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Risk Screening of Introduced African Catfish (*Clarias gariepinus*) (Burchell, 1822) in Sarawak Using the Fish Invasiveness Screening Kit (FISK v2)

CHIN HAN KIAT*[1] & KHAIRUL ADHA A. RAHIM[2]

[1]Inland Fisheries Division, Department of Agriculture Sarawak, 93050 Petra Jaya, Sarawak, Malaysia; [2]Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
*Corresponding author: chin_kiat84@hotmail.com
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ABSTRACT

African Catfish (*Clarias gariepinus*) is a popular non-native fish for aquaculture in Malaysia. The issues of non-native fish species have not been much discussed despite general perception of the negative effects of the species on the native biodiversity. Therefore, this study was conducted to estimate the possible risk of *C. gariepinus* in Sarawak using a semi-quantitative system of Fish Invasiveness Screening Kit version 2 (FISK v2). There are 49 questions in FISK v2 assessment which was assessed by three independent assessors with fisheries knowledge in Sarawak. Threshold was set at 19.0. Descriptive Statistics using SPSS 25.0 was used to run FISK score from three assessors. Result shows that *Clarias gariepinus* was categorised as "very high risk". *Clarias gariepinus* has a FISK score of 43.00 ± 1.00 with a certainty factor of 0.89 ± 0.08. Environmental and biological criteria, followed by the economic impacts for this species and the gaps in legislation and framework in Sarawak were discussed thoroughly. It can be concluded that this preliminary assessment might have indicate a sign of invasion of this non-native species to the local biodiversity. The tool could be more robust if more comprehensive data are included which eventually be useful to assist in decisions regarding future management of non-native species in Sarawak.

Keywords: *Clarias gariepinus*, FISK v2, freshwater fish, invasiveness, non-native, risk screening

INTRODUCTION

Aquaculture provides food security, economic stability and increase of employment (Agriculture Organisation of the United Nations Fisheries Department, 2000). This industry is expected to overtake the total production of captured fisheries by 2030 (Lam, 2016). Malaysia government has been actively expanding aquaculture industry through multiple initiatives in accordance to the National Agriculture Policy since 1984 such as cluster farming, subsidies, grants, anchor company, incubator programs and support services. Despite being a significant source of food for humans, aquaculture is also a key pathway for the introduction of non-native species (Tarkan *et al.*, 2020). Similarly, Malaysia has introduced 27 species for aquaculture (Rahim, 2012) with *Cherax quadricarinatus* being the latest permitted aquaculture species in 2020 (Department of Agriculture Sarawak, 2021). In 2020, aquaculture has recorded a production of 400,017 metric tonnes, which valued at RM3.6 billion, equal to 22% of national fisheries production, with freshwater catfish as the top contributor with 29,012.77 metric tonnes (Department of Fisheries Malaysia, 2020). Given the world's growing population, it is clear that even with current per capita consumption, future seafood demand cannot be met by capture fisheries.

De Silva *et al.* (2009) found that 12% of aquaculture produce (2.6 million tonne) were from non-native fish. However, increased anthropogenic activities will cause hardy non-native fish to be an invasive species. Singh and Lakra (2011) also concluded that despite being beneficial in aquaculture industry, non-native fish generally reduced the availability of native fish and became invasive by establishing in natural water bodies and later affected the fish biodiversity and aquatic ecosystems. *Clarias gariepinus* was brought into Malaysia from

Thailand since the late 1980s and has bloomed into one of the highest produced aquaculture species in Malaysia (Dauda *et al.,* 2018). Low *et al.* (2022) has mentioned the need to investigate on the potential impacts of *C. gariepinus* due to confirmed habitat and trophic competition in Peninsular Malaysia.

