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Biological parameters used in setting captive-breeding quotas for Indonesia's breeding facilities

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Abstract: *The commercial captive breeding of wildlife is often seen as a potential conservation tool to relieve pressure on wild populations, but laundering of wild-sourced specimens as captive bred can seriously undermine conservation efforts and provide a false sense of sustainability. Indonesia is at the center of such controversy; therefore, we examined Indonesia's captive-breeding production plan (CBPP) for 2016. We compared the biological parameters used in the CBPP with parameters in the literature and with parameters suggested by experts on each species and identified shortcomings of the CBPP. Production quotas for 99 out of 129 species were based on inaccurate or unrealistic biological parameters and production quotas deviated more than 10% from what parameters in the literature allow for. For 38 species, the quota exceeded the number of animals that can be bred based on the biological parameters (range 100–540%) calculated with equations in the CBPP. We calculated a lower reproductive output for 88 species based on published biological parameters compared with the parameters used in the CBPP. The equations used in the production plan did not appear to account for other factors (e.g., different survival rate for juveniles compared to adult animals) involved in breeding the proposed large numbers of specimens. We recommend the CBPP be adjusted so that realistic published biological parameters are applied and captive-breeding quotas are not allocated to species if their captive breeding is unlikely to be successful or no breeding stock is available. The shortcomings in the current CBPP create loopholes that mean mammals, reptiles, and amphibians from Indonesia declared captive bred may have been sourced from the wild.*

Keywords: captive bred, conservation, laundering, management, wildlife trade

Parámetros Biológicos Utilizados en el Establecimiento de Cuotas de Crianza en Cautiverio para las Instalaciones de Reproducción de Indonesia

Resumen: *La crianza de fauna en cautiverio con fines comerciales comúnmente es vista como una herramienta potencial de conservación para mitigar la presión sobre las poblaciones silvestres, pero el lavado de especímenes silvestres como criados en cautiverio puede debilitar seriamente los esfuerzos de conservación y proporcionar un sentido falso de la sustentabilidad. Indonesia se encuentra en el centro de dicha controversia; por lo tanto, examinamos el plan de producción de crianza en cautiverio (CBPP) de este país para el 2016. Comparamos los parámetros biológicos utilizados en el CBPP con los parámetros en la literatura y con los parámetros sugeridos por los expertos para cada especie e identificamos las limitaciones del CBPP. Las cuotas de producción para 99 de las 129 especies estuvieron basadas en parámetros biológicos erróneos o irreales y las cuotas de producción se desviaron más del 10% de lo que permiten los parámetros en la literatura. Para 38 especies, la cuota excedió el número de animales que pueden ser criados con base en los parámetros biológicos (rango 100% - 540%) calculados con ecuaciones del CBPP. Calculamos un resultado reproductivo más bajo para 88 especies con base en los parámetros biológicos publicados comparados con los parámetros utilizados en el CBPP. Las ecuaciones utilizadas en el plan de producción parecieron no responder por otros factores*

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(p. ej.: las diferentes tasas de supervivencia de los juveniles comparados con los animales adultos) involucrados en la crianza del gran número propuesto de especímenes. Recomendamos que el CBPP sea ajustado para que se apliquen parámetros biológicos realistas y publicados y que las cuotas de crianza en cautiverio no sean asignadas a las especies si su reproducción en cautiverio tiene pocas probabilidades de ser exitosa o si no hay un stock de reproducción disponible. Las limitaciones en el actual CBPP crean resquicios que implican que los mamíferos, reptiles y anfibios de Indonesia declarados como criados en cautiverio pueden haber sido obtenidos en vida silvestre.

Palabras Clave: conservación, criado en cautiverio, lavado, manejo, mercado de fauna

Introduction

Illegal and unsustainable wildlife trade is a major threat to biodiversity conservation (Rosser & Mainka 2002; Broad et al. 2003; Nijman 2010) and can lead to species declines (Van Balen et al. 2000; Shepherd & Ibarrondo 2005; Natusch & Lyons 2012) and ultimately threaten whole ecosystems (Duckworth et al. 2012; Challender et al. 2015). The lucrative global exotic pet trade is a major driver of the wildlife trade (Auliya et al. 2016) and puts additional pressure on wild populations as demand grows.

