al.* 2012). Where peatland areas straddle one or more river basins, these were combined into a single PSF river basin. Thus, PSF river basins were considered independent when they are separated by at least one river basin that does not contain peatland. In total, 10 PSF river basins were included in our analysis (Figure 2). We collated a list of stenotopic PSF fish species native to each river basin by sampling 208 blackwater localities (ie PSF streams characterized by tea-colored water owing to high levels of humic acids) across Malaysia and Indonesia over the period 1991–2010. A variety of fishing gear – such as tray-nets, scoop nets, and seines – was used to obtain a comprehensive sample of fish species, based on the physical characteristics (eg stream width and depth) of each sampling locality. Despite the absence of a standardized sampling regime, data across localities were likely comparable given that the method was chosen to sample the fish assemblage as comprehensively as possible. To verify and improve the coverage of our dataset, we performed an exhaustive search of the published literature for distributions of fish species (eg species descriptions, taxonomic revisions, and checklists; WebTable 1).

To evaluate the completeness of our primary data (ie



X Giam (a, c); HH Tan (b, d–m)

Figure 1. *Landscape and stenotopic fish biota of Sundaland's peatlands. Continuum of disturbance on peatlands: (a) a stream running through intact PSF in Sumatra, (b) a stream running through degraded PSF in Kalimantan, and (c) a canal in an oil palm estate. Stenotopic PSF species: (d)* Paedocypris carbunculus, *(e)* Boraras merah, *(f)* Rasbora patrickyapi, *(g)* Kottelatlimia hipporhynchos, *(h)* Ompok supernus, *(i)* Parakysis notialis, *(j)* Betta brownorum, *(k)* Betta uberis, *(l)* Parosphromenus opallios, *and (m)* Sphaerichthys selatanensis.

obtained by sampling), we generated species accumulation curves and computed incidence-based coverage estimator (ICE) and Chao2 species estimators in EstimateS 8.2.0 (Colwell *et al.* 2004). Sampling completeness was high across all basins except for that of Borneo's Kapuas River. However, the inclusion of secondary data (ie obtained from the literature) ensured that the species list for each basin was complete. The total number of species in each basin, after including secondary data, was close to or exceeded the "true" species richness calculated by the species estimators (WebFigure 1). We used the total number of species (from primary and secondary data, not from species estimators) in our analysis.

Our final dataset consisted of 102 stenotopic PSF freshwater fish species restricted to the basins investigated in this study. Most major PSFs were included; the only exceptions were PSFs in the Mahakam basin (West Kalimantan, Indonesia) and the Kamparkiri-Siak region (Sumatra, Indonesia), for which species lists and/or land-cover data were not available. Lists of sampling localities and literature consulted are presented in WebTable 1.

Scenarios of land-use change, 2010–2050

We calculated the deforestation rate in each river basin for the past decade by overlaying peatland land-cover maps for the years 2000 and 2010 (Miettinen *et al.* 2012) with basin boundaries (FAO 2005). The land-cover map identified five terrestrial land-cover types (forest, plantation/regrowth, mosaic, open, and urban). Because plantation/regrowth, mosaic, and open sites appeared to be similar for successive stages of PSF degradation, we pooled these areas to form a single "degraded peatland" category. The original land-cover type is thus forest, whereas degraded peatland and urban land cover are the two converted land-cover types.

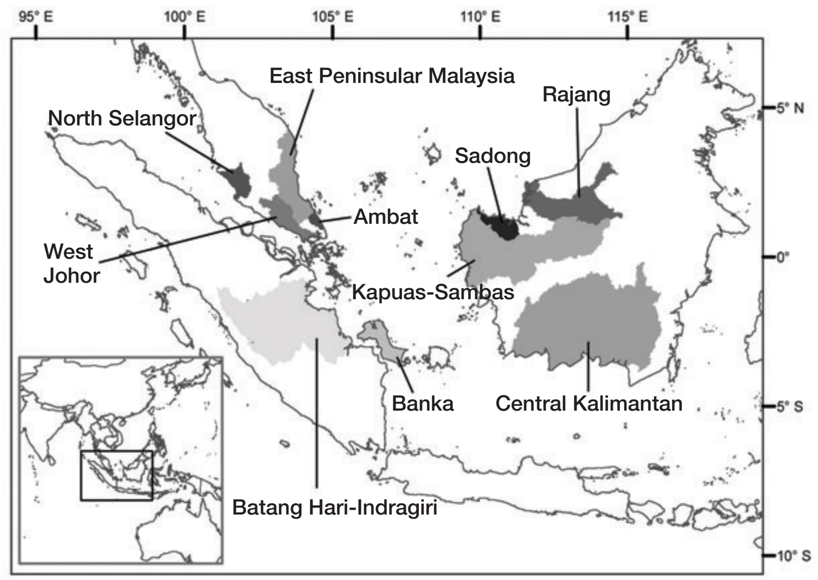
In this analysis, we considered three scenarios of land-use change, projected to 2050: (1) business-as-usual (BAU), where basin deforestation rates estimated for 2000–2010 were applied to 2010–2050; (2) conservation (CONSERV), where each basin's deforestation rate followed the slowest deforesting basin seen during the period 2000–2010 (except North Selangor [Figure 2], which was assigned a deforestation rate of zero because no deforestation occurred in 2000–2010); and (3) conversion (CONVERT), where each basin's deforestation rate followed the basin with the highest deforestation rate in 2000–2010. We assumed the ratio of urban to degraded peatland area in 2050 would be the same as that which existed in 2010. Summary land-cover statistics are presented in WebTable 2.

Although we did not have an a priori expectation of the likelihood of each scenario – which depends on factors such as the future market demand for crops grown on peatlands (eg oil palm and pulpwood) and government policy – these scenarios represent a range of probable land-use change trajectories, given they are based on historical rates of PSF conversion.

Matrix-calibrated species–area model

We predicted the number of fish species that would become extinct under the three land-use change scenarios described above, using the matrix-calibrated species–area model (MCSAM; Koh and Ghazoul 2010). Our estimates represent the number of fish species that will eventually become extinct and not merely those that will be lost by 2050 (Thomas *et al.* 2004); a lack of information on the time lag between habitat loss and fish extinctions precluded the latter estimation.

The MCSAM, previously applied to forecast local bird extinctions following peatland conversion to oil palm plantations (Koh *et al.* 2011), recognizes that converted landscapes may support some forest biodiversity and that different converted land-use types vary in their ability to support forest biodiversity (Gibson *et al.* 2011). Conversely, predictions from the conventional power-law species–area model (Arrhenius 1920) assume that all converted lands are completely inhospitable to forest biodiversity. Models are further explained in WebPanel 1.



Basins	Annual forest loss (2000–2010)	Number of species	Extinction projections: Basin CONSERV	BAU	CONVERT	Global CONSERV	BAU	CONVERT
Ambat	−3.83%	5	0.88 (± 0.00)	1.45 (± 0.01)	4.19 (± 0.01)	0.19 (± 0.00)	0.34 (± 0.01)	3.01 (± 0.01)
Banka	−3.79%	13	1.83 (± 0.01)	3.74 (± 0.01)	10.93 (± 0.01)	0.83 (± 0.01)	1.90 (± 0.01)	8.48 (± 0.01)
Batang Hari-Indragiri	−4.29%	26	3.64 (± 0.01)	8.26 (± 0.02)	21.91 (± 0.02)	1.28 (± 0.01)	3.23 (± 0.01)	18.58 (± 0.02)
Central Kalimantan	−1.69%	45	6.31 (± 0.02)	6.25 (± 0.02)	37.91 (± 0.04)	3.59 (± 0.01)	3.82 (± 0.01)	34.06 (± 0.04)
East Peninsular Malaysia	−2.97%	9	1.21 (± 0.00)	2.09 (± 0.01)	7.54 (± 0.01)	0.25 (± 0.00)	0.57 (± 0.01)	4.80 (± 0.01)
Kapuas-Sambas	−2.07%	34	4.72 (± 0.01)	5.74 (± 0.01)	28.63 (± 0.03)	2.48 (± 0.01)	3.28 (± 0.01)	25.63 (± 0.03)
North Selangor	0.45%	8	0	0	6.78 (± 0.01)	0	0	4.30 (± 0.01)
Rajang	−10.58%	7	0.99 (± 0.00)	4.33 (± 0.01)	5.88 (± 0.01)	0.05 (± 0.00)	2.06 (± 0.01)	3.79 (± 0.01)
Sadong	−19.98%	10	1.39 (± 0.01)	8.43 (± 0.01)	8.43 (± 0.01)	0.33 (± 0.00)	3.56 (± 0.01)	6.36 (± 0.01)
West Johor	−3.14%	9	1.21 (± 0.00)	2.20 (± 0.01)	7.56 (± 0.01)	0.32 (± 0.00)	0.60 (± 0.01)	5.42 (± 0.01)

Figure 2. *Projected number of freshwater fish species extinctions (basin and global) under the three land-use change scenarios. The locations of the PSF river basins and the location of Sundaland in Asia are shown.*

The MCSAM is expressed as:

$$S_{new} = S_{orig}\left(\frac{A_{new}}{A_{orig}}\right)^{\gamma(\Sigma_i^n p_i \sigma_i)} \qquad \text{(Equation 1)},$$

where A and S represent forest area and species richness, respectively, and the subscripts *orig* and *new* denote values before and after forest conversion. Additionally, p_i is the proportion of the *i*th converted land-use type relative to total converted land area, whereas σ_i is the sensitivity of the species assemblage toward the *i*th land-use type (calculated as the proportional reduction in species richness after conversion of forest into the *i*th land-use type). The γ constant reduces to the slope of the power-law model (z) when the converted area is completely inhospitable to the species assemblage ($\Sigma_i^n p_i\sigma_i = 1$).

MCSAM parameterization

The sensitivities of stenotopic PSF fish to degraded peatland and urban land cover (σ_i parameter) were assigned values of 0.667 and 1, respectively, based on a field study (Beamish *et al.* 2003; WebPanel 2). We estimated γ (equivalent to z, the slope of the power-law model in true island systems where the matrix is the completely inhospitable ocean) by compiling (fish) species–(basin) area relationships (SARs; following Drakare *et al.* 2006). We derived an estimate of $\gamma = 0.333 \pm 0.087$ (mean ± standard deviation [SD]) and used this value in the MCSAM (WebPanel 2). Parameter values used in the MCSAM are presented in WebTable 3.

Monte Carlo simulations to project basin extinctions

We performed Monte Carlo simulations to estimate the likely number of fish extinctions in each basin, while

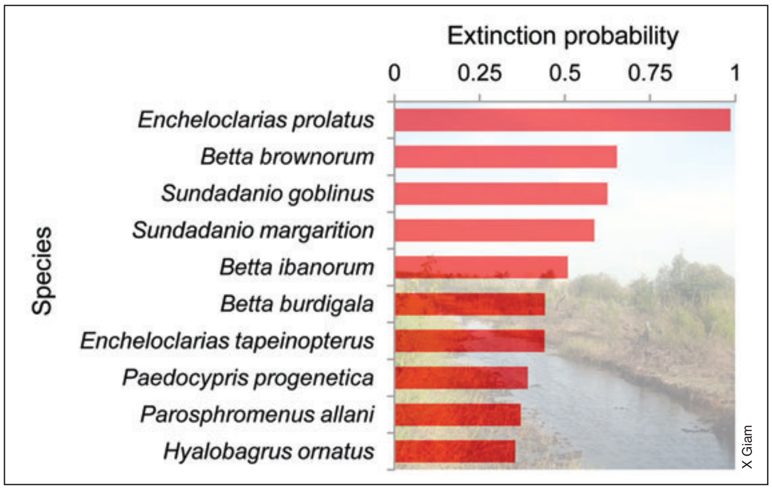


Figure 3. *Mean probability of global fish extinction under business-as-usual (BAU) deforestation rates for the 10 most vulnerable species (standard errors are presented in WebTable 4).*

incorporating the uncertainty around the γ parameter in the MCSAM. For a total of 10 000 iterations, we drew γ from a positive-truncated normal distribution with mean and SD derived from the meta-analysis of SARs (WebPanel 2) to calculate the number of species after conversion S_{new} (Equation 1). The number of extinct species S_{ext} was calculated as the difference between the number of species before and after land-use conversion, rounded to the nearest integer (Equation 2):

$$S_{ext} = round\ (S_{orig} - S_{new}) \qquad \text{(Equation 2).}$$

Global extinctions and relative species vulnerabilities

For every iteration of the Monte Carlo procedure, we sampled from each basin's species assemblage without replacement to generate a set of n extinct species, where n was predicted by the MCSAM (Equation 2). Giam *et al.* (2011) showed that local geographic range (number of drainages occupied by a species) is the best predictor of freshwater fish extinctions in Singapore. Moreover, habitat loss may exacerbate recruitment limitation in rare species (Rees *et al.* 2000; Myers and Harms 2009) owing to the "wastage" of individuals dispersed into unsuitable habitats, further predisposing rare species to extinction. We therefore assumed that the probability of each species going extinct in a basin is proportional to the number of sites in the basin for which each species is recorded (ie if species A is recorded from twice the number of sites as species B, then species B is twice as likely to go extinct as species A). Species added from published studies but not directly recorded in our surveys were assumed to be found in only one site in each basin. Given that all species considered in this analysis are restricted to PSFs in the 10 basins included in this study, we deemed a species as globally extinct when it is lost from all basins. By consolidating species extinctions across basins, we determined the number of global extinctions in every iteration of the Monte Carlo procedure. We reported the mean (and its standard error [SE]) of the number of global extinctions across 10 000 iterations. In addition, we calculated the mean (and SE) of the number of global extinctions contributed by each basin.