Risk screening represents the initial hazard identification stage of the overall risk analysis process and is designed to identify the potential risk of a non-native species being invasive in a defined assessment area (Copp *et al.,* 2009). The result from risk screening can later assist relevant agencies to decide on their next course of action on the non-native fish especially the lesser-known translocated species (Tarkan *et al.,* 2017). Fish Invasiveness Screening Kit (FISK), is a questionnaire based, semi-quantitative scoring system that assesses elements of a freshwater fish species' biogeography, invasion history, biology and ecology (Copp *et al.,* 2009). FISK also requires the assessor to provide a justification and a confidence ranking for each response. FISK has since been applied more widely (Copp, 2013), in comparison with other screening-level risk assessment protocols. FISK was one of two best scoring screening tools (Snyder *et al.,* 2013) and FISK has recently been revised to produce FISK v2 (Lawson Jr *et al.,* 2013), which provides greater applicability for warm climate regions.

Sarawak has 3,628 aquaculturists on freshwater species where more than 80% are smallholders (Department of Agriculture Sarawak, 2021). Therefore, the identification of the level invasiveness of a non-native fish is important as human activities correlates with the dispersion of this species. This research focused on *C. gariepinus* which is one of the important aquaculture species in Malaysia. In Malaysia, 48% of the aquatic species were threatened to a certain level (Chong *et al.,* 2010). Tropical climate countries such as South Africa and India has reported significant negative impacts of *C. gariepinus* to the aquatic ecosystem (Krishnakumar *et al.,* 2011; Kadye & Booth, 2012). Thus, the advances of screening kit for invasiveness of fish should be fully utilized to provide fast, reliable and economic result for preliminary investigation on a non-native species in Sarawak.

The study attempts to facilitate in species invasiveness identification process with the application of FISK v2. This can be done through determining the risk level and categorise the potential impacts of C. *gariepinus* in Sarawak and to assess the adoption of using FISK v2 in detection of invasive species in Sarawak.

MATERIALS AND METHODS

Risk Assessment Area

Sarawak, is one of the megadiverse countries in the world (Long, 2014). It is located at 1º33'11.8" N and 110º21'33.17" E. There are 22 river basins in Sarawak with an area of 124,064.42 km^2 (Department of Irrigation and Drainage Sarawak, 2023). The climate is tropical with hot and rain all year round and temperature of 21 ºC to 32 ºC. Southwest monsoon occurs from May to August, while northeast monsoon from November to February (Suhaila *et al.*, 2010) with an annual average rainfall of 250 cm (Hock, 2007). Thus, the large area of water combined with diverse aquatic ecosystems, habitats and suitable equatorial climate has promoted fish species establishment. A diversity study by Kamal *et al.* (2022) has recorded 546 species of fishes in Sarawak including 20 non-native species.

Species of Interest

The African Catfish (*Clarias gariepinus*) was chosen for risk screening for this study as this species was listed in the Invasive Alien Species (IAS) list of concern in the National Action Plan on Invasive Alien Species 2021 – 2025. *Clarias gariepinus* has shown adverse impacts of its introduction globally (Kadye & Booth, 2012). Furthermore, the study of risk screening using FISK v2 has been done only once done for *C. gariepinus* in Malaysia by Saba *et al*. (2020).

Risk Screening

The FISK v2 program was obtained from the Department of Fisheries Malaysia. This tool kit was chosen for this study due to the kit capability to clearly distinguish between invasive and non-invasive species through a semi-scoring system. A comparison study on the reliability between FISK v2 and Fish

Invasiveness Screening Test in Malaysia by Saba *et al.* (2020) has revealed that FISK v2 is more dependable as it has more questions and incorporates more aspects thought to be useful in predicting impending invasions.

This screening tool was comprised of two main sections and eight categories as shown in Table 1. There were 49 questions which need to be answered for each species assessment using the assessor's expertise, scientific literature, grey literature such as reports, working papers, online discussion forums. Assessment was conducted by the researcher and two fisheries officers from Department of Agriculture Sarawak, Inland Fisheries Division. All assessors were either degree or master holders in aquatic-related field with at least five years of working experience in fisheries industry in Sarawak.