Commercial captive breeding of wildlife is a potential conservation tool to alleviate the pressure on wild populations (Jepson & Ladle 2009; Nogueira & Nogueira-Filho 2011; Challender et al. 2015). Advocates argue that it reduces the demand for wild-sourced animals (Robinson et al. 2015). However, for traders to favor captive-bred animals over wild-sourced animals, they need to be equally or more profitable (Bulte & Damania 2005). Captive-breeding requires substantive investment in facilities, personnel, and operation costs (Snyder et al. 1996; Nijman & Shepherd 2015) relative to the low costs associated with obtaining wild-sourced specimens.

The laundering of wild-sourced specimens fraudulently declared as captive bred reportedly occurs on a large scale (Nijman & Shepherd 2009; Lyons & Natusch 2011; Nijman & Shepherd 2015) and may have grave impacts on wild populations (Natusch & Lyons 2012). Because trade in certain protected species is allowed, or less scrutinized, only for captive-bred specimens, there is incentive for traders and exporters to label wild-sourced specimens as captive bred to circumvent trade restrictions. This problem is recognized by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). At the 2016 CoP17, a resolution (Resolution Conf. 17.7) for the review of trade in animal species reported as produced in captivity was passed. This highlights concerns that there is growing evidence of illegal trade in wild-sourced specimens sold as captive bred and doubts about the legal origin of parental stocks of both native and nonnative captive-bred specimens (CITES 2016). As such, a regulatory mechanism specifically reviewing trade in animals from captive sources is in process to ensure compliance with CITES provisions (CITES 2016).

Indonesia has been in the spotlight for laundering wild-sourced animals into the international trade by declaring them captive bred (Lyons & Natusch 2011; Beastall & Shepherd 2013; Nijman & Shepherd 2015). Indonesia has an extensive harvest-quota system for wild-sourced native species to supply both domestic and international markets. Indonesian wildlife is categorized as protected or unprotected under Government Regulation number 7, 1999. Commercial exploitation of protected species is prohibited unless it concerns captive-bred animals (offspring of the second [F2] or subsequent generations) (Government Regulation number 8, 1999). Trade in wild-sourced specimens of unprotected species is allowed under a quota system. Businesses involved in commercial exploitation of wild and captive bred native species are required to submit trade records annually, and all specimens are supposed to be accompanied by legal documents. Nonnative species are not protected under current Indonesian legislation.

Indonesia's captive-breeding production plan (CBPP) quantifies the number of animals allowed to be produced by registered Indonesian captive-breeding facilities. It includes a breakdown of the species, breeding facilities involved, and equations used to derive quota numbers and was implemented to increase transparency and minimize laundering. We examined the CBPP for 2016. The CBPP is disseminated annually by the Indonesian government to stakeholders, including wildlife breeders and other countries' CITES authorities. We received the 2016 document from sources within these stakeholder groups. We compared the biological parameters used in the CBPP with parameters in the literature for each species, identified shortcomings of the CBPP, and explored the possibility that these shortcomings allow wild-sourced specimens to be laundered as captive bred. We considered improvements to the equations and data used in deriving the CBPP and to captive breeding.

Methods

How the CBPP Works

The CBPP separates species into 4 categories: I, CITES-listed and nationally protected species; II, nationally protected species not listed on CITES appendices; III,

Table 1. Summary of the species in Indonesia's captive-breeding production plan for pets for 2016.

		CITES[b]				*IUCN*[c]							*Native*[d]	
Taxon	*Category*[a]	*non-CITES*	*III*	*II*	*I*	*NE*	*DD*	*LC*	*NT*	*VU*	*EN*	*CR*	*yes*	*no*
Amphibians	IV	2						2					2	
Mammals	I		1	3				1	1	2			4	
	II	1						1					1	
	IV	16	1[e]	1[e]				15	1	2			18	
Reptiles	I			9		5		2		2			9	
	II	5				2		3					5	
	III	1	1	59		29	1	17	2	7	3	2	49	12
	IV	29				12		12	3	2			28	1
Total		54	3	72	0	48	1	53	7	15	3	2	116	13

[a]*Key: I, protected or Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) listed species; II, protected but not CITES listed; III, not protected but CITES listed; IV, neither protected nor CITES listed.*
[b]*Definitions: I, CITES Appendix I; II, CITES Appendix II and III, CITES Appendix III.*
[c]*International Union for the Conservation of Nature threat categories: NE, not evaluated by IUCN; DD, data deficient; LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; CR, critically endangered.*
[d]*Native to Indonesia.*
[e]*Listed in wrong category.*

Table 2. An example of the calculation of the reproductive output (reproduction) for the sugar glider (*Petaurus breviceps*) based on the input parameters in the detailed audit of Indonesia's captive-breeding production plan (CBPP) (CBPP 2016 allocated quota 4792 specimens).

