Integrated index to evaluate the conservation status and commercial interest of ornamental fish imported to Costa Rica

Índice integrado para evaluar el estado de conservación e interés comercial de peces ornamentales importados a Costa Rica

Steve A. Stephens-Cárdenas [1] y *Ana Robles-Herrera* [2*]
Escuela de Ciencias Biológicas, Universidad Latina de Costa Rica, San José, Costa Rica

Abstract

Ornamental fish species trading has exponentially increased on global scale, becoming a key driver for economic growth in several countries. Strict regulations have been developed, by governments and international organizations, to reduce and limit negative impacts of legal export/import of exotic species and local biota. However, understanding the local trends becomes fundamental to understand wildlife trade dynamics in specific countries. In order to improve the understanding on wildlife trading dynamics in Costa Rica the Relative Importance Index was adapted to develop an importance index that includes IUCN threat status to better inform the commercial trends based on both frequency, specimen volumes and conservation status for supporting institutional control and management of wildlife trading. The index was tested on sample of formal import request data of ornamental aquatic species provided by national regulatory agencies to assess the accuracy and congruence with traditional indicators. A total of 21 264 specimens from 81 species, mostly freshwater fish species were found in the request formats sample. Most requested species were *Betta splendens*, *Carassius auratus*, *Paracheirodon innesi* in congruence with international trading trends. The Conservation - Commercial Importance index identified 10 % of the species with high to very high trading importance, while the remaining were classified as low to moderate importance. This study provides a potential tool for improving national trade management and surveillance tools for better understanding of a commonly overlooked segment of biodiversity trading dynamics.

Key words: ornamental fish; biodiversity trading; management tools; importance index

Resumen

El comercio de especies de peces ornamentales ha aumentado exponencialmente a escala mundial, convirtiéndose en un motor clave para el crecimiento económico en varios países. Los gobiernos y organizaciones internacionales han desarrollado regulaciones estrictas para reducir y limitar los impactos negativos de la exportación/importación legal de especies exóticas y biota local. Sin embargo, comprender las tendencias locales se vuelve fundamental para entender la dinámica del comercio de vida silvestre en países específicos. Con el fin de mejorar la comprensión de la dinámica del comercio de vida silvestre en Costa Rica, el Índice de Importancia Relativa fue adaptado para desarrollar un Índice de Valor Relativo de Importancia Comercial que incluye el estado de amenaza de la UICN para informar mejor las tendencias comerciales en función de la frecuencia, los volúmenes de especímenes y el estado de conservación, para apoyar el control institucional y manejo del comercio de vida silvestre. El índice se probó con datos de solicitudes formales de importación de especies acuáticas ornamentales proporcionados por agencias reguladoras nacionales para evaluar la precisión y la congruencia con los indicadores tradicionales. Un total de 21 264 especimenes de 81 especies, en su mayoría especies de peces de agua dulce fueron encontrados en la muestra de formatos de solicitud. Las especies más solicitadas fueron *Betta splendens*, *Carassius auratus*, *Paracheirodon innesi* en congruencia con las tendencias del comercio internacional. El índice de Importancia Conservación - Comercial identificó 10 % de las especies con una importancia comercial alta a muy alta, mientras que el resto se clasificó como de importancia baja a moderada. Este estudio proporciona una potencial herramienta para mejorar la gestión del comercio nacional y las herramientas de vigilancia para una mejor comprensión de un segmento comúnmente pasado por alto de la dinámica del comercio de la biodiversidad.

Palabras clave: peces ornamentals; comercio de biodiversidad; herramientas de gestión; índice de importancia

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Legal international wildlife trade represents a profitable business that generates substantial revenues a year worldwide in exports alone (Jayalal & Ramachandran, 2012). In particular, the ornamental aquatic industry is a major engine in the commercial trade business, moving millions of marine species from their local habitats into particular and public aquariums and collections, around the world (King, 2019; Rhyne *et al.,* 2012;). The rising popularity of ornamental fish collection has resulted in a continuous translocation of species at a global scale, with detrimental ecological results (Singh & Lakra, 2011). Promoting the introduction of exotic animals to local environments and increased the risk of stablishing communities of invading species in ecosystems that are not able to withstand this kind of pressure (Broad *et al.,* 2003; Green *et al.,* 2020). The impact of these activities has a wide ecological spectrum, as ornamental fish, is a generic term than a wide variety of aquatic animals such as fish, crustaceans, mollusks and echinoderms, as well as corals (Vivas Delgado, 2019).