If there were no reliable proof of support, the question will be answered "Don't know". Each answered question including 'Don't know' responses were resulted in a score that is either directly related to the question itself or, in certain cases, indirectly computed by means of a weighting system from a 'parent' question, and the Q-specific score has a value ranging from 1 to 2 (Copp *et al.* 2005). The "Don't know" response indicated the inability by the assessor to provide information on a certain ecological aspect of the species being evaluated, either due to unavailability of information or, possibly, overall non-applicability of a certain question.

Table 1. Sections, categories and number of questions for FISK v2

Biogeography and historical data section		Biology and ecology section	
Category	No. of questions	Category	No. of questions
Domestication/ Cultivation	3	Undesirable (or persistence) traits	12
Climate and distribution	5	Feeding guild	4
Invasive elsewhere	5	Reproduction	7
		Dispersal mechanisms	8
		Tolerance attributes	5

In addition, the assessor was asked to give a degree of certainty that led to that answer, which weights the given answers. Response in FISK for any given assessment was allocated a certainty level (1 = very uncertain; 2 = mostly uncertain; 3 = mostly certain; 4 = very certain). The summation of the Q-specific values provided an outcome score ranging (theoretically) from a minimum of 15 to a maximum of 57. Based on this score, the potential risk of a species being invasive was then categorised as 'low', 'medium' or 'high', so that a species categorised as high-risk was regarded as invasive and considered for a full risk assessment (Copp *et al.* 2005).

The 'certainty factor' (CF) for the assessment was computed as: CF $\sum(CQi)/(4\times49)(i = 1,\ldots,49)$. Where, CQi was the certainty level for Qi, with 4 is the maximum achievable certainty level, and 49 is the total number of Qs comprising FISK. The CF ranges from a minimum of 0.25 where all 49 questions with certainty level equal to 1, will produce to a maximum CF of 1.

Threshold for Risk Categories

Thresholds for risk categories was defined by the FISK scoring which distinguished medium risk and high risk. Calibration has revealed that any fish with FISK scores higher than 19.0 indicates high invasive risk (Copp *et al.* 2009). Thresholds set by Lawson *et al.* (2015) was used as reference to categorise risk levels from the FISK score as shown in Table 2 because this study only involve two species of interest. Furthermore, the risk categorisation by Lawson *et al.* (2015) has further distinguished the high risk into "lower high risk", "medium high risk" and "very high risk" according to the FISK score.

Table 2. Risk categorisation by FISK score (Britton *et al.*, 2011; Lawson *et al.*, 2015)

Risk Category	FISK Scores	Invasiveness
Low - medium risk	1.0 - 19.0	Non-invasive
Lower high risk	19.1 - 25.0	Invasive
Moderately high risk	25.1 - 30.0	Invasive
Very high risk	30.1 - 57	Invasive

Table 3. Result of FISK score, certainty factor (CF), sectors affected and risk category for *Clarias gariepinus*

Partition	Mean (n = 3)	Standard deviation
Biogeography/Historical	19.00	1.73
Biology/Ecology	24.00	2.65
FISK score	43.00	1.00
Certainty factor	0.89	0.08
Sectors affected:		
Aquacultural	29.33	1.53
Environmental	31.67	1.53
Nuisance	2.33	1.15
Risk category	Very high risk	

Statistical Analysis

Descriptive Statistics was run through the FISK score from three assessors for the two species of interest separately. Any species for a specific RA area should be assessed by multiple independent assessors to increase the accuracy on the result (Tarkan *et al.*, 2017). Data analysis was processed through IBM® SPSS® Statistics 25.0.

RESULTS

FISK Score and Certainty Factor

The FISK v2 score for *Clarias gariepinus* was averaged at 43, which classified it as a high risk species, in the subcategory of “very high risk” as shown in Table 3. This value corresponds to biogeography/history 19 and biology/ecology 24. The average value of CF was 0.89 (>0.5), which represent a reliable value for the certainty of the result. Three questions related to the dispersal mechanism and undesirable traits were answered “Don’t know” by the assessors due to scarcity of biological information. The most affected sector for *C. gariepinus* was “Environmental” with a score of 31.67.