Calculation of reproductive factors[a]

$$\text{Renpro}_{\text{min or max}} = \text{PJP}^{*}\ \text{Reproduction}_{\text{min or max}}{}^{*}\text{FREP}^{*}\text{SUR}^{*}\text{INP}$$
$$\text{Renpro}_{\text{min}} = 80\%^{*}\ 1\ ^{*}\ 3\ ^{*}\ 80\%\ ^{*}\ 80\% \quad = 1.536$$
$$\text{Renpro}_{\text{max}} = 80\%\ ^{*}\ 2\ ^{*}\ 3\ ^{*}\ 80\%\ ^{*}\ 80\% \quad = 3.072$$

Calculation of reproductive output

$$\text{Reproduction}_{\text{min or max}} = \text{Breeding stock}^{*}\text{Renpro}_{\text{min or max}} + \text{Stock 2015}$$
$$\text{Reproduction}_{\text{min}} = 2080^{*}1.536 + 0 = 3195$$
$$\text{Reproduction}_{\text{max}} = 2080^{*}3.072 + 0 = 6390$$

[a]*Definitions: PJP (Prosentase Jumlah Induk Produktif), percent female animals reproducing; reproduction (min or max), minimum or maximum clutch or litter size per breeding event; FREP (Frekuensi Reproduktif), annual number of breeding events; SUR, survival rate of the produced animals; INP (Indeks Pemanfaatan), utilization index based on the assumption that a certain percentage of offspring can be used; breeding stock, number of adult female animals; stock 2015, surplus animals bred in captivity in 2015.*

CITES-listed species that are not nationally protected; and IV, species that are neither nationally protected nor listed on CITES. The majority of species (116) on the CBPP are native to Indonesia. Thirteen nonnative reptile species originate from other countries in Asia and the Pacific (5), Africa (5), and South America (3). Category IV for mammals erroneously includes 1 species listed in CITES Appendix III and 1 species in CITES Appendix II (Table 1 footnote). For 2016, a total quota of 4,273,029 captive-bred specimens was reportedly present for 118 of 129 species listed in the CBPP. For 24 species, the CBPP says, "Types can be used after being audited and receiving a recommendation from the Indonesian Institute of Sciences (LIPI)," Indonesia's CITES Scientific Authority.

The CBPP-based calculations on current breeding stock and remaining animals produced in 2015. Details of the number of breeding individuals per species present at 18 Indonesian breeding facilities and the proposed production plan per facility for 2016 are included. Five of the 18 facilities had no current breeding stock and were not allocated breeding quantities. In total, breeding stock was reportedly present for 81 of the 129 species. The proposed captive-breeding quantity was based on an equation calculating minimum and maximum reproduction factor (renpro):

$$\text{renpro}_{\text{min or max}} = \text{PJP}^{*}\ \text{reproduction}_{\text{min or max}}\ ^{*}\ \text{FREP}^{*}\text{SUR}^{*}\text{INP}, \tag{1}$$

where PJP (Prosentase Jumlah Induk Produktif) is the percentage of female animals reproducing, reproduction (min or max) is the minimum or maximum clutch or litter size per breeding event, FREP (Frekuensi Reproduktif) is the annual number of breeding events, SUR is the survival rate of the produced animals, and INP (Indeks Pemanfaatan) is the utilization index based on the assumption that a certain percentage of offspring can be used (see example in Table 2). The rationale behind the percentages used for PJP, SUR, and INP is unknown. The parameters mentioned above follow the terminology used in the CBPP.

