**Supplementary material S4 - Tables**

**Table 1.** Review of regulations for exotic species farming in the Amazon. The regulations were summarized according to geopolitical divisions for each country: at federal level for Bolivia, Colombia and Ecuador, at state level for Brazil, and province level for Peru.

Legend: RO – Rondônia, PA – Pará, AM – Amazonas, RR – Roraima, AP – Amapá, MA – Maranhão, MT – Mato Grosso, TO – Tocantins; H.F. High Forest, L.F. Low Forest. The symbol “+” denotes when the item was mentioned and “-” when there was no mention to it.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|   | **BRAZIL** | **BOLIVIA**  | **PERU**  | **COLOMBIA**  | **ECUADOR** |
| **Item** | RO | PA | AM | RR | AP | MA | MT | TO |  | H.F. | L.F |  |  |
| Allows the farming of NNF outside protected areas (APP) | **+** | **+** | **+** | **-** | **+** | **+** | **+** | **+** | **+** | **+** | **-** | **+** | **+** |
| Existence of current legislation on NNF farming in the region | **+** | **+** | **-** | **+** | **+** | **+** | **+** | **+** | **-** | **+** | **-** | **+** | **+** |
| Prohibits releases in the natural environment | **+** | **-** | **+** | **-** | **+** | **-** | **+** | **+** | **+** | **+** | **+** | **+** | **+** |
| Specifies the containment system to be used  | **+** | **+** | **+** | **-** | **+** | **+** | **+** | **+** | **-** | **+** | **-** | **-** | **-** |
| Imposes fines on NNF farming | **+** | **+** | **+** | **-** | **+** | **+** | **-** | **-**  | **-** | **-** | **+** | **+** | **+** |
| Existence of general invasive species legislation (Acts, specific policy per invasion) | **+** | **+** | **-** | **-** | **-** | **-** | **-** | **-**  | **-** | **+** | **+** | **+** | **+** |
| Species-specific regulations  | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-**  | **+** | **+** | **-** | **+** | **+** |
| Classifies the impacts of NNF by law | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **+** | **-** | **+** | **+** | **-** | **-** |
| Allows the farming of NNF in protected areas (APP) | **-** | **-** | **-** | **-** | **-** | **-** | **+** | **-**  | **-** | **-** | **-** | **-** | **-** |

**Table** 2. Relation between sample effort (data from Jézéquel et al., 2020) and NNF records in the Amazon Region (Ancova). DFn and DFd correspond to degrees of freedom to the numerator and denominator, while ges indicates the generalized eta square.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Variable | DFn | DFd | F | p | ges |
| By Year | Sampling | 1 | 14 | 0.156 | 0.699 | 0.011 |
| Year | 28 | 14 | 0.998 | 0.523 | 0.666 |
| Basin | 6 | 14 | 1.616 | 0.215 | 0.490 |
| By five decades (log x + 1) | Sampling | 1 | 10 | 0.801 | 0.392 | 0.074 |
| Five Years | 5 | 10 | 1.355 | 0.319 | 0.404 |
| Basin | 7 | 10 | 1.515 | 0.266 | 0.515 |
| By decades (log x+1) | Sampling | 1 | 14 | 0.804 | 0.804 | 0.005 |
| Decades | 10 | 14 | 1.063 | 0.446 | 0.432 |
| Basin | 7 | 14 | 1.444 | 0.264 | 0.419 |