The Score of Uncertainties

The overall mean certainty score for *C. gariepinus* was 3.57 ± 0.61 as shown in Table 4. The lowest mean certainty score was related to the dispersal mechanism category with 3.21 ± 0.47 for *C. gariepinus.* Two questions which produced a mean certainty score of less than 3.00 for the risk assessment of *C. gariepinus* were Q5 and Q43, both with a mean score of 2.67 and 2.33 respectively. Meanwhile, 12 questions answered with a full certainty of 4.00 by all assessors fall under the category of domestication/cultivation (1), invasive elsewhere (1), undesirable traits (6), reproduction (3) and persistent attributes (1).

DISCUSSION

The FISK score and CF from this study and the outcome of *Clarias gariepinus* from other authors using FISK v2 was shown in Table 5. All results have consistently showed that the African catfish is highly invasive. The CF value ranged between 0.64 and 0.89 has showed that the result of the current study is reliable and can be applied into the risk management plan. According to Medellin-Castillo (2022), CF value more than 0.5 is reliable to be used. In addition, a greater CF indicates that the assessors are more confident in their responses (Radocaj *et al.,* 2021). Similar result obtained by Vythalingam *et al.* (2022) using the maximum-entropy-based modelling has shown high invasive potential of *C. gariepinus* in almost whole Malaysia.

Table 4. Mean and standard deviation of certainty score among assessors and categories

Assessor/ Category	Certainty Score for *C. gariepinus* (n =3)
Assessor	3.57 ± 0.61
Domestication/Cultivation	3.61 ± 0.35
Climate and distribution	3.33 ± 0.81
Invasive elsewhere	3.60 ± 0.40
Undesirable traits	3.74 ± 0.14
Feeding guild	3.58 ± 0.52
Reproduction	3.76 ± 0.29
Dispersal mechanisms	3.21 ± 0.47
Persistence attributes	3.60 ± 0.40

Table 5. Comparison of FISK Score and certainty factor for *Clarias gariepinus* from other studies

Species	FS	CF	RC	ST	Location	Reference
	43	0.89	Very High	FISK v2	Sarawak, Malaysia	Current study
	32.5	0.83	High	FISK v2	Malaysia	Saba *et al.* (2020)
C. gariepinus	32	0.89	High	FISK v2	Croatia and Slovenia	Piria *et al.* (2016)
	26.8	0.87	High	FISK v2	Greece	Perdikaris *et al.* (2016)
	25.8	0.64	High	FISK v2	Turkey	Tarkan *et al.* (2014)

FISK score: FS; certainty factor: CF; risk category: RC; screening tools: ST

The Score of Uncertainties

The category of dispersal mechanism has scored the lowest mean certainty score for *C. gariepinus* as shown in Table 4. One question was answered "Don't Know" and three "Mostly Uncertain" answers on dispersal mechanism for the assessment of *C. gariepinus*. The inadequate understanding of biological features and the absence of information on the quantitative effects of the species are significant barriers to the prediction of non-native species impacts (Mastitsky *et al.*, 2010). When new information becomes available, unresolved questions must be revised in order to receive new scores and classification (Copp *et al.*, 2005).

The certainty score was relatively high which fall under "mostly certain", which shows that the assessors were equally knowledgeable about the species of interest. Differences in the certainty score among the FISK category which could differ from "Mostly Uncertain" to "Very Certain" has showed the use of more than one assessor is vital. The different level of carefulness for each assessor in answering the questions can be reduced through the use of a few independent assessors (Almeida *et al.*, 2013).