A spreadsheet in the CBPP containing a detailed audit of one of the breeding facilities shows how the calculated reproduction factor is used to calculate the minimum or maximum number of animals for each species that can be captive bred by breeding facilities in 2016 (Eq. (2)):

$$\text{captive} - \text{bred animals}_{\text{min or max}} = \text{breeding stock}\ ^{*}\ \text{renpro}_{\text{min or max}}\ \left(\text{CBPP Eq. 1}\right) + \text{stock 2015}. \tag{2}$$

Calculations with Published Biological Parameters

Parameters regarding the ecology and breeding biology of the examined species were retrieved from the CBPP and compared with parameters we obtained from published literature including scientific journals, books, and herpetocultural magazines in 6 different languages (Dutch, English, French, German, Mandarin, and Spanish), largely written by people with extensive experience in breeding these species (Supporting Information). Information was cross-checked with species experts and the AnAge database (available from: http://genomics.senescence.info/species [De Magalhaes & Costa 2009]). In many cases, reproduction is higher in captivity than in the wild (Auliya 2006; Mendyk 2011), and we took this into account by including breeding results obtained by private individuals or zoological institutes, who are often able to provide optimal husbandry conditions and therefore maximize reproductive outputs. To illustrate inaccuracies in the biological parameters used in the CBPP, we used the same equations as the CBPP to calculate reproductive output.

The CBPP uses the maximum clutch or litter size of animals in the calculations of the captive-breeding quota. In contrast and to provide a more realistic reproductive output, we used both the average clutch or litter size and a calculated average reproductive frequency (average number of annual breeding events) in the equations. In most frequency distributions, maximum clutch or litter sizes are exceptions. Moreover, clutch or litter sizes depend highly on circumstances (e.g., high-caloric diets [Mendyk 2011] and for reptiles often on size of the animal [Thomson & Pianka 2001]), and clutch sizes of multiclutching species tend to decrease throughout the breeding season (e.g., Georges et al. 2008). Using maximum clutch or litter sizes overestimates potential reproductive output. Where frequency information was not available, we took a conservative approach and used a minimum reproduction frequency (number of annual breeding events) of 1. The average reproductive frequency was calculated as

$$(\text{maximum number of annual breeding events} + 1)/2. \quad (3)$$

For example, for a species with maximum reproductive frequency of 5 and minimum of 1, the average reproductive frequency is $(5+1)/2 = 3$.

Within the CBPP, the fact that not every female animal may reproduce during the annual breeding season is taken into account with a separate parameter (PJP). Wherever captive-breeding information for a species was unavailable, data for taxonomically closely related species were used. Where taxonomy of reptile species in the CBPP differed from the latest taxonomic insights, we followed The Reptile Database (Uetz & Hošek 2015).

Results

Differences in Biological Parameters

For 99 out of 129 species, the calculated reproductive output based on published sources deviated by more than 10%, either negatively or positively, of the production quota used in the CBPP. Calculated reproductive outputs based on published literature and average reproductive frequencies were higher for five mammal species ($\bar{x} =$ 197%, range 100–359%) and lower for 15 mammal species ($\bar{x} = 49\%$, range 20–95%) than the CBPP reproductive output. The reproductive output calculated using published literature was lower for 71 reptile species ($\bar{x} = 60\%$, range 10–98%) than the CBPP reproductive output. For 22 reptile species, published parameters yielded a higher reproductive output ($\bar{x} = 141\%$, range 100–5602%) than the CBPP. For both amphibian species, the literature shows a single annual breeding event of 200–1000 eggs for the white-lipped tree frog (*Litoria infrafrenata*) (Williams & Hero 1998) and 200–2000 eggs for White's tree frog (*Litoria caerulea*) (Hero et al. 2004; Cabrera-Guzmán et al. 2013), which corresponds to only 2% and 3%, respectively, of the CBPP maximum reproductive output. This means that for the frog species, according to biological parameters in the literature, 98% and 97% of the allocated CBPP quota respectively cannot be bred with the current breeding stock. The use of incorrect biological parameters was not confined to Indonesia's native species and included several nonnative species such as the near threatened Parson's chameleon (*Calumma parsonii*).

For only 1 mammal species (binturong), the CBPP-allocated quota for species with available breeding stock was lower than the literature-based calculated reproductive output (74%). The CBPP-allocated quotas exceeded the literature-based calculated reproductive output for the remaining 21 species ($\bar{x} = 241\%$, range 104–898%). For 38 reptile species, allocated captive-breeding quotas were larger ($\bar{x} = 187\%$, range 101–485%) and for 54 reptile species were lower than the literature-based calculated reproductive output. The CBPP quotas allocated to both amphibian species comprised 6667% and 1497% of the calculated reproductive output for the white-lipped tree frog and White's tree frog.