To rank a species by its extinction vulnerability, we calculated the probability of each species becoming extinct by counting the number of iterations (out of 10 000) in which the species becomes globally extinct. We performed the Monte Carlo procedure 100 times and reported the mean (and SE) probability of each species becoming extinct. All analyses were conducted in R 2.13.1 (http://cran.r-project.org/).

Results and discussion

Out of 102 stenotopic species, the model predicts that an average of 16 (± 0.03 SE) species will be extinct globally by 2050 under the BAU scenario. The mean number of predicted extinctions increased to 79 (± 0.05) species in the CONVERT scenario and decreased to 9 (± 0.02) species in the CONSERV scenario (1.6% per annum) Global extinctions would be highest in the Central Kalimantan and Sadong basins in the BAU scenario, whereas Central Kalimantan and Kapuas-Sambas will experience the highest number of global extinctions in both the CONSERV and CONVERT scenarios (Figure 2). Similar patterns are evident for predicted extinctions at the basin level; the Sadong, Central Kalimantan, and Kapuas-Sambas PSF basins are expected to have the highest number of basin extinctions in the BAU, CONSERV, and CONVERT scenarios, respectively. Across all scenarios, larger numbers of global extinctions are expected in basins with high endemic species richness and, in the BAU scenario, high rates of deforestation.

We assessed the relative extinction vulnerability of individual fish species, taking into account their distribution across basins, relative rarity within basins, and basin deforestation rates. Under the BAU scenario, the five most vulnerable species are *Encheloclarias prolatus* (Clariidae), *Betta brownorum* (Osphronemidae), *Sundadanio goblinus*, *Sundadanio margarition* (both Cyprinidae), and *Betta ibanorum* (Osphronemidae). Notably, *E prolatus*, which is restricted to the Sadong basin (Matang PSF) in Sarawak, Malaysia, has a 99% chance of becoming extinct under this scenario (Figure 3; WebTable 4).

Our projections assumed that order of habitat loss is independent of species richness patterns within each basin. Seabloom *et al.* (2002) showed that species–area models underestimate extinctions if habitat loss occurs first in areas with high species richness and endemicity. However, our assumption is reasonable for PSFs for at least two reasons. First, variation in species richness within a PSF is likely low because of its homogeneous physiography (eg low altitudinal variation, tributaries connected resulting from the high water table and seasonal floods). Second, there is no evidence to suggest PSF conversion follows species richness patterns. He and Hubbell (2011) suggested that the endemic species–area model (derived from counting the endemic number of species lost in each successively larger habitat area) is more accurate than species–area models (counting the difference in the number of species observed when going from a larger to a smaller habitat area) in predicting extinctions; yet the need for species abundance data – which are rarely available for tropical species assemblages – precludes its application. Pereira *et al.* (2012) demonstrated that the conclusion derived by He and Hubbell (2011) is not generalizable because it depends on the scale and geometry of habitat loss. The MCSAM, on the other hand, recognizes that degraded environments may retain a fraction of the original forest biodiversity, an important point also highlighted by Pereira *et al.* (2012). Koh and Ghazoul (2010) also confirmed that the MCSAM predicts the number of extinct and threatened bird species in biodiversity hotspots more accurately than conventional models. Because of these advantages, we believe that MCSAM produces extinction projections that are more realistic than alternative models.

Globally, 60 freshwater fish species are known to have gone extinct (IUCN 2011). Our projections indicate that PSF conversion to a predominantly agricultural mosaic landscape in 2010–2050 will increase the number of extinctions by 26% (BAU scenario) and 132% (CONVERT scenario). While this, to the best of our knowledge, is the first study to project global extinctions of freshwater fish, species-discharge models have been used to project basin-level (local) extinctions that will result from future climate change and rates of anthropogenic water use (Xenopoulos *et al.* 2005; Xenopoulos and Lodge 2006; Spooner *et al.* 2011). Xenopoulos *et al.* (2005) estimated local losses of 4–22% (interquartile range) of fish species across drying river basins globally by 2070. Under our BAU scenario, land-use change to 2050 is projected to drive 14–62% (interquartile range: 17–34%) of stenotopic PSF fish species to extinction in Sundaland. As discharge reduction is not expected in Sundaland's basins (Xenopoulos *et al.* 2005), land-use change is probably the major threat to PSF fishes in this region.

We recommend that countries include PSFs in long-term conservation monitoring exercises. The population trends of fish communities should be assessed, especially in endemic-species-rich, rapidly deforested basins where global and basin-level extinctions are projected to be high (eg Central Kalimantan and Sadong basins). In addition to community-level monitoring, highly vulnerable species should be regularly monitored for population and distributional changes. Our analysis identifies vulnerable species for which the International Union for Conservation of Nature (IUCN) conservation status is uncertain. Of the 10 most vulnerable species, *E prolatus*, *E tapeinopterus*, and *B burdigala* require updated assessments whereas the others have never been evaluated (IUCN 2011). We also recommend that the IUCN assess the conservation status of the most vulnerable fish species identified in this analysis. Besides establishing a baseline from which population and range changes can be monitored, IUCN species assessments can inform the protection of globally endangered species and their associated habitats through national legislation as well as through the identification of High Conservation Value Forests (HCV Consortium for Indonesia 2009), a voluntary landscape management scheme that is widely adopted as a means of identifying set-aside conservation areas in production/plantation landscapes.

Currently, PSFs are being converted faster than any other forest type in Sundaland, largely because of the strong economic incentives for agricultural expansion (Koh *et al.* 2011). This is exacerbated by the misperception that PSFs are biodiversity-poor and therefore less worthy of protection than other lowland forest systems. Sundaland's PSFs are also important global storehouses of carbon (C); Indonesia and Malaysia store 67 gigatons of C in peat, representing 75% of total tropical peat soil C storage (Page *et al.* 2011). Carbon emissions resulting from large-scale conversion of this C sink (Miettinen *et al.* 2012) is expected to severely impact Earth's climate. The C payment scheme known as REDD+ (Reduced Emissions from Deforestation and Forest Degradation plus conservation, sustainable management of forests, and enhancement of forest carbon; UNFCCC 2010) may help offset the opportunity costs of conserving PSFs, thereby safeguarding its unique fish biota and C stocks. Indeed, in May 2011, the president of the Republic of Indonesia decreed a 2-year moratorium on new permits for converting PSFs as part of a bilateral REDD+ agreement with Norway (Instruksi Presiden Republik Indonesia No 10/2011; http://sipuu.setkab.go.id/PUUdoc/17176/INPRES0102011.pdf). However, not all PSFs are included in this moratorium, and it remains to be seen if the regulations will be enforced. In the shorter term, regional governments need to muster the political will to stop, or at least slow, the rates of forest conversion in basins where global freshwater fish extinctions are projected to occur.

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X Giam *et al*. – Supplementary Materials

WebPanel 1. Power-law model and matrix-calibrated species–area model (MCSAM)

Power-law model

The power-law model (Arrhenius 1920) is the classic species–area model used to project species extinctions following deforestation (Pimm *et al.* 1995; Brooks and Balmford 1996; Brooks *et al.* 1997; Brooks *et al.* 2002; Brook *et al.* 2003). The power-law model is expressed as:

$$S = cA^z \text{ (Equation 1),}$$

where A and S refer to habitat area (forest) and species richness, respectively. The parameter c is a scale-sensitive constant which, together with z, the exponent, controls the rate of change in the number of species with area (shape of curve) (Rosenzweig 1995; Tjørve 2003).

When deforestation occurs and forest area is reduced from its original size A_{orig} to a new size A_{new}, we can calculate the remaining number of species S_{new}, if we know the original number of species S_{orig}, and the value of z:

$$S_{orig} = cA_{orig}{}^z \qquad \text{(Equation 2)}$$
$$S_{new} = cA_{new}{}^z \qquad \text{(Equation 3).}$$

Combining Equations 2 and 3, we get:

$$S_{new} = S_{orig}\left(\frac{A_{new}}{A_{orig}}\right)^z \qquad \text{(Equation 4).}$$

Following that, the number of extinct species can be calculated by subtracting S_{new} from S_{orig}. The parameter z is often estimated from the relationship between area of oceanic islands and species richness. The model therefore assumes that deforested land is equivalent to the ocean in true island systems – that is, completely inhospitable to species. This assumption is likely to be unrealistic in most real-world scenarios. Indeed, human-modified landscapes, such as oil palm plantations, support some forest biodiversity (Fitzherbert *et al.* 2008) and different land-use types differ in their ability to support forest biodiversity (Gibson *et al.* 2011).

MCSAM

The MCSAM, on the other hand, takes into account the differential responses of biodiversity toward different converted land-use types (Koh and Ghazoul 2010). In this model, the parameter z is calibrated based on the overall sensitivity of the species assemblage toward the converted land-use type(*s*) (σ):

$$z = \gamma\sigma \qquad \text{(Equation 5),}$$

where γ is a constant and σ is the overall sensitivity of the species assemblage, quantified as the proportional reduction in the number of species after conversion ($0 \leq \sigma \leq 1$). When $\sigma = 0$ (no reduction in species; converted land is as good as original habitat [forest] for biodiversity), $z = 0$, and no extinctions will occur ($S_{new} = S_{old}$; Equation 4). When $\sigma = 1$ (loss of all species after conversion), $\gamma = z$ and the model reduces to the classical power-law model, where converted land is completely inhospitable to biodiversity.

If there are two or more converted land-use types, the overall sensitivity σ can be calculated as a weighted average of the sensitivity of the species assemblage toward each converted land-use type:

$$\sigma = \sum_i^n p_i \sigma_i \qquad \text{(Equation 6)},$$

where p_i is the proportion of the ith converted land-use type relative to total converted land area, while σ_i is the sensitivity of the species assemblage toward the ith land-use type (calculated as the proportional reduction in species richness after conversion of forest into the ith land-use type).

Combining Equations 5 and 6, we get the calibrated z parameter:

$$z = \gamma(\sum_i^n p_i \sigma_i) \qquad \text{(Equation 7)}.$$

Combining Equations 4 and 7, we get the MCSAM:

$$S_{new} = S_{orig}(\frac{A_{new}}{A_{orig}})^{\gamma(\sum_i^n p_i \sigma_i)} \qquad \text{(Equation 8)}.$$

WebPanel 2. MCSAM parameterization

Sensitivity of fish to the *i*th converted land-use type σ_i

The sensitivity of fish to urban land cover was set at 1 as species stenotopic to peatlands are unlikely to survive in concrete channels in urban areas. Degraded peatlands, on the other hand, do harbor some stenotopic PSF fish species, as seen from recent species discoveries (eg Tan and Kottelat 2008; Tan 2009). From our literature search, we found only one study that documented the proportional reduction of fish species associated with the conversion of an intact PSF to a plantation-mosaic landscape (ie degraded peatland; Beamish *et al*. 2003). In this study, fish were sampled across multiple sites over two sampling periods (ie before and after conversion, about 1.5 years apart) – four of five stenotopic PSF species were lost after conversion (WebTable 5). We therefore assigned this value (4/6 or 0.667) as the sensitivity of fish species toward degraded peatland. Although we recognize that the short length of time that elapsed between conversion and the second sampling period may not have allowed for fauna relaxation (ie the loss of all species that will eventually be extirpated) (Brooks *et al*. 1999), thus affecting the accuracy of the estimate, it remains the only available estimate derived from actual field data that allows us to project extinctions in a relatively unknown habitat. Moreover, this value falls within the range of values observed for birds, mammals, and invertebrates in degraded tropical forest in Southeast Asia (Sodhi *et al*. 2009), suggesting that it is reasonably reliable (WebFigure 2).