Threshold Calibration

Calibration of threshold is important to differentiate between medium risk and high risk. Moreover, local calibration is essential as certainty level was different among every species and its environment (Vilizzi *et al.*, 2019). The initial FISK threshold value from U.K. calibration using one assessor was 19.0 while the calibration in Japan with five assessors has showed very similar threshold value of 19.8 (Copp, 2013). Since FISK score for *C. gariepinus* was more than 30, threshold does not affect any categorisation between medium risk and high risk. Furthermore, small sample size could not produce its own calibration of threshold similar to the FISK v2 assessment on pleco or devil fish (Loricariidae) by Medellin-Castillo *et al.* (2022).

Environmental and Biological Criteria for Translocation and Colonisation

Direct impacts of *C. gariepinus* on the native fishes in Malaysia has not been identified. However, high FISK score of more than 30.0 which represents "Very High Risk" has suggested that these two species could bring harmful effects to the aquatic ecosystems. According to Rahim *et al.* (2013), the ability of non-native fish species to survive a wide range of environmental conditions has proven to be a crucial factor in their ability to establish themselves in natural habitats. Structural equation models (SEMs) on *C. gariepinus* invasion in Peninsular Malaysia has shown that the fish pose negative impacts on *C. batrachus* and later displace the species due to food competition (Low *et al.,* 2022) Similar condition were described by Saba *et al.* (2020) at the Pusu River in the Klang Valley, where *O. niloticus* triumphs in food, environment and space has surpassed *B. schwananfeldii* to become the dominant fish. There has been concerns over the endemic fish to survive over the competition of food and space with non-native fishes. According to Chong *et al.* (2010), 37 freshwater fish species that are highly or somewhat endangered attribute their plight to their susceptibility as endemic species.

Apart from aquaculture escape, *C. gariepinus* has been one of the species released intentionally into recreational lakes or river for sports fishing, as "rejected" fish and religious acts (Hashim *et al.,* 2019). Successful translocation *C. gariepinus* is related with its ability to "walk" on land to a better habitat. *Clarias gariepinus* is able to use its pectoral fins to move on land or very shallow waters which gives them the name of the walking catfish (Li *et al.,* 2018). This is enhanced by the ability of this species to stay out of water for a few hours. African Catfish belongs to Clariidae family which means air-breathing (Haymer & Khedkar, 2022). The arborescent organs of *C. gariepinus* are formed by a pair of suprabranchial chambers that are placed in the dorsal-posterior region of the branchial cavity and have extensions from the upper portions of the second and fourth gill arches (Belão *et al.,* 2011). Furthermore, *C. gariepinus* is able to spawn in shallow water. Mating takes place between solitary pairs of animals in shallow water among flooded terrestrial or semi-aquatic sedges and grasses (Bruton, 1979).

Economic Impacts

All FISK questions are automatically categorised into a number of categories, some of which mirror three different economic sectors likely to have an impact which are "Aquacultural", "Environmental" and "Nuisance" (Copp *et al.,* 2005). High FISK score was observed under the impact category of "Environmental" and "Aquacultural" with a mean score of more than 28.0 with low "Nuisance" score below 3.0 as shown in Table 3. Furthermore, high FISK score under the impact category of "Environmental" and "Aquacultural" has further justify the importance of *C. gariepinus* as the third highest aquaculture produce in Sarawak (Department of Fisheries Malaysia, 2020). Mastitsky *et al.* (2010) has produced results that are similar, with high invasive species displaying high scores in the "Aquacultural" and "Environmental" sectors and low scores for "Nuisance". African catfish has proven to have high impact in aquaculture with strong biology characteristics as an aquaculture species. These biological factors include efficiency in foraging, growth, mortality, the duration of the grow-out period, and vulnerability to environmental changes, disease, and overcrowding, as well as economic factors (Wu, 1989). Additionally, other study has demonstrated that the introduction of non-native fish frequently has direct economic effects, ensuring food security and raising income (Gozlan *et al.*, 2010). Four aquaculture species, *O. mossambicus, O. niloticus, C. gariepinus* and *C. quadricarinatus*, was listed as species of concern under the National Action Plan on Invasive Alien Species 2021-2025 despite being widely distributed in the water ecosystems in Malaysia. Moreover, freshwater catfish is the second highest produced species from aquaculture in Malaysia with 29,012.77 tonne valued at RM129.66 million (Department of Fisheries Malaysia, 2020). However, due to issues with calculating environmental costs resulting from a lack of sufficient data and methods for meaningful comparisons, the economic effects of species introductions have rarely been assessed (Lee & Gordon, 2006). Therefore, non-native aquaculture species were suggested to be removed from the list for species of concern and be placed under a comprehensive programme on awareness, mitigation, prevention, control and eradication. A sustainable management on non-native aquaculture species is more preferable than a prohibition on its introduction (Lin *et al.,* 2015). Nevertheless, the risk of introductions must therefore be weighed against any potential current economic and social benefits (Perdikaris *et al.,* 2016).