Other CBPP Irregularities

Further examination of the detailed audit revealed that the proposed quotas were not actually based on the calculated captive-bred animals $_{\text{min or max}}$; rather, numbers from a separate sheet in the CBPP called the "proposed production plan" and a sum-product equation seem to have been used. Because of this, the proposed quotas remained the same even when the biological input parameters were adjusted.

Table 3. Calculation of reproductive factors based on Indonesia's captive-breeding production plan (CBPP) versus biological parameters from published literature.*

Short-beaked echidna (*Tachyglossus aculeatus*)	Timor python (*Python timoriensis*)
CBPP	CBPP
$\text{Renpro}_{\text{min}} = 70\%*1*1*80\%*80\% = 0.896$	$\text{Renpro}_{\text{min}} = 80\%*20*1*80\%*80\% = 10.24$
$\text{Renpro}_{\text{max}} = 70\%*2*1*80\%*80\% = 1.792$	$\text{Renpro}_{\text{max}} = 80\%*20*1*80\%*80\% = 10.24$
$\text{Reproduction}_{\text{min}} = 15*10.24 + 18 = 31$	$\text{Reproduction}_{\text{min}} = 60*10.24 + 74 = 688$
$\text{Reproduction}_{\text{max}} = 15*10.24 + 18 = 45$	$\text{Reproduction}_{\text{max}} = 60*10.24 + 74 = 688$
CBPP for 2016: 50 specimens	CBPP for 2016: 473 specimens
Published literature	Published literature
$\text{Renpro}_{\text{min}} = 70\%*1*1*80\%*80\% = 0.448$	$\text{Renpro}_{\text{min}} = 80\%*4*1*80\%*80\% = 2.048$
$\text{Renpro}_{\text{max}} = 70\%*1*1*80\%*80\% = 0.448$	$\text{Renpro}_{\text{max}} = 80\%*8*1*80\%*80\% = 4.096$
$\text{Reproduction}_{\text{min}} = 15*0.448 = 7$	$\text{Reproduction}_{\text{min}} = 60*2.048 = 123$
$\text{Reproduction}_{\text{max}} = 15*0.448 = 7$	$\text{Reproduction}_{\text{max}} = 60*4.096 = 246$
Reproductive output: 7 specimens	Reproductive output: 184 specimens
Remaining 2015: 18 specimens	Remaining 2015: 74 specimens
Realistic quantity 25 specimens	Realistic quantity 258 specimens

**Variables defined in Table 2.*

The CBPP contains biological parameters for 124 of the 129 species (Supporting Information) but lacks data for the banded civet (*Hemigalus derbyanus*), binturong (*Arctictis binturong*), Bismarck ringed python (*Bothrochilus boa*), green anaconda (*Eunectes murinus*), and masked flying fox (*Pteropus personatus*). Despite this, breeding quantities were allocated for all these except binturong, raising the question as to how quotas for these species were determined.

There appeared to be inconsistencies between the allocated quotas and maximum biological output calculated using CBPP parameters (e.g., Table 3). Excluding species without allocated quotas, the difference between the allocated quotas and maximum biological output was the largest for mammals ($n = 21$, $\bar{x} = 181\%$, range 67–540%), followed by reptiles ($n = 91$, $\bar{x} = 80\%$, range 2–366%) and amphibians ($n = 2$, $\bar{x} = 71\%$, range 41–100%). For 38 species, the quota exceeded the number of animals that can be bred based on the biological parameters (range 100–540%) and the equations used in the CBPP.

For earless monitor (*Lanthanotus borneensis*) and Southeast Asian box turtle (*Cuora amboinensis*), no breeding stock is reportedly present at any of the breeding facilities, yet quotas have been allocated for both species: 20 earless monitors allocated to 1 company and 1995 Southeast Asian box turtles allocated to another. The earless monitor was included in CITES Appendix II, and at CITES CoP17, a zero quota for wild-sourced specimens was agreed to. However, that a captive-breeding quota has been allocated with no preexisting breeding stock raises serious concerns that reportedly captive-bred earless monitor may have been taken from the wild.