The constant γ (z in power-law SAR)

We compiled (fish) species–(basin) area relationships (SARs; following Drakare *et al*. 2006) to parameterize γ. As SARs are sensitive to habitat and climate type (Drakare *et al*. 2006), we only considered SARs of tropical forest basins. From the literature, we compiled four sets of SARs that encompass the major tropical forest regions of South America, Central America, West Africa (Tedesco *et al*. 2005), and Southeast Asia. We fit a log-linearized power-law

SAR model to each dataset and recorded the slope of the model (z) (WebTable 6). We calculated the mean and standard deviation of z to estimate the γ parameter in the MCSAM (Koh *et al*. 2011).

WebTable 1. List of (a) sampling localities and (b) literature consulted to build the species dataset. Geographic coordinates are available from authors upon request.

(a) Sampling localities

No	*Description of locality*	*Date of sampling*
	Ambat	
1	Malaysia, Johor: Stream about 25 km north of Desaru-Kota Tinggi Rd junction with Mawai; Kota Tinggi	14 Aug 1991
2	Malaysia, Johor: Sg Selangi; 15 km from Kota Tinggi to Tg Sedili	27 Mar 1992
3	Malaysia, Johor: Sg Selangi; 15 km from Kota Tinggi to Tg Sedili	22 Apr 1992
4	Malaysia, Johor: Kota Tinggi; Mawai-Desaru Rd	15 Oct 1992
5	Malaysia, Johor: Kota Tinggi; Sg Tementang	13 Jan 1994
6	Malaysia, Johor: Kota Tinggi; Bukit Aping sign; stream ~20 km on turnoff to Desaru (~52.5 km before Desaru)	5 Jun 1995
7	Malaysia, Johor: ~20 km off turnoff towards Desaru, with Bukit Aping sign, ~54.5 km to Sungei Rengit	31 Jul 1995
8	Malaysia, Johor: Remnant swamp forest along coastal road between Desaru and Tanjung Sedili, ~15 km before Sungei Sedili Kechil bridge	20 Oct 2009
9	Malaysia, Johor: Brown water stream draining from swamp forest along road between Tanjung Sedili and Kota Tinggi	20 Oct 2009
10	Malaysia, Johor: Sungei Tementang, stream along road Kota Tinggi-Kuantan, ~km 268.5 Kuantan/km 60.5 Johor Bahru	21 Oct 2009
	Banka	
1	Indonesia, Banka Island: Kawasan Sungai Liat, Kampung Jelit, 3 km from main road (Sungai Liat) to Tanjung Persema Beach	2 Mar 1993
2	Indonesia, Banka Island: 96.5 km south of Pangkalpinang	3 Mar 1993
3	Indonesia, Banka Island: 99.4 km south of Pankalpinang, 2.6 km north of Serdang	3 Mar 1993
4	Indonesia, Banka Island: 4 km before Kampung Bikang from Pangkalpinang	3 Mar 1993
5	Indonesia, Banka Island: 2 km before Kampung Bikang from Pangkalpinang, degraded swamp forest	3 Mar 1993
6	Indonesia, Banka Island: Between Kampung Kurau and Kampung Balilik, 25 km north of Koba	3 Mar 1993
7	Indonesia, Banka Island: 9 km east of Muntok	3 Mar 1993
8	Indonesia, Banka Island: Heath forest 2 km east of Kampung Bilek	3 Mar 1993
9	Indonesia, Banka Island: Kampung Tebing, 65.5 km east of Muntok	3 Mar 1993
10	Indonesia, Banka Island: 3 km north of Payung	3 Mar 1993
11	Indonesia, Banka Island: 5.5 km north of Payung	5 Mar 1993
12	Indonesia, Banka Island: 28 km north of Payung	5 Mar 1993
13	Indonesia, Banka Island: Mongkol Forest Reserve (Hutan Lindung Mongkol)	7 Mar 1993

No	*Description of locality*	*Date of sampling*
	Batang Hari-Indragiri	
1	Indonesia, Sumatra, Jambi: Sg Alai at 28 km on road Muara Bungo-M Tebo between 0.5 hour by motorboat downriver of bridge to about 1 hour upriver, including small tributaries and Danau Gresik	30–31 May 1994
2	Indonesia, Sumatra, Jambi: Danau Jamining near Kg Transos ~5 km on unpaved road to south of road Muara Bungo-Muara Tebo at km 36 (12 km before M Tebo); tributary of Sg Tebo; area cleared about 10 years before; pH 6.1; Bk4–55	31 May 1994
3	Indonesia, Sumatra, Jambi: Danau Semangkat, a lake connected to Batang Hari by Sg Bangko.	6 Jun 1994
4	Indonesia, Sumatra, Jambi: swamp near Pematang Lumut, 40 km before Kuala Tungkal on road from Jambi (95 km) and Simpangtuan (36 km).	7 Jun 1994
5	Indonesia, Sumatra, Jambi/Riau: Peat swamp draining into Sg Bengkwan, tributary of Indragiri River	15 Jun 1995
6	Indonesia, Sumatra, Jambi: stream with grassy banks near Pangkalankasai, 43 km from Rengat on Rengat-Jambi Road; pH 5	15 Jun 1995
7	Indonesia, Sumatra, Jambi, swamp forest 1 km from Pamatang-Lumut between Jambi and Rengat; pH 4.1	15 Jun 1995
8	Indonesia, Sumatra, Jambi: Berbak Nature Reserve, Sg Air Hitam Dalam; pH 4.0 Blackwater	16 Jun 1995
9	Indonesia, Sumatra, Jambi: Danau Pinang, lake in forest connected to Sg Pijoan	28 May1996
10	Indonesia, Sumatra, Jambi: T-junction of Sg Pijoan; ~half-hour by boat upriver of Pijoan	28 May 1996
11	Indonesia, Sumatra, Jambi: Sg Keruh; ~2 km south of main road at km 23 on road Jambi-Tembesi (tributary of Sg Pijoan)	28 May 1996
12	Indonesia, Sumatra, Jambi: Sg Bakung, north tributary stream adjoining Danau Arang Arang and Sunagi Arang Arang, Arang Arang	29 May 1996
13	Indonesia, Sumatra, Jambi: Danau Arang Arang, 2 stations at eastern end	29 May 1996
14	Indonesia, Sumatra, Jambi: Danau Rasau, a black water lake draining to Batang Hari, opposite Kampung Rantau Panjang	2 Jun 1996
15	Indonesia, Sumatra, Jambi: Ayer Hitam, Darkie water reserve	6 Jun 1996
16	Indonesia, Sumatra, Jambi: Second stream on road towards Muara Bulian, after interjunction at crossroads towards Palembang, Muara Bulian and Jambi	7 Jun 1996
17	Indonesia, Sumatra, Jambi: Pijoan, Danau Souak Padang	8 Jun 1996
18	Indonesia, Sumatra, Jambi: Bayou (peat swamp forest) Rantau Panjang, ~30 minutes (row) behind Kg Rantau Panjang	1 Nov 1996
19	Indonesia, Sumatra, Jambi: Pijoan, Leibong Sepbaju, stream in swamp forest	21 Nov 1996
20	Indonesia, Sumatra, Jambi: Sg. Ayer Merah, feeder stream to Danau Souak Padang ~15 minutes (row) upstream	21 Nov 1996
21	Indonesia, Sumatra, Jambi: East Jambi, peat swamp forest 15 km east from turnoff towards Muara Sabak	22 Nov 1996
22	Indonesia, Sumatra, Jambi: East Jambi, stream next to swamp forest and rubber plantation, km 32 into turnoff (westwards) to Pematang Lumut before turnoff to Kuala Tungkal	22 Nov 1996
23	Indonesia, Sumatra, Riau: Upper part Indragiri, Sg Jakil, swamp forest	25 Nov 1996
24	Indonesia, Sumatra, Jambi: Sumatra: Jambi, Danau Arang Arang (Muara Kompeh area), brown water lake	25 Jul 1997
25	Indonesia, Sumatra, Jambi: Sg Bakong, tributary to Danau Arang Arang,	25 Jul 1997

No	Description of locality	Date of sampling
	swamp forest	
26	Indonesia, Sumatra: South Sumatra, Sungai Sentang, ~20-minute walk through rubber plantation and swamp forest after 4.8 km drive in, 12 km from Jambi to Bayung Lencir (216 km to Palembang), near Desa Sukajaya	27 Jul 1997
27	Indonesia, Sumatra: South Sumatra, ~1 hour upstream from access road to Sungei Merdak, 12 km into Desa Suka Jaya	11 Dec 2003
	Central Kalimantan	
1	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Kec. Sabangau; Sungai Kanan Besar, blackwater canal on west side of Sungai Sabangau	22 Aug 2009
2	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Kec Sabangau; man-made logging canal on east side of Sungai Sabangau	22 Aug 2009
3	Indonesia, Kalimantan Tengah: Rungan-Kahayan basin, Sungei Rijak, km 84 along road from Palangkaraya to Telakin	18 Sep 2007
4	Kalimantan Tengah: Mangkutup-Kapuas basin	19 Sep 2007
5	Indonesia, Kalimantan Tengah: Kahayan basin; Sebangau River, feeder stream and fisherfolk’s catch	21 Sep 2007
6	Indonesia, Kalimantan Tengah: Rungan-Kahayan basin, blackwater stream at km 46 Palangkaraya-Kasongan Road	27 Sep 2007
7	Indonesia, Kalimantan Tengah: Kahayan basin, Rungan River; Sungei Panta, blackwater river draining into Rungan River and its confluence, connected to Nyaru Menteng (village)	5 Mar 2008
8	Indonesia, Kalimantan Tengah: Kahayan basin, Rungan River; Tangkiling, blackwater stream after km 46 Palangka Raya-Kasongan road	5 Mar 2008
9	Kalimantan Tengah: Sebangau basin, Sebangau River; blackwater canal draining from forest, left side upstream of village	6 Mar 2008
10	Kalimantan Tengah: Sebangau basin, Sebangau River; blackwater canal draining from forest, right side upstream of village	6 Mar 2008
11	Kalimantan Tengah: Sebangau basin, Sebangau River; blackwater canal draining from forest, left side upstream of village	6 Mar 2008
12	Kalimantan Tengah: Kapuas basin; Bargugus, blackwater stream ~47 km after bridge over Kahayan River at Palangka Raya	7 Mar 2008
13	Kalimantan Tengah: Kapuas basin; Bukit Gelaga, stream ~15 km into left side-road from turnoff to Bargugus	7 Mar 2008
14	Indonesia, Kalimantan Tengah: Kahayan basin, Rungan River; blackwater stream at km 80 Palangka Raya-Tumbang Telakian road, access via km 45 Palangka Raya-Kasongan road	8 Mar 2008
15	Kalimantan Tengah: Kotawaringin basin; Pangkalan Bun outskirts, blackwater ditch along road to Kumai Terminal	10 Mar 2008
16	Kalimantan Tengah: Kotawaringin basin; Sungei Pasir Panjang, outskirts of Pangkalan Bun, along road leading to Kumai	11 Mar 2008
17	Kalimantan Tengah: Kotawaringin basin; Sungei Karang Enyir, outskirts of Pangkalan Bun, connected to Sungei Bamban via ditch; near Kampung Karang Panjang	12 Mar 2008
18	Kalimantan Tengah: Kumai basin; Sungei Nyeri, blackwater river near Kampung Seitendang (Seit = river)	12 Mar 2008
19	Kalimantan Tengah: Kotawaringin basin; Sungei Bu’un, along road towards Pangkalan Bun; near car wash	12 Mar 2008
20	Kalimantan Tengah: Mentaya basin; Pundu-Plantarang area, Sungei Kora, km 148 Palangka Raya-Sampit road	14 Mar 2008
21	Kalimantan Tengah: Mentaya basin; Pundu-Plantarang area, stream at	14 Mar 2008