Despite the often underestimated, or unknown, economic importance of this commercial activity, a comprehensive analyses of wildlife trade patterns and activities, at global and local scales is still missing (Fukushima, Mammola & Cardoso, 2020). Even though, great advances in structuring a global legal regulatory framework have been made through the implementation of the CITES Convention, there are still legal gaps when it comes to fine grained activities developed in species trade (Andersson *et al.,* 2021). The CITES Convention (www.cites.org) has become a fundamental instrument in mitigating species overexploitation by ensuring legal, long-term sustainability and traceable practices in international trade activities (Nakamura & Kuemlangan, 2020). The trade in ornamental species has been recognized worldwide as one of the main causes of the introduction of exotic species into new environments, especially in countries with limited legislation regarding the import of living organisms and their proper maintenance (Soundararajan *et al.,* 2015).

In Costa Rica, given its great biodiversity, legal wildlife trade of aquatic species has become a powerful industry (Gluszek et al., 2020). In between 1998 and 2004, international ornamental aquatic species trade transactions included over 800000 organisms of 352 different species (Allen *et al.,* 2017). According to Allen *et al.* (2007), the Costa Rican Institute of Fishing and Aquaculture (INCOPESCA, by its initials in Spanish) valued the total imports of ornamental fish in the country between 2008 and 2013 in around $ 641 000 USD.

The objective of this study is to propose an index that identifies key species to be monitored due to the interest of wildlife traders and their global conservation status, based on available import permission applications provided national trading institutions and globally accepted conservation assessments. The proposed index has the potential to provide additional evidence to support national and international agencies in placing regulatory actions over imports and control over trading on marine biodiversity typically used in ornamental fish species trading.

The index was derived from random a sample of import permission requirements of ornamental fish, dated from July, 2019 to January, 2020, provided by the Costa Rican National Service for Animal Health (SENASA as in Spanish). A total sample of 23 permit application forms, for both marine and freshwater species, was provided. Documents were filtered and sensitive information was removed. No data regarding the import dates or country of origin was provided. Each form contained mostly common names for every species and breed, as well as the approved quantity.

A database was generated with all the registered species and breeds, the import requirement frequency, and the number total number of individuals per species in the sample. The species import frequency (IF) is an indicator of the number of times a species appeared on the invoices. Number of individuals per species was calculated as the sum all the individuals of the species that were registered on the permit application samples.

An Importance Value Index measures the proportional contribution of a taxonomic unit in the structure of a community sample. This predictor incorporates frequency and biometric variables that describe the relative abundance/density of a biological unit in a sample (Netto, Amaral & Coraiola, 2015). In order to produce a meaningful indicator, that accurately estimates the dominance of a species, in the bulk of commercial export transactions per time unit, we explored several importance value indexes, previously developed and adopted in multiple disciplines. Ultimately, we derived a relative importance index, Commercial - Conservation Importance Index (CCI Index) based on a revision of indexes developed to address fish diet composition (George & Hadley, 1979; Hart *et al.,* 2002), and forest composition/dominace (Ellenberg & Mueller-Dombois, 1974). Additionally, we examined the Use Importance Index developed for ethnobotanical studies (Hoffman & Gallaher, 2007).