**Table 3.** Actions that promoted or allowed the invasion of non-native fishes in the studied sites.

|  |  |
| --- | --- |
| **Species** | **Example of actions that promoted the invasions** |
| *Arapaima gigas* | **Brazil and Bolivia**: introduced in Bolivia from Peru and expanded in Mamoré and Iténez basins. Re-introductions from aquaculture in Iténez, Guaporé (from escapes in Brazil) and in Mamoré River (juveniles sold to fish farmers). In the Tapajós basin escapes from fish farming tanks. |
| *Brachyplatystoma juruense* | **Bolivia**: introduced in the lower Bolivian Amazon (Riberalta) probably passed the STP (fish passages) in Jirau and Santo Antonio hydroelectric impoundments |
| *Colossoma macropomum, Piaractus brachypomus, P. mesopotamicus* | **Bolivia:** fish farming has introduced hybrids of *Colossoma macropomum*, *Piaractus brachypomus* and *P. mesopotamicus* |
| *Colossoma macropomum; Piaractus mesopotamicus* | **Bolivia:** stocking strategies of hybrids by the government and by local (municipal) authorities, especially in the Chapare Region (Department of Cochabamba)  |
| *Cyprinus carpio* | **Bolivia**: introduced purposely or accidentally for ornamental purposes in Lake Alalay, Lake Vacas, and many other high-altitude reservoirs in Cochabamba, Tarija, La Paz  |
| *Gambusia affinis* | **Bolivia:** introduced purposely or accidentally by aquarium releases in lake Alalay, Cochabamba  |
| *Oncorhynchus aguabonita; Oncorhynchus mykiss; Salmo trutta; Odontesthes bonariensis* | **Bolivia:** introduction in high-altitude lakes promoted by the government, and re-introductions carried out in several occasions |
| *Oreochromis niloticus; Coptodon rendalli* | **Brazil (Amapá):** Government encouraged distributing fry (Gama, 2008; Tavares-Dias, 2011); Strong incentives for fish farming promoted by private companies; Brazil (Amazonas): introduced purposely or accidentally by fish farming releases in impacted urban streams, Igarapé Fortaleza and Araguari River (Gama, 2008, Oliveira et al., 2017); **Brazil (Rondônia):** introduced purposely or accidentally by fish farming releases (Soares et al., 2020)**Bolivia:** introduced intentionally for fish farming in the Chapare and Yungas regions and introduced in Amazonian upstream reservoirs (Concepcion Lake, San Ignacio de Velasco Lake) |
| *Poecilia reticulata; Xiphophorus helleri; Xiphophorus maculatus; Trichopodus trichopterus; Danio rerio* | **Brazil (Amazonas):** introduced purposely or accidentally by fish farming or aquarium releases in impacted urban streams in Manaus (Beltrão et al., 2019); **Bolivia**: introduced purposely or accidentally by aquarium releases in Lake Alalay, Cochabamba  |
| *Salmo trutta; Oncorhynchus mykiss; Oncorhynchus aguabonita; Odontesthes bonariensis* | **Bolivia:** there have been state-supported incentives for (re-) introduction, propagation and commercialization  |
| *Semaprochilodus insignis* | **Bolivia**: introduced from Brazil (intentional introduction), Passive response both by government and local stakeholders |

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**Table 4.** Published invasion record and related field impact.