No	Description of locality	Date of sampling
	km 142 Palangka Raya-Sampit road. Swollen by rains, tea colour water, fast flowing, peaty-sand bottom.	
22	Indonesia, Kalimantan Tengah: Kahayan basin; Bereng Bengkel, Kecamatan Sabangau, access via track at 20 km along Palangka Raya-Banjarmasin road; Blackwater swampy area; Selambau (long net) and scoop net	15 Mar 2008
23	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Rungan River basin: Sungai Hampangen, ~50 km from Palangka Raya to Kasongan; UNPAR educational forest plot; heath forest, black water, white sand base, peaty banks with large root mats	15 Aug 2009
24	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Kahayan basin: Sungai Tahai, flowing into Rungan River, ~30 km outside of Palangka Raya town	16 Aug 2009
25	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Kahayan basin: Danau Sangumang, an oxbow lake flowing into Rungan River opposite Danau Tahai	17 Aug 2009
26	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Kahayan basin: Bukit Tangkiling, dam and government fisheries hatchery centre	18 Aug 2009
27	Indonesia, Kalimantan Tengah: Kabupaten Pulong Pisau; Kahayan basin: Danau Sabuah, western end linking to Danau Teheng	20 Aug 2009
28	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Tahai, junction of Sungai Tahai with Danau Tahai	21 Aug 2009
29	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Tahai, Sungai Panta; dried out river connected to Rungan River. Clayey bottom, stagnant pools of water at bottom of river channel.	21 Aug 2009
30	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Tahai, Sungai Danau Bunter, draining from Danau Bunter; clayey bottom, warm water draining from oxbow lake	21 Aug 2009
31	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Kec Sabangau; blackwater stream on east side of Sungai Sabangau; peaty bottom, banks with Pandanus, draining from forest about 2 km upstream	22 Aug 2009
32	Indonesia, Kalimantan Tengah: Kota Palangka Raya: Kec. Sabangau, Kereng Bangkirai, Sungai Sabangau	22 Aug 2009
	East Peninsular Malaysia	
1	Malaysia, Johor: About km 177, Johor Bahru-Kuantan Road (north of Mersing)	19 Oct 1991
2	Malaysia, Pahang: About 100 km south of km 68, Johor Bahru-Kuantan	19 Oct 1991
3	Malaysia, Pahang: About 100 km south of km 16, Johor Bahru-Kuantan	19 Oct 1991
4	Malaysia, Pahang: About 500 m before km 10 from Kuantan to Gambang	20 Oct 1991
5	Malaysia, Pahang: About 200 southwest of km 33 Segamat-Kuantan Road	20 Oct 1991
6	Malaysia, Pahang: About 200 m north of km 16 Johor Bahru-Kuantan Road. Sg Soi	20 Oct 1991
7	Malaysia, Pahang: Km 88 Kuantan-Mersing Road; Blackwater	9 Mar 1992
8	Malaysia, Pahang: Pool along Mersing-Pekan Rd (73 km to Kuantan, 400 m Sg Beto)	9 Mar 1992
9	Malaysia, Pahang: Km 69, Mersing-Kuantan Road; Blackwater stream across road	9–10 Mar 1992
10	Malaysia, Pahang: Km 69, Pekan-Mersing Road. Blackwater 1km north of 3°22’4.1”N, 103°25’13.8”E	10 Mar 1992
11	Malaysia, Pahang: Pekan-Mersing Road	10 Mar 1992

No	Description of locality	Date of sampling
12	Malaysia, Terengganu: Rantau Abang, km 56 Kuantan-Kuala Terengganu Road	18 Mar 1992
13	Malaysia, Pahang: Creek on road from Segamat to Kuantan, 88 km before Kuantan	23 Jul 1992
14	Malaysia, Pahang, Km 16 on road from Kuantan to Pekan	23 Jul 1992
15	Malaysia, Pahang, Km 66 on road Kuantan-Pekan-Mersing	24 Jul 1992
16	Malaysia, Pahang: Km 68 to Kuantan	15 May 1995
17	Malaysia, Terengganu: Cukai, stream across road at ~km 20 along Kamaman-Kuala Terengganu road linking Mukim Bijai to Mukim Ibuk	27 Feb 2009
18	Malaysia, Terengganu: Cukai, stream across road at ~km 21.5 along Kamaman-Kuala Terengganu road linking Mukim Bijai to Mukim Ibuk	27 Feb 2009
19	Malaysia, Terengganu: Cukai, stream across road at ~km 25 along Kamaman-Kuala Terengganu road linking Mukim Bijai to Mukim Ibuk	27 Feb 2009
20	Malaysia, Pahang: Stream across road at km 264 Johor Bahru/km 65 Kuantan along Pekan-Rompin road; and 400 m south stream between km 264 and km 263 Johor Bahru	1 Mar 2009
21	Malaysia, Pahang: Brown water river across Karak Highway (from Kuala Lumpur to Cukai), ~km 34 Cukai	2 Mar 2009
22	Malaysia, Pahang: Pekan, blackwater stream along road ~km 10 Pekan/km 37 Kuantan road	3 Mar 2009
23	Malaysia, Pahang: Tea colour stream along access road to south shore of Tasik Chini, ~5 km before Tasik Chini	3 Mar 2009
24	Malaysia, Pahang: Stream flowing from south bank of Sungei Pahang along Pekan-Mentinga road, at ~km 13–14	3 Mar 2009
25	Malaysia, Pahang: Ditch parallel to road along Pekan-Tasik Chini road, near km 3 Pekan/km 45 Mentinga	4 Mar 2009
26	Malaysia, Pahang: Pools along stream bed in swamp forest of Forest Reserve at junction of Kampong Leban Condong (along Pekan-Rompin road) and road 63 to Muadzam Shah	4 Mar 2009
27	Malaysia, Pahang: Stream across road at ~31 km before Muadzam Shah along road 63	4 Mar 2009
28	Malaysia, Pahang: Stream across road at km 38 Kuala Rompin/km 51 Bukit Ibam, along road 63 Kampong Leban Condong-Muadzam Shah; remnant swamp forest	5 Mar 2009
29	Malaysia, Pahang: Stream across road at ~km 35.5 Kuala Rompin/km 53.5 Bukit Ibam, along road 63 Kampong Leban Condong-Muadzam Shah	5 Mar 2009
	Kapuas-Sambas	
1	Indonesia, Kalimantan Barat: Kabupaten Sambas: Sg. Sinabar, blackwater tributary of Sg Sambas; (01°22.27’N, 109°31.53’E); pH 4.7; Bk10-white papers	18 Apr 1998
2	Indonesia, Kalimantan Barat: Kabupaten Sintang: small tea-colour stream at ~km 402 Pontinanak on Sintang-Putussibau Road	21 Apr 1998
3	Indonesia, Kalimantan Barat: Kabupaten Sintang: blackwater stream at ~km 373.5 Pontianak on Sekadau-Sintang road, ~11.3 km towards Sekadau from Sintang	22 Apr 1998
4	Indonesia, Kalimantan Barat: Kabupaten Sintang: tea-colour stream at ~km 377 Pontianak on Sekadau-Sintang road, near junction to Nanga Pinoh	22 Apr 1998
5	Indonesia, Kalimantan Barat: Kabupaten Sintang: unnamed blackwater tributary at ~2 km into Sg Ketungau (00º23.70’N 111º37.21’E)	23 Apr 1998
6	Indonesia, Kalimantan Barat: Kabupaten Sanggau: blackwater stream at	25 Apr 1998

No	*Description of locality*	*Date of sampling*
	km 352 Pontianak on Sekadau-Sintang road	
7	Indonesia, Kalimantan Barat: Kabupaten Pontianak: Sg Laur, tea-colour tributary of Danau Perkat, draining into Sg Tayan	26 Apr 1998
8	Indonesia, Kalimantan Barat: Kabupaten Pontianak: Lubok Raundal (lake), ~500 m walk inland from Sg Tayan	26 Apr 1998
9	Indonesia, Kalimantan Barat: Kabupaten Pontianak: Sg Jelimpo, blackwater stream at Anjungan ~1 km east of 00º21.02'N 109º11.08'E	28 Apr 1998
10	Indonesia, Kalimantan Barat: Kabupaten Pontianak: peat swamps at Anjungan 'D', ~8 km west into side road at km 66 Pontianak on Pontianak-Anjungan road	28 Apr 1998
11	Indonesia, Kalimantan Barat: Kabupaten Pontianak: freshwater swamp forest ~1 km east of THH9858, Kg Anjungan	28 Apr 1998
12	Indonesia, Kalimantan Barat: Kabupaten Pontianak: Sg Kepayan, blackwater brook at km 58 Pontianak on Pontianak-Anjungan road, ~7 km before Kg Anjungan	29 Apr 1998
13	Indonesia, Kalimantan Barat: Kabupaten Pontianak: peat swamps ~200 m west of Sg Kepayan	29 Apr 1998
14	Indonesia, Kalimantan Barat: Kapuas basin, Melawi sub-basin; Sungei Sawak, blackwater stream at km 377 to Pontianak, along road from Sintang to Pontianak, near turnoff to Nanga Pinoh (00°01.421'S 111°26.993'E)	15 Aug 2007
15	Indonesia, Kalimantan Barat: Kapuas basin; Anjungan, Sungei Kepayan Hulu, peat swamp forest (00°19.208'N 109°09.665'E), 45 m above sea level; peat swamp, access via track at km 60 Pontianak along old coastal road, about 1 km along logger's plank track, closed canopy	17 Aug 2007
	North Selangor	
1	Malaysia, Selangor: North Selangor Peat Swamp Forest, in stream near padi field on western boundary	15 May 1991
2	Malaysia, Selangor: North Selangor Peat Swamp Forest, along north-western boundary	15 May 1991
3	Malaysia, Selangor: North Selangor Peat Swamp Forest, in puddle along logging trail	15 May 1991
4	Malaysia, Selangor: North Selangor Peat Swamp Forest, in large canal along mud track on forest outskirts	15 May 1991,18–20 Jun 1991
5	Malaysia, Selangor: North Selangor Peat Swamp Forest, stream at km 34 mark on road to Tg Malim	17 Jun 1991
6	Malaysia, Selangor: North Selangor Peat Swamp Forest, stream 0.2 km from km 45 mark on road to Sg Besar	17 Jun 1991
7	Malaysia, Selangor: North Selangor Peat Swamp Forest, 0.8 km from km 45 mark on road to Sg Besar	18 Jun 1991
8	Malaysia, Selangor: North Selangor Peat Swamp Forest, stream at km 50 mark to Tg Malim (United Plantations Bhd)	18 Jun 1991
9	Malaysia, Selangor: North Selangor Peat Swamp Forest, stream at km 43 marker on road to Sg Besar	18–19 Jun 1991
10	Malaysia, Selangor: North Selangor Peat Swamp Forest, stream at km 47 mark on road to Tg Malim	18–19 Jun 1991
11	Malaysia, Selangor: North Selangor Peat Swamp Forest, stream at 0.7 km from km 41 mark on road to Tg Malim	19 Jun 1991
12	Malaysia, Selangor: North Selangor Peat Swamp Forest, Sg Tengi	19–20 Jun 1991
13	Malaysia, Selangor: North Selangor Peat Swamp Forest, pool at about km 47 on road to Tg Malim	20 Jun 1991
14	Malaysia, Selangor: North Selangor Peat Swamp Forest, 39 km mark on	24 Aug 1991

No	*Description of locality*	*Date of sampling*
	Sg Besar-Tg Malim Road (43 km from Tg Malim to Sg Besar)	
15	Malaysia, Selangor: 32 km Rawang-Kuala Selangor Road	24 Aug 1991
16	Malaysia, Selangor: North Selangor Peat Swamp Forest, 50 km mark on Sg Besar-Tg Malim Road (United Plantations Bhd)	25 Aug 1991
17	Malaysia, Selangor: North Selangor Peat Swamp Forest, 0.2 km from 37 km mark on Sg Besar-Tg Malim Road	25 Aug 1991
18	Malaysia, Selangor: North Selangor Peat Swamp Forest, 0.5 km from 36 km mark on Sg Besar-Tg Malim Road	25 Aug 1991
19	Malaysia, Selangor: North Selangor Peat Swamp Forest, 0.65 km from 35 km mark on Sg Besar-Tg Malim Road	25 Aug 1991
20	Malaysia, Selangor: North Selangor Peat Swamp Forest, 43 km on Tg Malim-Sg Besar Road	14 Sep 1991
21	Malaysia, Selangor: North Selangor Peat Swamp Forest, between 43 and 33 km, Tg Malim-Sg Besar Road	?? Jun 1992
22	Malaysia, Selangor: North Selangor Peat Swamp Forest, 0.2 km from km 45 Tg Malim-Sg Besar Road	18 Sep 1992
23	Malaysia, Selangor: North Selangor Peat Swamp Forest, Sg Perak, Ulu Basir, north bank of Sg Bernam	19 Sep 1992
24	Malaysia, Selangor: North Selangor Peat Swamp Forest, Sg Perak, north shore of Sg Bernam	19 Sep 1992
25	Malaysia, Selangor: Bridge at km 32, Rawang-Kuala Selangor Road	19 Sep 1992
26	Malaysia, Selangor: 800 m from junction of Batu Arang Road and Rawang-Kuala Selangor Road	20 Sep 1992
27	Malaysia, Selangor: North Selangor Peat Swamp Forest, Sabak Bernam	?? Apr 1993
28	Malaysia, Selangor: North Selangor Peat Swamp Forest, Sabak Bernam	?? Sep 1993
29	Malaysia, Selangor: North Selangor Peat Swamp Forest, unnamed stream	?? Sep 1994
30	Malaysia, Selangor: North Selangor Peat Swamp Forest, km 43 to Sungei Besar, along road to Sungei Besar from Tanjung Malim	21 Dec 1994
31	Malaysia, Selangor: North Selangor Peat Swamp Forest, km 36 to Sungei Besar, km 46 to Tanjung Malim; blackwater ditch draining from remnant peat swamp	5 Jan 2005
32	Malaysia, Selangor: North Selangor Peat Swamp Forest, km 37.5 to Tanjung Malim; blackwater ditch	5 Jan 2005
33	Malaysia, Selangor: North Selangor Peat Swamp Forest, km 39.5 to Tanjung Malim, blackwater ditch	5 Jan 2005
34	Malaysia, Selangor: North Selangor Peat Swamp Forest, km 40 to Tanjung Malim, km 42 to Sungei Besar; blackwater ditch	5 Jan 2005
35	Malaysia, Selangor: North Selangor Peat Swamp Forest, km 34 to Tanjung Malim, km 48 to Sungei Besar; blackwater ditch (03°40.364’N 101°20.389’E)	5 Jan 2005
36	Malaysia, Selangor: North Selangor Peat Swamp Forest, km 49 to Sungei Besar; blackwater ditch	5 Jan 2005
37	Malaysia, Selangor: North Selangor Peat Swamp Forest, blackwater ditch along road near km 39 to Tanjung Malim (km 43 to Sungei Besar)	27 Mar 2006
38	Malaysia, Selangor: North Selangor Peat Swamp Forest, blackwater ditch along road near km 43 Tanjung Malim	27 Mar 2006
39	Malaysia, Selangor: North Selangor Peat Swamp Forest, blackwater pools by road side near km 44 to Tanjung Malim	27 Mar 2006
40	Malaysia, Selangor: North Selangor Peat Swamp Forest, blackwater ditch ~200 m before km 36 to Tanjung Malim (km 46 to Sungei Besar)	27 Mar 2006
41	Malaysia, Selangor: North Selangor Peat Swamp Forest, seepage stream	2 Jan 2009