The CCI Index is based on three main variables extracted from fundamental of the requisitions: the relative Species Frequency

(rSF), relative Species Abundance (rSA) and the relative Species Representativity (rSR). Plus an additional variable that incorporates the conservation status of the species as defined by the IUCN Red List of Threatened Species Criteria (IUNC, 2021) (www.iucnredlist.org). The rSF is the number of times a species (multiple breeds/subspecies of the same species count as 1), appears in the total sample of examined application forms. The rSA, is a measure of the abundance of a single species relative to the total amount of individuals reported in the complete set of application forms. The rSR, measures the total number of times a breed/subspecies is reported relative to the total number of taxonomic units required export purposes in the forms.

The IUCN Red List Criteria is produced by the IUCN Red List of Threatened Species initiative (www.iucnredlist.org), stablished by the International Union of Conservation of Nature (IUCN). As a leading authority on the assessment of conservation status of animal and plant species around the world (Rodrigues *et al.,* 2006), the IUCN Red List defines Threat Status Categories based on extinction risk analysis using scientific evidence on restricted geographical range, populations size and trends, and extinction probability analyses (IUCN, 2021). To integrate the IUCN Criteria as part of the CCI Index, a numerical value, Red List Categories (RLC), was assigned to each of the categories ranging from 1 for Least Concern, to 12 for Critically Endangered (table 1), representing incremental extinction risk status. To avoid underestimating risk, and following the original recommendation of IUCN (2001), as well as the consensus of several authors (Bland *et al.,* 2017; Parsons, 2016), the Not Evaluated (NE) and Data Deficient (DD) where not excluded as true risk categories. Instead, we assigned numerical values of 6 for NE and 9 for DD, following cross species evidence showing that species classified as NE and DD are predicted to be Vulnerable (VU) and Endangered (EN), respectively (Caetano *et al.*, 2022).

Table 1. IUCN extinction risk categories with numerical values assigned for index calculation.

IUCN Category	Code	RLC value
Critically Endangered	(CR)	12
Endangered	(EN)	9
Data Deficient	(DD)	
Vulnerable	(VU)	6
Not Evaluated	(NE)	
Near Threatened	(NT)	3
Least Concern	(LC)	1

As a preliminary step, we estimated the Proportional Weight of a Species (*PWi*) as a calculation of the percentages of abundance, representativity and frequency, coupled with the numerical factor according to the IUCN red list classification (Equation 1).

Equation 1. Proportional Weight of a Species (*PWi*) Calculation

$$PW_i = [(rSA_i + rSR_i) \cdot rSF_i] \cdot RLC_i^{\,2}$$

Where,

rSA_i = Relative abundance of individuals per species in the sample * 100

rSR_i = Relative frequency for th e breeds/subspecies per species requested * 100

rSF_i = Relative frequency for the species in the total amount of processed requisitions* 100

RLC_i = IUCN Red List Categories values for the evaluated species

The Commercial - Conservation Importance Index (*CCIi*) was then stablished as the standardized Proportional Weight of a given Species (*PWi*), to set a proper comparison scale (Equation 2).

Equation 2. *Standardized Commercial - Conservation Importance Index* (*CCIi*).

$$CCI_i = LOG_{10}(PW_i)$$

PWi = Relative weight of the frequency for the species of interest

In order to stablish a categorical scale that allows a rapid assessment we defined five major categories according to the 20th percentiles, with an index range of 1.25 units each. Category was ranked from 1 to 5, from the lowest to the highest percentile, were category 1 represents both threatened, or not, species with the least commercial importance, and category 5, the species with the highest importance given their high threat status or a disproportionally high commercial interest (table 2).

As result, a total of 21 264 specimens (3 544 specimens/month) of 160 varieties/subspecies from 81 different species were found in the consulted invoices. Of the requested species, almost all species, 78 species, were fish (Actinopterygii), while ornamental crabs (Crustacea), shrimp (Malacostraca) and fresh water snails (Gastropoda) were represented by one species each. In terms of total volume of specimens requested only 7 species accumulated approximately half of the total volume of requests (≈49 %), being the Siamese fighting fish, Betta splendens, the species with the highest amount of requests, 19.30 %, followed

by the goldfish, *Carassius auratus*, with 8.91 % of the requests. On the remaining species, 60 species reported specimen volumes of less than 1 %, making up for a cumulative percentage of ≈22 % (figure 1a).