|  |  |  |
| --- | --- | --- |
| **Taxon** | **Record published**  | **Field impact** |
| *Colossoma macropomum* | **Brazil (Tocantins):** This species was captured in 2007 and 2008 in some stretches of the Middle Tocantins River (Marques and Guedes, personal communication) |   |
| *Piaractus mesopotamicus* | **Brazil (Tocantins):** This species has been captured in some stretches of the Middle Tocantins River (Marques and Guedes, personal communication) |   |
| *Coptodon rendalli* |   | **Brazil (Tocantins):** Cassemiro et al. (2018) have predicted that *Coptodon rendalli* has occupied 2% and has potential to occupy 49.8% of Tocantins-Araguaia Basin;**Peru**: The invasion of this species is compromising the abundance of native cichlids because of competition for reproductive sites with these native fish (García-Dávila, personal communication) |
| *Heterotilapia buttikoferi* | **Brazil (Tocantins):** recorded in the UHE-Serra da Mesa, upper Tocantins River (Bartolette et al., 2012)  |   |
| *Oreochromis niloticus* | **Brazil (Amazonas):** Found in three small streams inside the city of Manaus (Beltrão, 2007; Guarido, 2014; Beltrão et al., 2019) | **Brazil (Tocantins):** Cassemiro et al. (2018) predicted that species can occupy 92.1% of the Tocantins-Araguaia Basin; and according to those authors this species have occupied 1% the Tocantins-Araguaia Basin; **Brazil (Amapá):** The invasion of the species is putting pressure on populations of native cichlids, which are in low population density (27% native to 73% of *O. niloticus*) (Bittencourt et al., 2014). **Brazil (Amapá):** A large concentration of enterprises with the creation of Tilápia in this State is in environmentally frigid areas, which can cause environmental damage in case of release or escape, which normally occurs (Gama, 2008). **Peru**: The invasion of this species is compromising the abundance; Mendes and Murrieta (2018) reported the presence of the parasitic copepod *Neoergasilus japonicas* (native to East Asia) in specimens of *Colossoma macropomum* in the San Martin Region of the Peruvian Amazon, the parasite probably entered with tilapia that is heavily cultivated in the region of native cichlids because this environment is the site of reproduction of these native fish (García Dávila, personal communication). Additionally, *O. niloticus* was directly observed by F. Duponchelle and Uwe Römer in the small streams of the Allpahuayo-Mishana Reserve (Itaya and Nanay basins), close to Iquitos, while sampling for *Apistogramma* spp. |
| *Oreochromis urolepis* |  | **Brazil (Tocantins):** Cassemiro et al., (2018) have predicted that *Oreochromis urolepis* can occupy 96.0 % of the Tocantins-Araguaia Basin; however, according to the authors, this species has not yet occupied any cell within the Tocantins-Araguaia Basin.  |
| *Omobranchus punctatus*  | **Venezuela:** (Lasso-Alcalá et al., 2011): Established in the Orinoco Delta and the Gulf of Paria, as well as at the mouth of the Amazon River and the Amazon coast.  |  |
| *Symphysodon aequifasciatus* | **Peru**: recorded in the low and mid Nanay Basin (Tello and Canepa, 1991) |   |
| *Danio rerio* | **Brazil (Amazonas)**: Found in three small streams inside the city of Manaus (Beltrão et al., 2019) **Peru:** reported in small streams of the Iquitos-Nauta Highway, in the lower basin of the Itaya River, Loreto Region in the Peruvian Amazon (MINAM, 2016) |   |
| *Poecilia reticulata* | **Brazil (Amazonas):** Abundant in polluted streams inside of the city of Manaus (Beltrão, 2007; Guarido, 2014; Beltrão et al., 2019)**Peru:** It was introduced in 1965 in the Sauce Lake, San Martin Region in the Peruvian Amazon, and was also reported in 14 out of the 20 locations evaluated in the Huallaga River basin (Ortega et al., 2007; Cossio, 2010). | **Brazil (Tocantins)**: Claro-García and Shibatta (2013) believe that *P. reticulata* may have been established on the local ichthyofauna. It was found in five of the 21 sampled stretches in upper Tocantins River, and it was the highest abundant in one of them. |
| *Poecilia sphenops* | **Peru:** recorded in a river below the Aguaytia River, in the Ucayali River, in the Ucayali Region (Minam, 2016) |   |
| *Xiphophorus helleri* | **Brazil (Amazonas):** Found in three small streams inside the city of Manaus (Beltrão, 2007; Guarido, 2014; Beltrão et al., 2019) |   |
| *Xiphophorus maculatus* | **Brazil (Amazonas):** Found in three small streams inside the city of Manaus (Beltrão, 2007; Guarido, 2014; Beltrão et al., 2019) |   |
| *Arapaima gigas* | **Brazil (Rondônia)**: *A. gigas* invasion in Upper Madeira River (Doria et al., 2020).  | **Brazil (Rondônia)**: Impact on local fisheries composition (Doria et al., 2020).**Bolivia**: example from the Tumichucua Lagoon in which there was a study in the 80s before the *A. gigas*, and where this study was replicated in 2008 the *A. gigas* was present (Miranda-Chumacero et al., 2014);  |
| *Trichopodus trichopterus* | **Brazil (Amazonas):** record in one large stream inside the city of Manaus (Beltrão et al., 2019). **Peru:** record on the polluted waters of the Moronacocha Lagoon, in the vicinity of Iquitos (Ortega et al., 2007), reported in the lower and mid basin of the Nanay and Itaya rivers (Carlos Chuquipiondo personal communication). |   |

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**Table 5.** Current legislation on aquaculture, fisheries and environmental licensing by countries and states.