No	Description of locality	Date of sampling
	near km 35 Tanjung Malim road	
42	Malaysia, Selangor: North Selangor Peat Swamp Forest, stream near km 37 Tanjung Malim road	2–3 Jan 2009

Rajang

1	Malaysia, Sarawak: Sibu area, 4.2 km north of airport runway on Jl Teku	15 May 1994
2	Malaysia, Sarawak: Sibu area, Sg Sibong, ~1 km north of Durin fessy on Sri Aman-Sibu Road	15 May 1994
3	Malaysia, Sarawak: Sibu, blackwater ditch near remnant peat swamp forest, behind old site of Sibu airport	3 Mar 1998
4	Malaysia, Sarawak: Sibu, Sungei Nibung, just north of Durin bridge over Rejang River	14 May 2008
5	Malaysia, Sarawak: Sibu, Kemuyang area, heath/peat swamp, along road to Sibu Golf Course, leading to city dump	15 May 2008

Sadong

1	Malaysia, Sarawak: Blackwater stream in forest at km 7 on road from Kuching to Batu Kawa	3 Jul 1992
2	Malaysia, Sarawak: 11.8 km before turnoff to Sg Cina Matang, ~10 km from Kuching	4 Sep 1995
3	Malaysia, Sarawak: Batu Kawa area, ~2 km after bridge, ~10 km from Kuching town, Taman Koperkusa	13 Jan 1996
4	Malaysia, Sarawak: Batu Kawa - Matang area, up to 50 m before blackwater river	14 Jan 1996
5	Malaysia, Sarawak: Ditch along road from Kuching to Matang, ~8.5 km after Sg Sarawak bridge	14 Jan 1996
6	Malaysia, Sarawak: Matang area, near water treatment plant	15 Jan 1996
7	Malaysia, Sarawak: 8.3 km after Gedong, ~200 m into peat swamp forest from left side of road towards Gedong, ~11.0 km after turnoff towards Gedong from Serian-Sri Aman road	16 Jan 1996
8	Malaysia, Sarawak: 11.1 km after Gedong, towards Serain-Sri Aman road, ~50 m into peat swamp forest	16 Jan 1996
9	Malaysia, Sarawak: Blackwater river before Matang, ~5km before turnoff to Batu Kawa, from 500 m into river bank to the main confluence	30 Aug 1996
10	Malaysia, Sarawak: Peat swamp forest, 11.4 km towards Gedong from turnoff on Serian-Sri Aman road	31 Aug 1996
11	Malaysia, Sarawak: Sg Stunggang, 4.8 km before Lundu ferry point at Bg Kayan	2 Sep 1996
12	Malaysia, Sarawak: Peat swamp forest, 38.1 km towards Simunjan, from Kuching-Sri Aman road	4 Sep 1996
13	Malaysia, Sarawak: Peat swamp forest at Balai Ringin, ~0.5 km after Sg Kerang, towards Sri Aman	5 Sep 1996
14	Malaysia, Sarawak: Bau-Lundu area, Sungai Stunggang, swamp forest, 51.0 km towards Lundu from Bau on Bau-Lundu road	2 Oct 1998
15	Malaysia, Sarawak: Matang peat swamps, along road from Kuching to Matang, before turn-off to Batu Kawa/Lundu	11 Jul 2007
16	Malaysia, Sarawak: Sungei Stunggang, swamp forest stream along road from Kuching to Lundu, before Batang Kayan bridge	11 Jul 2007
17	Malaysia, Sarawak: Kuching area, remnant peat swamp at Matang, along Jalan Ma Ong, next to telecommunications tower, about 15 km	12 May 2008

No	*Description of locality*	*Date of sampling*
	after blackwater river along road from Kuching to Kubah National Park	
18	Malaysia, Sarawak: Simunjan area, remnant swamp forest ~10 km into road towards Simunjan, along Serian-Sri Aman road (near turnoff to Kampung Minggu)	16 May 2008
19	Malaysia, Sarawak: Sematan, stream flowing into Sungei Sematan, along road to Kampung Sebako; remnant swamp forest	10 Oct 2009
	West Johor	
1	Malaysia, Johor: Johor near Pontian	4 Mar 1992
2	Malaysia, Johor: Near Pontian, Kg Jasa Sepakat	4 Mar 1992
3	Malaysia, Johor: Pontian, Sri Bunian, Kg Pt. Tekong (Pt 112)	8 May 1992
4	Malaysia, Johor: About 3 km north of Ayer Hitam, North Bank of Sg Sambrong in swamp forest	6 Aug 1992
5	Malaysia, Johor: Ayer Hitam, blackwater peat swamp ~87 km to Johor Bahru on N–S highway (Site 1)	8 Dec 1994
6	Malaysia, Johor: Pontian, ~4 km before Sri Bunian towards Johor Bahru direction, Kampung Jasa Sapakat (PT 2/26)	1Aug 1995
7	Malaysia, Johor: Pontian, ~5 km into track from Kampung Jasa Sapakat site	1 Aug 1995
8	Malaysia, Johor: Sri Bunian, Kampung Pt Tekong, irrigation ditch	1 Aug 1995
9	Malaysia, Johor: Pontian, ~3–4 km towards Kukup (Pontian Kechil), after Sri Bunian, opposite sluice gate	1 Aug 1995
10	Malaysia, Johor: Ayer Hitam, remnant peat swamp forest ~500 m after turnoff at km 219 Seremban/km 97 Johor Bahru, along old road from Ayer Hitam to Yong Peng	1 Dec 1995
11	Malaysia, Johor: Pontian, blackwater ditch at ~3–4 km towards Kukup	1 Dec 1995
12	Malaysia, Johor: Pontian, Kampung Jasa Sapakat, Sri Bunian	1 Dec 1995
13	Malaysia, Johor: Pontian, Sri Bunian, Kampung Jasa Sapakat, blackwater ditch running through oil palm plantation	1 Jul 1998
14	Malaysia, Johor: Ayer Hitam, Hutan Simpang Ayer Hitam Utara (Permanent Forest Reserve); peat swamp forest, access via track opposite Kg Parit Jon, ~40 km North of Ayer Hitam town	1 Oct 2005
15	Malaysia, Johor: Ayer Hitam, Hutan Simpang Ayer Hitam Utara (Permanent Forest Reserve); peat swamp forest, access via track opposite Kg. Parit Jon, ~40 km North of Ayer Hitam town	1 Mar 2006
16	Malaysia, Johor: Canal system (Parit) along Pontian Kechil-Pekan Nanas road, km 183 Melaka/km 50 Johor Bahru; right turnoff road to Pontian, oil palm estate at Kampung Jasa Sepakat	1 Oct 2009

(b) Literature consulted

No	*Species recorded*	*Literature consulted*
	Banka	
1	*Encheloclarias tapeinopterus* (Bleeker)	Ng PKL and Lim KKP. 1993. The Southeast Asian catfish genus Encheloclarias (Teleostei: Clariidae), with descriptions of four new species. *Ichthyol Explor Fresh* **4**: 21–37
2	*Chaca bankanensis* (Bleeker)	Tan HH and Ng HH. 2000. The catfishes (Teleostei: Siluriformes) of central Sumatra. *J Nat Hist* **34**: 267–303.
3	*Ompok leiacanthus* (Bleeker)	Tan THT and Ng PKL. 1996. Catfishes of the *Ompok leiacanthus* (Bleeker, 1853) species group (Teleostei: Siluridae) from southeast Asia, with description of a new species. *Raffles B*

No	Species recorded	Literature consulted
		Zool **44**: 531–42.
	Batang Hari-Indragiri	
1	*Barbucca diabolica* (Roberts)	Tan HH and Kottelat M. 2009. The fishes of the Batang Hari drainage, Sumatra, with description of six new specis. *Ichthyol Explor Freshwaters* **20**: 13–69.
2	*Encheloclarias kelioides* (Ng and Lim)	Tan HH and Kottelat M. 2009. The fishes of the Batang Hari drainage, Sumatra, with description of six new specis. *Ichthyol Explor Fresh* **20**: 13–69.
3	*Sundadanio goblinus* (Conway *et al.*)	Conway KW, Kottelat M, and Tan HH. 2011. Review of the southeast Asian miniature cyprinid genus *Sundadanio* (Ostariophysi: Cyprinidae) with descriptions of seven new species from Indonesia and Malaysia. *Ichthyol Explor Fresh* **22**: 251–88.
	Central Kalimantan	
1	*Betta strohi* (Schaller and Kottelat)	Tan HH and Ng PKL. 2005. The fighting fishes (Teleostei: Osphronemidae: Genus Betta) of Singapore, Malaysia and Brunei. *Raffles B Zool* **13**: 43–99.
2	*Boraras brigittae* (Vogt)	Conway KW and Kottelat M. 2011. *Boraras naevus*, a new species of miniature and sexually dichromatic freshwater fish from peninsular Thailand (Ostariophysi: Cyprinidae). *Zootaxa* **3002**: 45–51.
3	*Boraras merah* (Kottelat)	Kottelat M. 1991. Notes on the taxonomy of some Sundaic and Indochinese species of Rasbora, with description of four new species (Pisces: Cyprinidae). *Ichthyol Explor Fresh* **2**: 177–91.
4	*Hyalobagrus flavus* (Ng and Kottelat)	Ng HH and Kottelat M. 1998. *Hyalobagrus*, a new genus of miniature bagrid catfish from southeast Asia (Teleostei: Siluriformes). *Ichthyol Explor Fresh* **9**: 335–46.
	East Peninsular Malaysia	
1	*Neohomaloptera johorensis* (Herre)	Ng HH and Tan HH. 1999. The fishes of the Endau drainage, Peninsular Malaysia with descriptions of two new species of catfishes (Teleostei: Akysidae, Bagridae). *Zool Stud* **38**: 350–66.
2	*Systomus lineatus* (Duncker)	Kottelat M. 1996. The identity of *Puntius eugrammus* and diagnoses of two new species of striped barbs (Teleostei: Cyprinidae) from Southeast Asia. *Raffles B Zool* **44**: 301–16.
	Kapuas-Sambas	
1	*Barbucca diabolica* (Roberts)	Kottelat M and Widjanarti E. 2005. The fishes of Danau Sentarum National park and the Kapuas Lakes Area, Kalimantan Barat, Indonesia. *Raffles B Zool* **13**: 13–173.
2	*Betta pinguis* (Tan and Kottelat)	Tan HH and Kottelat M. 1998. Two new species of *Betta* (Teleostei: Osphronemidae) from the Kapuas Basin, Kalimantan Barat, Borneo. *Raffles B Zool* **46**: 41–51.
3	*Chaca bankanensis* (Bleeker)	Kottelat M and Widjanarti E. 2005. The fishes of Danau Sentarum National park and the Kapuas Lakes Area, Kalimantan Barat, Indonesia. *Raffles B Zool* **13**: 13–173.
4	*Channa pleurophthalma* (Bleeker)	Kottelat M and Widjanarti E. 2005. The fishes of Danau Sentarum National park and the Kapuas Lakes Area, Kalimantan Barat, Indonesia. *Raffles B Zool* **13**: 13–173.
5	*Cyclocheilichthys janthochir* (Bleeker)	Kottelat M and Widjanarti E. 2005. The fishes of Danau Sentarum National park and the Kapuas Lakes Area, Kalimantan