Table 2. Importance categories based on the relative Commercial - Conservation Importance index classification.

Importance	Priority of consern level	CCI
1	Low: High/Low threat species with low commercial interest	≤1.25
2	Moderately Low: High/Low threat species with/or low commercial interest	1.25 > ≤ 2.50
3	Moderate: High/Low threat species with moderate commercial interest	2.50 > ≤ 3.25
4	Moderately high: High/Low threat species with/or high commercial interest	3.25 > ≤ 5
5	High: Threatened species with high commercial interest	> 5

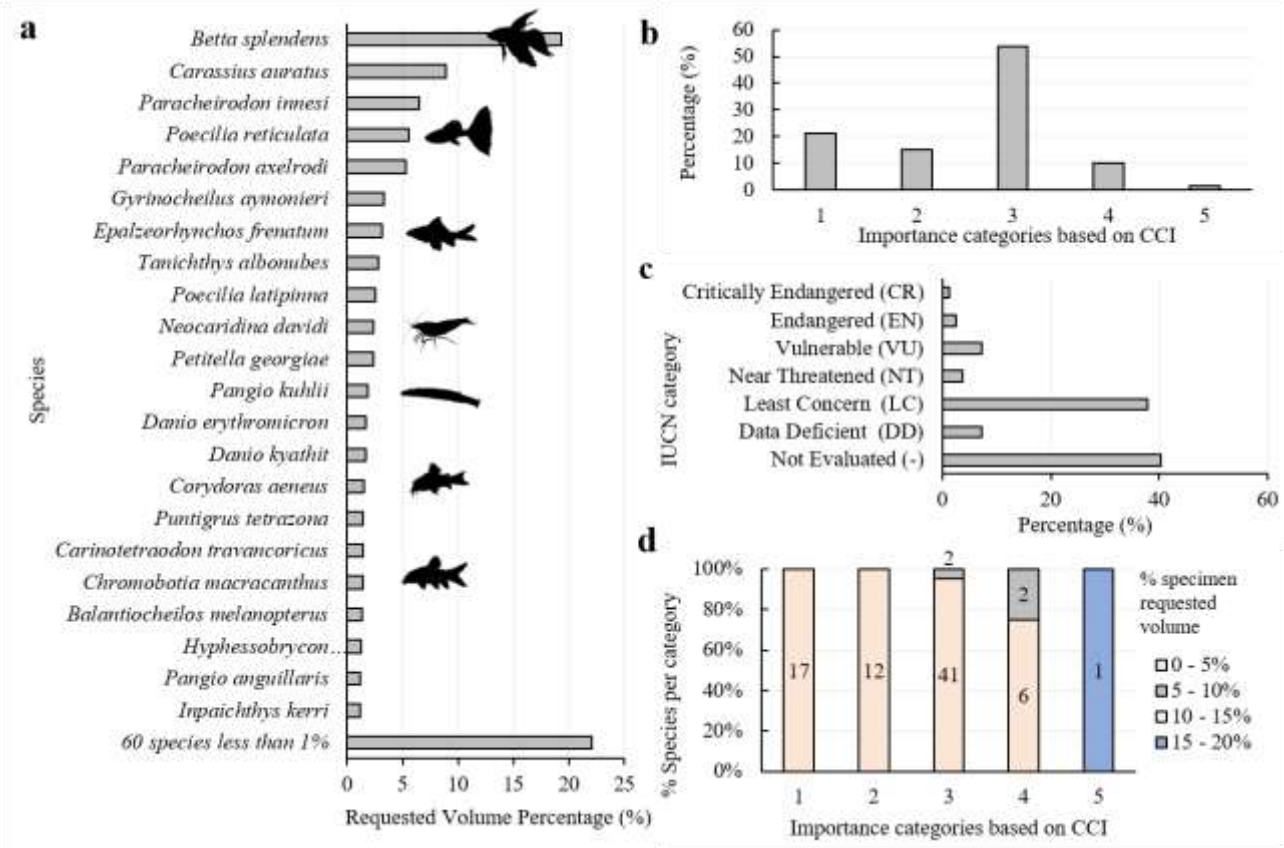

Figure 1. Species frequencies of species as classified according to a) Import request volumes per species on sample, b) Importance based on CCI Values, b) IUCN threat status, and d) Congruence of commercial importance index with import request volumes.