Discussion

Despite being a promising starting point to audit commercial captive-breeding operations in Indonesia, the CBPP has shortcomings: the quotas are based on incorrect and unrealistic biological parameters relative to what is known of the species' breeding biology in published literature, quotas are allocated for species with no registered breeding stock, and allocated quotas in relation to the maximum reproductive output appear to be inconsistently assigned.

Biological Parameters

Many species included in the CBPP originate from remote regions of Indonesia, such as isolated islands or Indonesian New Guinea, and biological information for these species is often lacking, bringing into question the veracity of the parameters used in the CBPP. We found that some biological parameters used in the CBPP varied wildly from the information available in the literature, which resulted in a mismatch between the CBPP quotas and the number of animals that can be biologically bred. For example, the red-eyed crocodile skink (*Tribolonotus gracilis*) lays only 1 egg per clutch (Miralles 2004), but a clutch size of 5–12 is used in the CBPP. For Parson's chameleon, the CBPP uses a clutch size of 24–100 and a frequency of 4 clutches per year, yet according to the literature it produces only 1 clutch of 20–65 eggs annually (Bartlett & Bartlett 1995; Le Berre & Bartlett 2009).

A number of species require specialized care to maintain, let alone breed (Ziegler et al. 2009; Mendyk 2014). Boelen's python (*Simalia boeleni*) is 1 species for which captive-breeding programs have been largely unsuccessful (Austin et al. 2010). Nonetheless, because a zero-harvest quota was established for wild-sourced specimens, all exports have been declared as captive bred or born in captivity (Lettoof 2015). Wild female Boelen's pythons brooding eggs are located and neonates collected when they hatch (Lettoof 2015). The juvenile snakes are then exported as captive bred providing a false impression of captive breeding to evade the zero-harvest quota, even though under CITES, they should be declared as "ranched." Short-beaked echidnas (*Tachyglossus aculeatus*) are also difficult to breed in captivity. Specimens at U.S. zoos (119) have given birth to just 19 F1 individuals over the past 108 years (up to 2013), and only 4 survived beyond 18 months (Beastall & Shepherd 2013). Only in 2014 was the second documented F2 offspring born in captivity (Wallage et al. 2015). It is very unlikely that the CBPP-allocated quota (50 specimens) can be fulfilled from only F2 captive-bred specimens.

For many species, reproductive success in captivity can be substantially higher than in the wild (e.g., multiclutching in captive varanid species [Auliya 2006; Mendyk 2011]). This is likely related to high-caloric diets in captivity (Mendyk 2011) but can result in serious health problems due to excessive reproductive cycling (Mendyk 2014). For many species, clutch size depends on body size (e.g., monitor lizards [King & Green 1999]), but clutch sizes in species that have multiple clutches usually decrease throughout the season (e.g., Georges et al. 2008) and not all females have multiple clutches (Mendyk 2011; Naretto et al. 2015). The equations used by Indonesia overlook the fact that not all eggs or offspring are viable (e.g., Horn & Visser 1989; Géczy 2009). When taking these factors into account, the use of average rather than maximum clutch sizes and reproductive frequencies would provide more realistic parameters of maximum reproductive outputs than the CBPP equations.

Problems with the Equations Used

Indonesia's CBPP is based on 2 equations that are supposed to be used to calculate the potential breeding output. Considering that the number of captive-bred animals did not change within the detailed audit when the parameters were changed, but continued reflecting the number from the proposed production plan, biological parameters appear to inadvertently not be accounted for in the calculation process. This is further supported by the proposed captive-breeding quantities that frequently exceed the maximum possible reproduction according to CBPP formulas. To improve Indonesia's CBPP, the number of animals allowed to be bred in captivity should be based on consistent information and the use of standardized equations that take biological parameters into account and do not exceed the maximum reproduction possible.

It is unclear what the rationale is behind the percentages used for PJP, SUR, and INP in Eq. (1). Further explanation was requested from the government of Indonesia but no response was received. It is unclear if INP is based on the assumption that only a certain percentage is viable for trade and the remaining is not or if the remaining percentage is retained for population maintenance. Moreover, the standard percentages used differ from what the literature indicates, for example, the PJP for the common spiny bandicoot (*Echymipera kalubu*) is set at 80%, yet the literature indicates a percentage as low as 67% (Cuthbert & Denny 2014).