No	Species recorded	Literature consulted
		Barat, Indonesia. *Raffles B Zool* **13**: 13–173.
6	*Encheloclarias baculum* (Ng and Lim)	Ng PKL and Lim KKP. 1993. The Southeast Asian catfish genus *Encheloclarias* (Teleostei: Clariidae), with descriptions of four new species. *Ichthyol Explor Fresh* **4**: 21–37
7	*Hemibagrus olyroides* (Roberts)	Roberts TR. 1989. The freshwater fishes of Western Borneo (Kalimantan Barat, Indonesia). *Mem Calif Acad Sci* **14**: 1–210.
8	*Hyalobagrus leiacanthus* (Ng and Kottelat)	Ng HH and Kottelat M. 1998. *Hyalobagrus*, a new genus of maniature bagrid catfish from Southeast Asia (Teleostei: Siluriformes). *Ichthyol Explor Fresh* **9**: 335–46.
9	*Leptobarbus melanopterus* (Weber and de Beaufort)	Kottelat M and Widjanarti E. 2005. The fishes of Danau Sentarum National park and the Kapuas Lakes Area, Kalimantan Barat, Indonesia. *Raffles B Zool* **13**: 13–173.
10	*Nagaichthys filipes* (Kottelat and Lim)	Kottelat M. 1991. Notes on the taxonomy and distribution of some western Indonesian freshwater fishes, with diagnoses of a new genus and six new species (Pisces: Cyprinidae, Belontiidae, and Chaudhuriidae). *Ichthyol Explor Fresh* **2**: 273–87.
11	*Parosphromenus quindecim* (Kottelat and Ng)	Diagnoses of six new species of *Parosphromenus* (Teleostei: Osphronemidae) from Kottelat M and Ng PKL. 2005. Malay Peninsula and Borneo, with notes on other species. *Raffles B Zool* **13**: 101–13.
12	*Silurichthys sanguineus* (Roberts)	Roberts TR. 1989. The freshwater fishes of Western Borneo (Kalimantan Barat, Indonesia). *Mem Calif Acad Sci* **14**: 1–210.
13	*Sphaerichthys vaillantii* (Pellegrin)	Kottelat M and Widjanarti E. 2005. The fishes of Danau Sentarum National park and the Kapuas Lakes Area, Kalimantan Barat, Indonesia. *Raffles B Zool* **13**: 13–173.
14	*Sundadanio rubellus* (Conway *et al*.)	Conway KW, Kottelat M., and Tan HH. 2011. Review of the Southeast Asian miniature cyprinid genus *Sundadanio* (Ostariophysi: Cyprinidae) with descriptions of seven new species from Indonesia and Malaysia. *Ichthyol Explor Fresh* **22**: 151–288.
15	*Systomus lineatus* (Duncker)	Kottelat M. 1996. The identity of *Puntius eugrammus* and diagnoses of two new species of striped barbs (Teleostei: Cyprinidae) from Southeast Asia. *Raffles B Zool* **44**: 301–16.
	Rajang	
1	*Encheloclarias baculum* (Ng and Lim)	Ng HH and Tan HH. 2000. A new species of *Encheloclarias* from Sumatra. *J Fish Biol* **57**: 536–39.
	Sadong	
1	*Encheloclarias prolatus* (Ng and Lim)	Ng HH and Tan HH. 2000. A new species of *Encheloclarias* from Sumatra. *J Fish Biol* **57**: 536–39.
	West Johor	
1	*Hyalobagrus ornatus* (Duncker)	Ng HH and Kottelat M. 1998. *Hyalobagrus*, a new genus of maniature bagrid catfish from Southeast Asia (Teleostei: Siluriformes). *Ichthyol Explor Fresh* **9**: 335–46.
2	*Systomus lineatus* (Duncker)	Kottelat M. 1996. The identity of *Puntius eugrammus* and diagnoses of two new species of striped barbs (Teleostei: Cyprinidae) from Southeast Asia. *Raffles B Zool* **44**: 301–16.

WebTable 2. Summary of PSF land-cover statistics

	2000			2010			2050		
Basins	*Forest*	*Degraded peatland*	*Urban*	*Forest*	*Degraded peatland*	*Urban*	*Forest (CONSERV)*	*Forest (BAU)*	*Forest (CONVERT)*
Ambat	29.59	209.69	0.00	20.03	219.07	0.00	10.14	4.20	0.00
Banka	266.61	229.65	1.26	181.25	315.01	1.26	91.79	38.71	0.02
Batang Hari-Indragiri	8230.36	9271.57	2.75	5310.48	12189.80	4.03	2689.35	920.43	0.71
Central Kalimantan	17773.31	16389.66	5.53	14993.28	19134.52	12.03	7592.95	7592.95	2.01
East Peninsular Malaysia	1954.18	1243.62	1.36	1445.62	1751.53	2.07	732.10	432.93	0.19
Kapuas-Sambas	8274.68	1979.66	0.00	6711.48	3529.52	0.00	3398.85	2904.60	0.90
North Selangor	762.33	880.61	53.57	797.68	835.20	63.76	797.68	797.68	0.11
Rajang	1988.82	840.86	14.91	649.95	2170.46	23.69	329.15	7.41	0.09
Sadong	969.33	555.79	10.80	104.35	1414.49	17.09	52.85	0.01	0.01
West Johor	66.27	1634.29	0.00	48.16	1652.59	0.00	24.39	13.43	0.01

Notes: We present the area (km^2) of each terrestrial land-cover type (ie forest, degraded peatland, urban) in 2000 and 2010, as calculated by Miettinen *et al.* (2011). Within each basin, for peatland areas with no associated remote-sensing data (mean percentage of peatland area not mapped: 8.3%), the proportion of land-cover types is assumed to be the same as in areas that were successfully mapped. Finally, we project forest area (km^2) in 2050, following the three land-use change scenarios (CONSERV, BAU, and CONVERT) based on deforestation rates in 2000 and 2010.

WebTable 3. Summary of parameter values applied in the MCSAM to project extinctions

Basins	γ (± SD)	$\sigma_{degraded}$	σ_{urban}	$p_{degraded}$	p_{urban}	S_{orig}	A_{orig}	A_{new} *CONSERV*	A_{new} *BAU*	A_{new} *CONVERT*
Ambat	0.333 (± 0.087)	0.667	1	1.0000	0	5	20.03	10.14	4.20	0.00
Banka				0.9960	0.0040	13	181.25	91.79	38.71	0.02
Batang Hari-Indragiri				0.9997	0.0003	26	5310.48	2689.35	920.43	0.71
Central Kalimantan				0.9994	0.0006	45	14993.28	7592.95	7592.95	2.01
East Peninsular Malaysia				0.9988	0.0012	9	1445.62	732.10	432.93	0.19
Kapuas-Sambas				1.0000	0	34	6711.48	3398.85	2904.60	0.90
North Selangor				0.9291	0.0709	8	797.68	797.68	797.68	0.11
Rajang				0.9892	0.0108	7	649.95	329.15	7.41	0.09
Sadong				0.9881	0.0119	10	104.35	52.85	0.01	0.01
West Johor				1.0000	0	9	48.16	24.39	13.43	0.01

Notes: γ (± SD): exponent of MCSAM derived from meta-analysis of fish species–basin area relationships across four tropical forest regions (± standard deviation used in Monte Carlo simulations); $\sigma_{degraded}$ and σ_{urban}: sensitivity of fish species toward degraded peatland and urban land cover, respectively; $p_{degraded}$ and p_{urban}: proportion of converted area attributed to degraded peatland and urban land cover, respectively; S_{orig}: original fish species richness (in 2010); A_{orig}: original PSF area (in 2010); A_{new}: PSF area in 2050 following the three land-use change scenarios (CONSERV, BAU, and CONVERT).

WebTable 4. Probability of global extinction and distribution of 102 fish species

		Mean probability of extinction (± SE)			*PSF river basins*									
Rank	*Species*	*CONSERV*	*BAU*	*CONVERT*	*AB*	*BK*	*BT*	*CK*	*EP*	*KP*	*NS*	*RJ*	*SD*	*WJ*
1	*Encheloclarias prolatus* (Ng and Lim)	0.2564 (± 0.0005)	0.9861 (± 0.0001)	0.9862 (± 0.0001)	0	0	0	0	0	0	0	0	1	0
2	*Betta brownorum* (Witte and Schmidt)	0.0142 (± 0.0001)	0.6527 (± 0.0005)	0.7333 (± 0.0004)	0	0	0	0	0	0	0	1	1	0
3	*Sundadanio goblinus* (Conway *et al*.)	0.3023 (± 0.0005)	0.6249 (± 0.0005)	0.9936 (± 0.0001)	0	0	1	0	0	0	0	0	0	0
4	*Sundadanio margarition* (Conway *et al*.)	0.0117 (± 0.0001)	0.5866 (± 0.0005)	0.7851 (± 0.0004)	0	0	0	0	0	0	0	1	1	0
5	*Betta ibanorum* (Tan and Ng)	0.0271 (± 0.0002)	0.5091 (± 0.0005)	0.5086 (± 0.0005)	0	0	0	0	0	0	0	0	1	0
6	*Betta burdigala* (Kottelat and Ng)	0.2211 (± 0.0004)	0.4414 (± 0.0005)	0.9743 (± 0.0002)	0	1	0	0	0	0	0	0	0	0
7	*Encheloclarias tapeinopterus* (Bleeker)	0.2218 (± 0.0004)	0.4411 (± 0.0005)	0.9742 (± 0.0002)	0	1	0	0	0	0	0	0	0	0
8	*Paedocypris progenetica* (Kottelat *et al*.)	0.1635 (± 0.0004)	0.3918 (± 0.0004)	0.9624 (± 0.0002)	0	0	1	0	0	0	0	0	0	0
9	*Parosphromenus allani* (Brown)	0.006 (± 0.0001)	0.3706 (± 0.0005)	0.6265 (± 0.0005)	0	0	0	0	0	0	0	1	1	0
10	*Hyalobagrus ornatus* (Duncker)	0.1969 (± 0.0004)	0.3548 (± 0.0004)	0.9688 (± 0.0002)	0	0	0	0	0	0	0	0	0	1
11	*Ompok supernus* (Ng)	0.3256 (± 0.0005)	0.3257 (± 0.0004)	0.9967 (± 0.0001)	0	0	0	1	0	0	0	0	0	0
12	*Rasbora patrickyapi* (Tan)	0.3253 (± 0.0005)	0.3256 (± 0.0004)	0.9967 (± 0.0001)	0	0	0	1	0	0	0	0	0	0
13	*Betta strohi* (Schaller and Kottelat)	0.3246 (± 0.0005)	0.3252 (± 0.0004)	0.9968 (± 0.0001)	0	0	0	1	0	0	0	0	0	0
14	*Encheloclarias* sp. “Kal Teng”	0.3255 (± 0.0005)	0.3249 (± 0.0004)	0.9969 (± 0.0001)	0	0	0	1	0	0	0	0	0	0

		Mean probability of extinction (± SE)			*PSF river basins*									
15	*Betta uberis* (Tan and Ng)	0.3251 (± 0.0004)	0.3243 (± 0.0004)	0.9968 (± 0.0001)	0	0	0	1	0	0	0	0	0	0
16	*Eirmotus furvus* (Tan and Kottelat)	0.1116 (± 0.0003)	0.2823 (± 0.0004)	0.9143 (± 0.0003)	0	0	1	0	0	0	0	0	0	0
17	*Betta renata* (Tan)	0.1118 (± 0.0003)	0.2807 (± 0.0005)	0.9138 (± 0.0003)	0	0	1	0	0	0	0	0	0	0
18	*Ompok leiacanthus* (Bleeker)	0.067 (± 0.0003)	0.2755 (± 0.0004)	0.9682 (± 0.0002)	0	1	1	0	0	0	0	0	0	0
19	*Paedocypris micromegethes* (Kottelat *et al.*)	0.0025 (± 0.0001)	0.2711 (± 0.0005)	0.4579 (± 0.0005)	0	0	0	0	0	0	0	1	1	0
20	*Encheloclarias kelioides* (Ng and Lim)	0.0723 (± 0.0002)	0.2532 (± 0.0004)	0.9846 (± 0.0001)	0	0	1	0	1	0	0	0	0	0
21	*Paedocypris* sp. “Banka”	0.1146 (± 0.0003)	0.2498 (± 0.0004)	0.8992 (± 0.0003)	0	1	0	0	0	0	0	0	0	0
22	*Sundadanio gargula* (Conway *et al.*)	0.1145 (± 0.0003)	0.2497 (± 0.0004)	0.8986 (± 0.0003)	0	1	0	0	0	0	0	0	0	0
23	*Paedocypris* sp. “Pahang”	0.1217 (± 0.0003)	0.2226 (± 0.0004)	0.9669 (± 0.0002)	0	0	0	0	1	0	0	0	0	0
24	*Betta simorum* (Tan and Ng)	0.0844 (± 0.0003)	0.2191 (± 0.0004)	0.8598 (± 0.0004)	0	0	1	0	0	0	0	0	0	0
25	*Betta mandor* (Tan and Ng)	0.1686 (± 0.0004)	0.2049 (± 0.0004)	0.9307 (± 0.0003)	0	0	0	0	0	1	0	0	0	0
26	*Paedocypris* sp. “Kapuas”	0.1693 (± 0.0004)	0.2049 (± 0.0004)	0.9301 (± 0.0003)	0	0	0	0	0	1	0	0	0	0
27	*Betta rutilans* (Witte and Kottelat)	0.1693 (± 0.0004)	0.2048 (± 0.0004)	0.9306 (± 0.0002)	0	0	0	0	0	1	0	0	0	0
28	*Parosphromenus quindecim* (Kottelat and Ng)	0.1693 (± 0.0004)	0.2045 (± 0.0004)	0.9306 (± 0.0002)	0	0	0	0	0	1	0	0	0	0
29	*Betta midas* (Tan)	0.1697 (± 0.0004)	0.2045 (± 0.0005)	0.9299 (± 0.0002)	0	0	0	0	0	1	0	0	0	0