When applying the CCI Index to the test sample, most species were classified within the range of low to moderate importance categories (90 %), with 17 species (21 %) assigned to low, 15 species (15 %) as Moderately Low and 43 species (54 %) as of Moderate importance. Only 10 % of the total sample were assigned as Moderately High, 8 species (9 %) and only 1 species (1 %) as of High importance. This last soecies being on classified as Vulnerable according to IUCN and having a considerable volume of requested specimens according to the sample (Figure 1b). In terms of the threat status stablish by IUCN, most species were classified as either "Not evaluated (NE)" or "Least concern (LC)", with 32 and 31 species respectively. While only 9 species were classified in the broad category of Threatened, which includes "Vulnerable (VU)", "Endangered (EN)" and "Critically Endangered (CE)" with 6, 2 and 1 species respectively. The remaining species are classified as either "Data Deficient (DD)", 3 species, or "Near Threatened (NT)" with 3 species figure 1c).

A cross validation was performed to check the concordance of the CCI Index classification with the specimen volumes percentage classification. The species with highest volumes were classified as high import frequency and very high quantity of individuals imported (category 5), while species with moderate to high volume requests where classified half in category 4 and half in category 3, as the IUCN threat index was the deciding factor for these species. For categories 1, 2, 3 once more IUCN index was the selective factor in classifying species with low volume demands (figure 1d).

The results obtained show a major interest on the Siamese fighting fish (*Betta splendans*), goldfish (*Carassius auratus*), Neon tetra (*Paracheirodon innesi*), Guppy *(Poecilia reticulate*), Cardinal tetra (*Paracheirodon axelrodiin*) as key ornamental aquatic species for importation in Costa Rica. These species are in accordance with previous national and international trends (Allen *et al*., 2017; Atalah *et al*., 2022; Teletchea, 2016). Although no negative ecological effects have been reported when these species have been introduced into nonnative ecosystems, most of these species have shown high adaptability, as well as accelerated reproduction rates (Magalhães & Jacobi, 2013). Additionally, most of these species are extremely prone to the spread of pathogens (Mendoza & Aguilera, 2015), as well as a series of environmental problems, such as the displacement of native species (Mendoza & Aguilera, 2015), and ecosystem dynamics alteration (Capps & Flecker, 2013; Daga *et al*., 2015; Knight, 2010; Magalhães & Jacobi, 2008).

The CCI showed congruence on the commercial importance classification with the raw specimen requirement volumes. However, the key implementation is that the inclusion of the IUCN threat categories helped highlighting species that otherwise will stay unremarked given the relatively low volumes on requirements in spite of its high caution or threat status (Biondo & Burki, 2019; Challender *et al*., 2015). The CCI Index generates preliminary information of a comparative nature to identify the most important species in terms of imports, but also, becomes a much needed indirect indicator of both national potential hazards and the pressures that these species are experiencing on their native habitats (Evers *et al*., 2019).

The implementation of stricter legislation regarding the import of ornamental fish, as well as the sale and maintenance of the species, including adequate oversight of the processes, is fundamental in the protection of native biodiversity. The results of the present investigation can act as a baseline that will allow the Costa Rican authorities to identify the most relevant species for the importation of aquatic flora and fauna for ornamental purposes. This study represents an initial effort in developing formal and objective analytical tools that improve the management and supervision of generally overlooked segment of the intricate wildlife trade phenomenon.

Conflicts of interests

The authors declare no conflict of interest related to this manuscript.

Author Contributions

Steve A. Stephens Cárdenas and Ana Robles Herrera: conceptualization, writing, editing, methodological design development, financing acquisition.

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