|  |  |  |
| --- | --- | --- |
| **Country**  | **State** |  **Current legislation** |
| **Brazil** | **Rondônia** | * Law 3,437 of 9 September 2014. Provides for aquaculture in the State of Rondônia and provides other measures. Official Daily of the State of Rondônia, N ° 2538, 2014 (Griffiths et al., 2010).
 |
| **Pará** | * Law 6.713 of January 25, 2005. Provides for fisheries and aquaculture policy in the State of Pará, regulating the activities of development, development and environmental management of fisheries and aquaculture resources and other measures. Official Daily of the State of Pará, 2005.
* Decree No. 2020 of 01/24/2006. Regulates Law No. 6,713, of January 25, 2005, which provides for the Fisheries and Aquaculture Policy in the State of Pará, regulating the activities of development, development and environmental management of fisheries and aquaculture resources, and makes other provisions. Official Daily of the State of Pará, January 25, 2006.
* Normative Instruction No. 004/2013. Provides for the environmental licensing of aquaculture enterprises and activities in the State of Pará and provides other measures. Official Daily of the State of Pará, May 10, 2013.
 |
| **Amazonas** | * Law No. 4330 of May 30, 2016. Disciplines aquaculture activity in the State of Amazonas and provides other measures Official Daily of the State of Amazonas, on May 30, 2016.
 |
| **Roraima**  | * CEMACT Resolution No. 1 OF 04/02/2018. Provides for Simplified Environmental Licensing and other provisions. Official Daily of the State of Roraima, April 10, 2018.
* Law No. 516 of January 10, 2006. "Provides FOR FISHING in the State of Roraima, establishing measures to protect the ichthyofauna, and takes other measures." Official Daily of the State of Roraima, No. 252 of January 11, 2006.
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| **Amapá**  | * Complementary Law No. 5 of August 18, 1994. Establishes the Environmental Protection Code of the State of Amapá and provides other measures. Official Gazette of the State of Amapá, 19/08/1994.
 |
| **Maranhão**  | * Government of the State of Maranhão. Law No. 10535 of December 7, 2016. Provides for the management of Brazilian and exotic wildlife at the State level and establishes other measures. Official Daily of the State of Maranhão, December 7, 2016.
* Government of the State of Maranhão. Law No. 10421 of March 21, 2016. Provides for the protection and regulation of shrimp farming, recognizing it as an agrosilvopastoril activity, of relevant social and economic interest, establishing the conditions for its sustainable development in the State of Maranhão, for which other measures are taken**.**
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|  | **Mato Grosso** | Decree No. 337, of December 23, 2019. Disciplines the environmental licensing procedure for the cultivation of NNS, hybrid and exotic aquaculture species within the scope of the State of Mato Grosso and other measures. Official Daily of the State of Mato Grosso, N ° 27658, on December 26, 2019.● Law No. 10669 of January 16, 2018. Changes and repeals provisions of Law No. 8,464, of April 4, 2006, changes provisions of Law No. 9,408, of July 1, 2010, and makes other provisions. Official Daily of the State of Mato Grosso, on January 16, 2018. ● Law No. 8,830, of January 21, 2008. Provides for the State Management Policy and Protection of the Upper Paraguay Basin in State of Mato Grosso and gives other measures. Official Daily of the State of Mato Grosso, on January 21, 2008. |
|  | **Tocantins** | ● COEMA / TO Resolution Nº 88 OF 05/12 / 2018.Disposes on the Environmental Licensing of Aquaculture in the State of Tocantins. Official Gazette of the State of Tocantins, December 7, 2018.● Complementary Law No. 13, of July 18, 1997. Published in the Official Gazette Provides for the regulation of fishing, aquaculture, pisciculture, protection of aquatic fauna and other measures. Official Gazette of the State of Tocantins, No. 614, 1997. |

|  |  |  |
| --- | --- | --- |
| **Bolivia**  |  | **●** Res. Adm VMABCCGDE N ° 13/2015 of June 8, 2015.● Res. Adm. SERNAP N° 60/2017 of July 12, 2017.● D. S. 3044 of January 7, 2017. |
| **Peru** | **Highland forest** | **●** Law No. 26839 of July 8, 1997.● Ministerial Resolution No. 522-2018. November 27, 2018. |
| **Lowland forest** | **●** Law N° 26839 OF JULY 8, 1997.● Supreme Decree No. 002/91 / PE. |
| **Colombia**  |  | **●** Decree 1220 of 2005. Regulation of Title VIII of Law 99 of 1993 on Environmental Licenses.● RESOLUTION 0848 23 May 2008 of the Ministry of Environment.● Decree 1780, 2015; Ministry of Agriculture; RESOLUTION 2287 December 29, 2015; Ministry of Agriculture.● Decree Law 2811 of 1974 (article 258) prohibition or restriction of introduced species.● Decree 1608 of 1978 (articles 138 to 141) introduction of fauna.● Law 13 of 1990 (articles 46, 49 and 50) licensing.● Regulatory Decree 2256 of 1991 cultivation of foreign species.● Law 165 of 1994 for the Convention on Biological Diversity.● Resolution No. 000531 of 1995 of the National Institute of Fisheries and Aquaculture, for restocking in continental waters.● Decree 1300 of 2003 sanitary control of imported species.● Decree 1220 of 2005 of the Ministry of the Environment, concept and scope of environmental licenses.● Resolution 0848 of 2008 of the Ministry of the Environment, listing of exotic and invasive species in Colombia.● Decree 2041 of 2014 regulates the obligation of environmental licenses.● Decree 1780 of 2015 of the Ministry of Agriculture, cultivation of foreign fish.● Resolution 2287 of 2015 of the National Aquaculture and Fishing Authority, declaring foreign species as domesticated species.● Resolution 2879 of December 29, 2017 of the National Aquaculture and Fishing Authority to minimize the risk of escape of foreign species. |
| **Equador**  |  | **●** Organic Law for the Development of Aquaculture and Fisheries. Regulates the movement of fauna, which applies also to aquatic resources. Supplement to the Official Registry 187, 21-IV-2020 (Art.54, Art. 214). |

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