		Mean probability of extinction (± SE)			*PSF river basins*									
30	*Leptobarbus melanopterus* (Weber and de Beaufort)	0.1689 (± 0.0004)	0.2045 (± 0.0004)	0.9301 (± 0.0003)	0	0	0	0	0	1	0	0	0	0
31	*Parosphromenus anjunganensis* (Kottelat)	0.1691 (± 0.0004)	0.2044 (± 0.0004)	0.9302 (± 0.0002)	0	0	0	0	0	1	0	0	0	0
32	*Sphaerichthys vaillanti* (Pellegrin)	0.1695 (± 0.0004)	0.2043 (± 0.0004)	0.9301 (± 0.0003)	0	0	0	0	0	1	0	0	0	0
33	*Betta pinguis* (Tan and Kottelat)	0.1699 (± 0.0004)	0.2043 (± 0.0004)	0.9298 (± 0.0002)	0	0	0	0	0	1	0	0	0	0
34	*Osteochilus partilineatus* (Kottelat)	0.1689 (± 0.0004)	0.2042 (± 0.0004)	0.9301 (± 0.0003)	0	0	0	0	0	1	0	0	0	0
35	*Sundadanio rubellus* (Conway *et al.*)	0.1684 (± 0.0004)	0.2037 (± 0.0004)	0.9302 (± 0.0003)	0	0	0	0	0	1	0	0	0	0
36	*Silurichthys sanguineus* (Roberts)	0.1691 (± 0.0004)	0.2034 (± 0.0004)	0.9306 (± 0.0002)	0	0	0	0	0	1	0	0	0	0
37	*Hyalobagrus flavus* (Ng and Kottelat)	0.0986 (± 0.0003)	0.2028 (± 0.0004)	0.9903 (± 0.0001)	0	0	1	1	0	0	0	0	0	0
38	*Betta tomi* (Ng and Kottelat)	0.1022 (± 0.0003)	0.1898 (± 0.0004)	0.8016 (± 0.0004)	1	0	0	0	0	0	0	0	0	0
39	*Pectenocypris micromysticetus* (Tan and Kottelat)	0.0685 (± 0.0002)	0.1794 (± 0.0004)	0.8049 (± 0.0004)	0	0	1	0	0	0	0	0	0	0
40	*Parosphromenus linkei* (Kottelat)	0.1783 (± 0.0004)	0.1779 (± 0.0004)	0.9807 (± 0.0001)	0	0	0	1	0	0	0	0	0	0
41	*Pseudomystus funebris* (Ng)	0.1783 (± 0.0004)	0.1778 (± 0.0004)	0.9805 (± 0.0001)	0	0	0	1	0	0	0	0	0	0
42	*Parosphromenus opallios* (Kottelat and Ng)	0.1778 (± 0.0004)	0.1778 (± 0.0004)	0.9807 (± 0.0001)	0	0	0	1	0	0	0	0	0	0
43	*Encheloclarias baculum* (Ng and Lim)	0.0113 (± 0.0001)	0.1741 (± 0.0004)	0.8928 (± 0.0003)	0	0	0	0	0	1	0	1	1	0
44	*Parosphromenus alfredi* (Kottelat and Ng)	0.081 (± 0.0003)	0.1525 (± 0.0003)	0.738 (± 0.0004)	1	0	0	0	0	0	0	0	0	0
45	*Pseudomystus heokhuii* (Lim and	0.0571	0.1521	0.7538	0	0	1	0	0	0	0	0	0	0

		Mean probability of extinction (± SE)			PSF river basins									
	Ng)	(± 0.0002)	(± 0.0004)	(± 0.0004)										
46	*Systomus foerschi* (Kottelat)	0.1216 (± 0.0003)	0.1222 (± 0.0003)	0.9513 (± 0.0002)	0	0	0	1	0	0	0	0	0	0
47	*Nanobagrus immaculatus* (Ng)	0.1218 (± 0.0003)	0.1221 (± 0.0003)	0.9508 (± 0.0002)	0	0	0	1	0	0	0	0	0	0
48	*Parakysis notialis* (Ng and Kottelat)	0.1222 (± 0.0003)	0.1217 (± 0.0003)	0.9507 (± 0.0002)	0	0	0	1	0	0	0	0	0	0
49	*Sundadanio echinus* (Conway *et al.*)	0.0879 (± 0.0003)	0.1079 (± 0.0003)	0.7754 (± 0.0004)	0	0	0	0	0	1	0	0	0	0
50	*Betta schalleri* (Kottelat and Ng)	0.0468 (± 0.0002)	0.1066 (± 0.0003)	0.6623 (± 0.0005)	0	1	0	0	0	0	0	0	0	0
51	*Parosphromenus tweediei* (Kottelat and Ng)	0.0507 (± 0.0002)	0.0995 (± 0.0003)	0.7291 (± 0.0005)	0	0	0	0	0	0	0	0	0	1
52	*Betta persephone* (Schaller)	0.0511 (± 0.0002)	0.0992 (± 0.0003)	0.7291 (± 0.0004)	0	0	0	0	0	0	0	0	0	1
53	*Pectenocypris korthusae* (Kottelat)	0.093 (± 0.0003)	0.0927 (± 0.0003)	0.9134 (± 0.0003)	0	0	0	1	0	0	0	0	0	0
54	*Betta chloropharynx* (Kottelat and Ng)	0.0388 (± 0.0002)	0.0893 (± 0.0003)	0.5991 (± 0.0004)	0	1	0	0	0	0	0	0	0	0
55	*Parachela cyanea* (Kottelat)	0.0277 (± 0.0001)	0.0801 (± 0.0003)	0.8952 (± 0.0003)	0	0	1	0	0	1	0	0	0	0
56	*Channa pleurophthalma* (Bleeker)	0.0277 (± 0.0002)	0.0798 (± 0.0003)	0.8957 (± 0.0003)	0	0	1	0	0	1	0	0	0	0
57	*Parosphromenus filamentosus* (Vierke)	0.0747 (± 0.0003)	0.0751 (± 0.0002)	0.8714 (± 0.0003)	0	0	0	1	0	0	0	0	0	0
58	*Paedocypris carbunculus* (Britz and Kottelat)	0.075 (± 0.0003)	0.075 (± 0.0003)	0.8714 (± 0.0004)	0	0	0	1	0	0	0	0	0	0
59	*Parosphromenus sumatranus* (Klausewitz)	0.0268 (± 0.0002)	0.0726 (± 0.0002)	0.495 (± 0.0005)	0	0	1	0	0	0	0	0	0	0
60	*Hyalobagrus leiacanthus* (Ng and Kottelat)	0.0547 (± 0.0002)	0.0667 (± 0.0002)	0.9277 (± 0.0002)	0	0	0	1	0	1	0	0	0	0

		Mean probability of extinction (± SE)			*PSF river basins*									
61	*Boraras brigittae* (Vogt)	0.0548 (± 0.0002)	0.0665 (± 0.0002)	0.9275 (± 0.0003)	0	0	0	1	0	1	0	0	0	0
62	*Pseudeutropius moolenburghae* (Weber and de Beaufort)	0.0221 (± 0.0002)	0.0581 (± 0.0002)	0.8023 (± 0.0004)	0	0	1	1	0	0	0	0	0	0
63	*Systomus gemellus* (Kottelat)	0.0119 (± 0.0001)	0.0563 (± 0.0002)	0.9346 (± 0.0003)	0	1	1	1	0	0	0	0	0	0
64	*Hemirhamphodon kapuasensis* (Collette)	0.045 (± 0.0002)	0.0553 (± 0.0002)	0.5449 (± 0.0005)	0	0	0	0	0	1	0	0	0	0
65	*Parosphromenus ornaticauda* (Kottelat)	0.0448 (± 0.0002)	0.0548 (± 0.0002)	0.5463 (± 0.0005)	0	0	0	0	0	1	0	0	0	0
66	*Sphaerichthys acrostoma* (Vierke)	0.0543 (± 0.0002)	0.0544 (± 0.0002)	0.7883 (± 0.0005)	0	0	0	1	0	0	0	0	0	0
67	*Betta foerschi* (Vierke)	0.0543 (± 0.0002)	0.054 (± 0.0002)	0.7888 (± 0.0005)	0	0	0	1	0	0	0	0	0	0
68	*Pangio pulla* (Kottelat and Lim)	0.0478 (± 0.0002)	0.0479 (± 0.0002)	0.7494 (± 0.0005)	0	0	0	1	0	0	0	0	0	0
69	*Osteochilus pentalineatus* (Kottelat)	0.0477 (± 0.0002)	0.0476 (± 0.0002)	0.7489 (± 0.0005)	0	0	0	1	0	0	0	0	0	0
70	*Brevibora* sp. “Kal Teng”	0.0478 (± 0.0002)	0.0472 (± 0.0002)	0.7496 (± 0.0004)	0	0	0	1	0	0	0	0	0	0
71	*Betta waseri* (Krummenacher)	0.0227 (± 0.0001)	0.0426 (± 0.0002)	0.6828 (± 0.0004)	0	0	0	0	1	0	0	0	0	0
72	*Kottelatlimia hipporhynchos* (Kottelat and Tan)	0.0423 (± 0.0002)	0.0423 (± 0.0002)	0.7127 (± 0.0004)	0	0	0	1	0	0	0	0	0	0
73	*Sundadanio retiarius* (Conway *et al.*)	0.0381 (± 0.0002)	0.0382 (± 0.0002)	0.6789 (± 0.0005)	0	0	0	1	0	0	0	0	0	0
74	*Cyclocheilichthys janthochir* (Bleeker)	0.0302 (± 0.0002)	0.0367 (± 0.0002)	0.9126 (± 0.0003)	0	0	0	1	0	1	0	0	0	0
75	*Betta pulchra* (Tan and Tan)	0.0185 (± 0.0001)	0.0364 (± 0.0002)	0.3669 (± 0.0005)	0	0	0	0	0	0	0	0	0	1