Including animals from previous breeding seasons in the CBPP equation may artificially inflate the allocated quota because these animals may be included in the same quota for multiple years. From the final allocated quota, it is unclear what part comprises last year's remaining stock or newly bred animals. By including animals bred during the previous season, there is a higher possibility of larger sized (juvenile to subadult) animals that are more likely to have been wild-sourced being laundered as captive bred under the guise of being born in the previous seasons. To increase the transparency of the CBPP, animals bred in the previous year should be kept out of equations for that particular season to reduce laundering opportunities and still allow surplus animals to be traded.

The CBPP equations do not take into account several factors that affect the number of animals that can be bred. For example, for breeding facilities to be sustainable in the long term, survival of existing adult breeding stock and the gradual addition of juvenile individuals to the breeding stock needs to be taken into account. This means for some species that closed-cycle breeding operations can take several years. Juvenile survival rates can differ from adults, and it can take several years for juveniles to reach sexual maturity (Schoppe 2008).

Conservation Concerns

Indonesia's captive-breeding facilities have been scrutinized for falsely declaring wild-sourced specimens as captive bred (e.g., Natusch & Lyons 2012; Nijman & Shepherd 2015), and there have been large discrepancies between reported breeding stock and the actual breeding stock present at breeding facilities in Indonesia (Nijman & Shepherd 2009; Lettoof 2015). More worrisome still is the lack of suitable breeding facilities observed at several companies claiming to be commercially breeding wildlife (Nijman & Shepherd 2009).

Even with adequate facilities present, the large quantities for which captive breeding is allowed pose significant logistical challenges. For 2016 alone, Indonesia allocated a quota to breed 4,273,029 animals, in large part consisting of tokay geckos (*Gekko gecko*) (2,856,000). A recent study revealed that wild-sourced tokay geckos are laundered en masse through registered captive-breeding facilities because it is economically not feasible to breed such large numbers and still make any profit, considering the enormous operational investments and the low sale prices (Nijman & Shepherd 2015). For breeding facilities to be economically viable, a cheaper, more acceptable alternative to wild-sourced specimens needs to be provided to the consumer (Bulte & Damania 2005; Damania & Bulte 2007). However, when profit margins are significantly reduced through costs of breeding, rearing, and maintaining the large quantities for which captive breeding is allowed, even the industry itself acknowledges commercial breeding for some species as cost-ineffective (Soehartono & Mardiastuti 2002).

The current approach (the CBPP) to setting quotas for the captive-bred pet trade is a conservation concern and poses a serious threat to the conservation of Indonesian wildlife because a false sense of sustainability is established when wildlife is laundered through breeding facilities. Population declines due to extensive collection have already been reported for several species (Shepherd & Ibarrondo 2005; Lyons & Natusch 2011). This is of particular concern for critically endangered species in the CBPP such as the Sulawesi forest turtle (*Leucocephalon yuwonoi*) and Roti island snake-necked turtle (*Chelodina mccordi*) and some range-restricted species whose conservation status have yet to be assessed (e.g., earless monitor). Deliberate misdeclaration of wild-sourced animals as captive bred also undermines the objectives and implementation of both national wildlife legislation and international wildlife-trade regulations such as CITES.

Based on previous studies of Indonesia's captive-breeding facilities and our findings, it seems unlikely that Indonesian breeders are breeding the numbers claimed in the CBPP, and some of the animals may be wild sourced. For many species, quotas are much higher than what top-notch breeding facilities can realistically produce, and these quotas may be exploited to launder wild-sourced specimens. We recommend that the CBPP be adjusted by setting new biologically realistic quotas that include all relevant factors influencing breeding success; withdrawing quotas for species that have not been audited by LIPI or for which no breeding stock is available; requiring greater transparency about the underlying scientific sources used for CBPP calculations; and including regular, unannounced inspections of breeding facilities. Because of the existing shortcomings in the CBPP, the captive-bred status of Indonesian animals cannot be guaranteed, which undermines legitimate commercial breeders and traders and impedes conservation efforts. Until the abovementioned changes have been implemented, Indonesian mammals, reptiles, and amphibians declared as captive bred cannot be assumed to be so because they may have been sourced from the wild.

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Supporting Information

An overview of biological parameters obtained from Indonesia's CBPP and from the literature and a comparison of allocated captive-breeding quota of Indonesian breeding facilities with the literature and species experts (Appendix S1) is available online. The authors are solely responsible for the content and functionality of these materials.

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