		Mean probability of extinction (± SE)			*PSF river basins*									
76	*Hemibagrus olyroides* (Roberts)	0.0302 (± 0.0002)	0.0359 (± 0.0002)	0.9122 (± 0.0003)	0	0	0	1	0	1	0	0	0	0
77	*Boraras merah* (Kottelat)	0.0285 (± 0.0002)	0.0351 (± 0.0002)	0.7726 (± 0.0004)	0	0	0	1	0	1	0	0	0	0
78	*Hemirhamphodon chrysopunctatus* (Brembach)	0.0319 (± 0.0002)	0.0319 (± 0.0002)	0.6161 (± 0.0005)	0	0	0	1	0	0	0	0	0	0
79	*Parosphromenus parvulus* (Vierke)	0.0296 (± 0.0002)	0.0292 (± 0.0002)	0.5901 (± 0.0004)	0	0	0	1	0	0	0	0	0	0
80	Betta *tussyae* (Schaller)	0.0138 (± 0.0001)	0.0263 (± 0.0002)	0.5149 (± 0.0005)	0	0	0	0	1	0	0	0	0	0
81	*Parosphromenus nagyi* (Schaller)	0.0129 (± 0.0001)	0.025 (± 0.0002)	0.4947 (± 0.0006)	0	0	0	0	1	0	0	0	0	0
82	*Sphaerichthys selatanensis* (Vierke)	0.024 (± 0.0002)	0.0241 (± 0.0001)	0.519 (± 0.0006)	0	0	0	1	0	0	0	0	0	0
83	*Betta anabatoides* (Bleeker)	0.0227 (± 0.0001)	0.0225 (± 0.0001)	0.4985 (± 0.0005)	0	0	0	1	0	0	0	0	0	0
84	*Rasbora kalbarensis* (Kottelat)	0.0075 (± 0.0001)	0.0215 (± 0.0001)	0.5251 (± 0.0005)	0	0	1	0	0	1	0	0	0	0
85	*Luciocephalus aura* (Tan and Ng)	0.0096 (± 0.0001)	0.0197 (± 0.0001)	0.6138 (± 0.0005)	0	0	1	1	0	0	0	0	0	0
86	*Hemirhamphodon tengah* (Collette)	0.0191 (± 0.0001)	0.0193 (± 0.0001)	0.4457 (± 0.0005)	0	0	0	1	0	0	0	0	0	0
87	*Ompok weberi* (Hardenberg)	0.0127 (± 0.0001)	0.0153 (± 0.0001)	0.8114 (± 0.0004)	0	0	0	1	0	1	0	0	0	0
88	*Barbucca diabolica* (Roberts)	0.0018 (± 0)	0.0082 (± 0.0001)	0.844 (± 0.0003)	1	0	1	1	0	1	0	0	0	0
89	*Systomus rhomboocellatus* (Koumans)	0.0041 (± 0.0001)	0.0051 (± 0.0001)	0.5813 (± 0.0005)	0	0	0	1	0	1	0	0	0	0
90	*Kottelatlimia katik* (Kottelat and Lim)	0.0001 (± 0)	0.0012 (± 0)	0.6735 (± 0.0005)	0	0	1	1	0	1	0	0	1	1
91	*Chaca bankanensis* (Bleeker)	0.0001	0.0006	0.5847	1	1	1	1	0	1	0	0	0	0

		Mean probability of extinction (± SE)			*PSF river basins*									
		(± 0)	(± 0)	(± 0.0005)										
92	*Silurichthys phaiosoma* (Bleeker)	0	0.0003 (± 0)	0.2685 (± 0.0004)	0	1	0	1	0	1	0	1	0	0
93	*Nagaichthys filipes* (Kottelat and Lim)	0	0.0003 (± 0)	0.5918 (± 0.0005)	0	1	1	1	1	1	0	0	1	1
94	*Systomus lineatus* (Duncker)	0	0.0002 (± 0)	0.4562 (± 0.0004)	0	0	1	1	1	1	0	0	0	1
95	*Betta livida* (Ng and Kottelat)	0	0	0.603 (± 0.0005)	0	0	0	0	0	0	1	0	0	0
95	*Encheloclarias curtisoma* (Ng and Lim)	0	0	0.8698 (± 0.0003)	0	0	0	0	0	0	1	0	0	1
95	*Mystus bimaculatus* (Volz)	0	0	0.4634 (± 0.0005)	0	0	1	0	0	0	1	0	0	0
95	*Neohomaloptera johorensis* (Herre)	0	0	0.0847 (± 0.0003)	0	1	1	1	1	1	1	0	1	0
95	*Osteochilus spilurus* (Bleeker)	0	0	0.0323 (± 0.0002)	1	1	1	1	1	1	1	1	0	1
95	*Paedocypris* sp. “North Selangor”	0	0	0.9995 (± 0)	0	0	0	0	0	0	1	0	0	0
95	*Parosphromenus harveyi* (Brown)	0	0	0.7134 (± 0.0005)	0	0	0	0	0	0	1	0	0	0
95	*Silurichthys indragiriensis* (Volz)	0	0	0.539 (± 0.0005)	0	0	1	0	0	0	1	0	0	0

Notes: Species are ranked by their mean extinction probability under the BAU scenario. Abbreviations for PSF river basins – AB: Ambat; BK: Banka; BT: Batang Hari-Indragiri; CK: Central Kalimantan; EP: East Peninsular Malaysia; KP: Kapuas-Sambas; NS: North Selangor; RJ: Rajang; SD: Sadong; WJ: West Johor. A value of “1” represents presence in a particular basin, while “0” represents absence. *Brevibora* sp. “Kal Teng”, *Encheloclarias* sp. “Kal Teng”, *Paedocypris* sp. “Banka”, *Paedocypris* sp. “Kal Teng”, *Paedocypris* sp. “Kapuas”, *Paedocypris* sp. “Pahang” are species that are currently being described by Heok Hui Tan, Peter Ng, and their co-workers.

WebTable 5. Stenotopic PSF fish species present before and after conversion of a part of the North Selangor PSF in Peninsular Malaysia

Species	*Before conversion*	*After conversion*
Osteochilus spirulus (Bleeker)	1	0
Neohomaloptera johorensis (Herre)	1	0
Mystus bimaculatus (Volz)	1	0
Silurichthys indraginensis (Volz)	1	1
Betta livida (Ng and Kottelat)	1	1
Parosphromenus harveyi (Brown)	1	0

Notes: Data from Beamish *et al*. (2003). A value of "1" represents presence, while "0" represents absence.

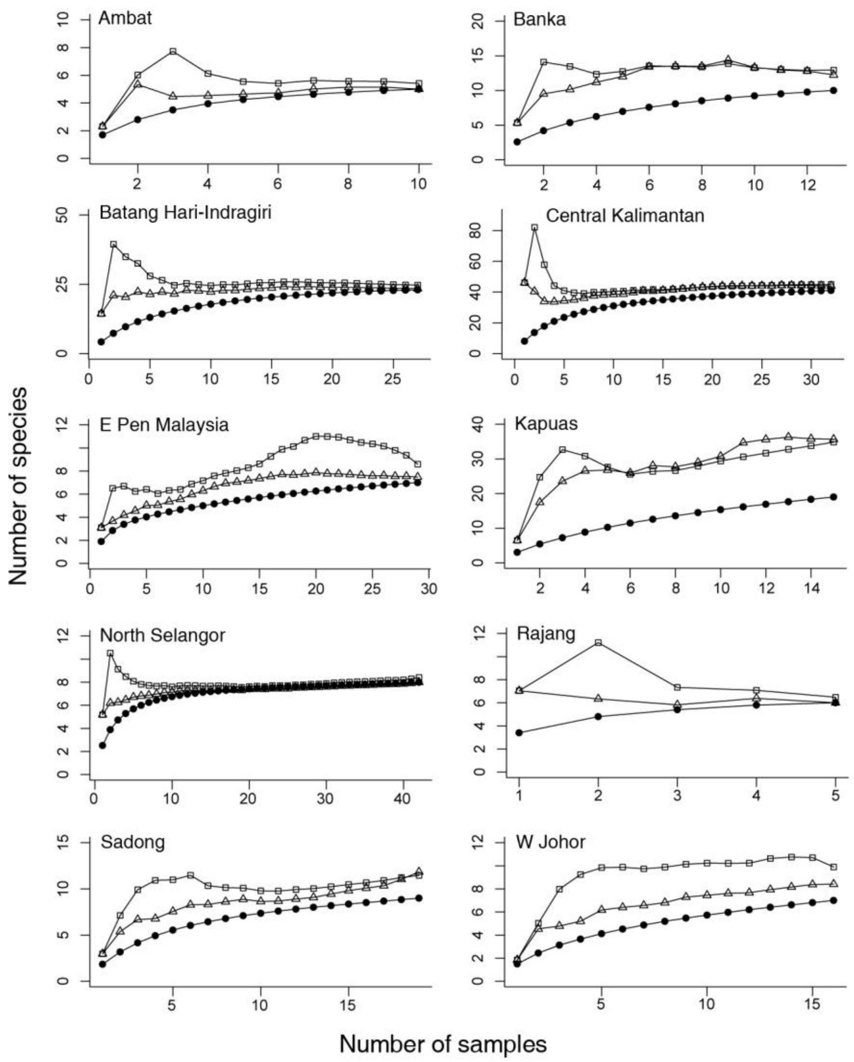
WebTable 6. Summary of fish species–basin area SARs and *z* values across major tropical forest regions

Region	*No of basins*	*Min area (km^2)*	*Max area (km^2)*	z	R^2
South America	40	108.9	5248828.5	0.32	0.52
Central America	49	108.9	109302.9	0.25	0.46
West Africa	52	800.0	3457000.0	0.30	0.80
Southeast Asia	9	6054.0	85283.0	0.46	0.68

Notes: Min Area: area of smallest basin; Max Area: area of largest basin; *z*: point estimate for *z*; R^2: proportion of variance explained by SAR model.

WebFigure 1. Summary of species data across basins. (a) Species accumulation curves for field sampling data across basins. Filled circles: observed species richness (Mao Tau estimator); squares: estimated species richness (ICE estimator); triangles: estimated species richness (Chao2 estimator). (b) Table showing the total number of sampling sites, species from sampling data and literature, estimated species richness [using ICE and Chao2 species estimators (Colwell et al. 2004, and sampling completeness of field data (calculated as species from sampling data divided by average of ICE and Chao2 estimators).

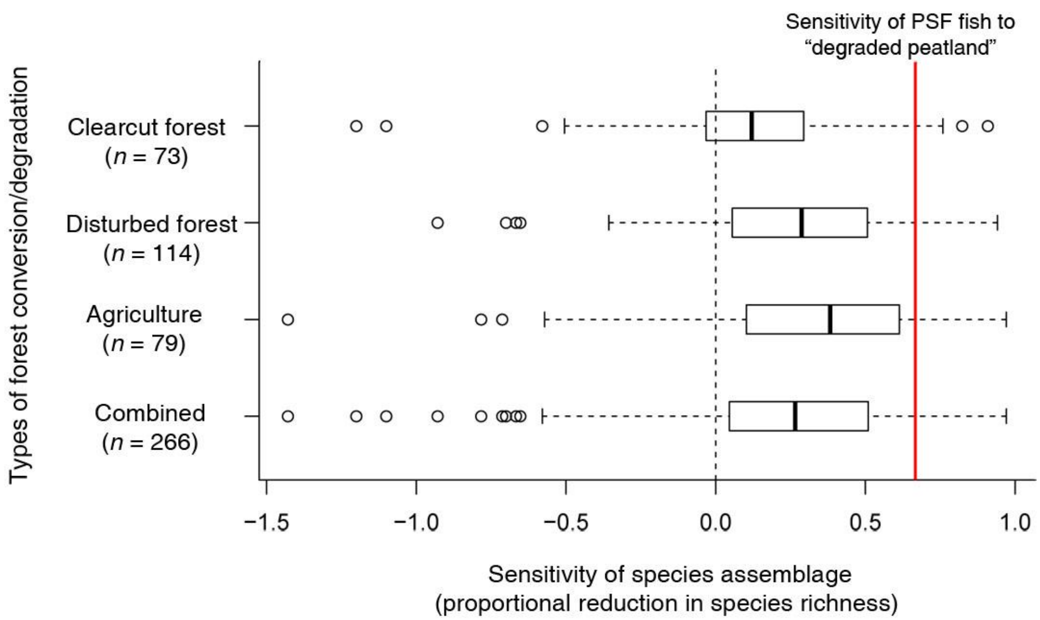
(a)



(b)

Basin	No. of sites	Spp. from sampling data	Spp. from secondary data	Total spp.	ICE	Chao2	Complete-ness
Ambat	10	5	0	5	5.4	5.0	0.96
Banka	13	10	3	13	13.0	12.3	0.79
Batang Hari-Indragiri	27	23	3	26	24.7	23.5	0.95
Central Kalimantan	32	41	4	45	44.9	43.9	0.92
East Peninsular Malaysia	29	7	2	9	8.6	7.5	0.87
Kapuas-Sambas	15	19	15	34	34.8	35.7	0.54
North Selangor	42	8	0	8	8.4	8.0	0.98
Rajang	5	6	1	7	6.5	6.0	0.96
Sadong	19	9	1	10	11.5	11.8	0.77
West Johor	16	7	2	9	9.9	8.4	0.76
All basins	208	91	11	102	-	-	-

WebFigure 2. Boxplots summarizing the sensitivity of birds, mammals, and invertebrates to different types of forest degradation that are equivalent to the “degraded peatland” land-use designation in the current study. Sensitivity is defined as the proportional reduction in species richness between a pristine site and a degraded site. Sensitivity can range from < 0 (degraded site has more species than pristine site) to 0 (species richness of pristine site equals that of degraded site) to 1 (100% of the species found in the pristine site are lost from the degraded site). Our data is derived from Sodhi *et al*. (2009), who conducted a meta-analysis of all studies that compared species richness in a pristine versus a degraded site in Southeast Asia. Each observation is a pair-wise comparison of species richness in a pristine versus degraded site. The bold line, box edges, and whiskers denote the median, the interquartile range, and the 1.5× interquartile range of sensitivity, respectively. The sensitivity of stenotopic PSF fish to “degraded peatland” (red line) falls within the range of values observed in other taxa. The total number of observations in each degradation category (n) is also shown.



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