Gaps in Legislation and Framework

Import Risk Assessment (IRA) is the risk assessment method currently applied and implemented by the Department of Fisheries Malaysia. Compare to FISK v2, IRA is not comprehensive. There is no direct scoring, weighting, or other matrix applied to the data on the form to determine the relative relevance of each section. Furthermore, IRA has a lengthy work process which consumes time. The process will need to be repeated if the application of the species is the same, which depletes the workforce. According to Jaeger (2003), problems with government services frequently involve excessive administrative costs, time spent on monotonous tasks, accountability, consistency in the delivery of results, accuracy and transparency. FISK is a semi-quantitative scoring system that runs on the Excel® platform and has menus that are driven by Visual Basic® (Mastitsky *et al.*, 2010). The fact that FISK is self-explanatory and simple to use, indicates that FISK v2 is now relevant to nearly all climatic zones has validated its relative success as a screening tool for freshwater fishes (Lawson Jr. *et al.*, 2013). As a result, the process flow of an import application can be greatly reduced. The goal of FISK is to assist decision-makers in creating legislation, policies, and management plans to address non-native species challenges rather than serve as a decision-making tool (Tricarico *et al.*, 2010). Kamal *et al.* (2022) has highlighted the need of further assessment on non-native fish while 109 species of fish species in Sarawak need to be properly managed.

The list of restricted fish in Malaysia's fisheries acts and ordinance should be updated in accordance to the risk assessment done for non-native species through the National Action Plan on Invasive Alien Species 2021-2025. For example, the list of restricted fish species under the State Fisheries Ordinance 2003 in Sarawak has only *Scleophages formosus* and *Probarbus jullieni* where the list was never updated. The most recent improvement for prohibited import of non-native fish list was in 2011 where 34 species were not allowed for import, sell, rear or keep under the Fisheries Rules (Prohibited Import, etc, for Fish) 1990. In brief, even though the Department of Fisheries Malaysia is in charge of the majority of fisheries-related issues, there is no alignment of prohibited lists in Malaysia because they vary across each state.

There has been a global effort in data compilation, research collaboration, and legislation for non-native fish (Perdikaris *et al.*, 2016). Accordingly, the Malaysia Biodiversity Information System (MyBIS) managed by the Malaysia Biodiversity Centre should be frequently updated and add further descriptions, handling techniques, and pictures of the species. The involvement of local universities and development agencies could spur the data collection, collaboration and input for improvement in legislation. Currently, the Department of Fisheries is the organisation in charge of resolving all fisheries-related issues, including those involving aquatic invasive alien species. Due to the insufficient manpower, this circumstance has led to a decline in task efficacy and quality. Thus, delegating present governance to local governments and academic institutions can therefore speed up the situation with aquatic invasive alien species. Ambak and Jalal (2006) proposed that the management of the fisheries at the reservoirs be placed under local authority under the Ministry of Rural Development or Ministry of Agriculture for better coordination and collaboration. According to Faguet (2014), decentralisation in governance could boost political competition, enhance public accountability, decrease political instability, and enact restrictions on government power that are compatible with incentives. Furthermore, this is also in line with the Target 3 in Goal 1 of the National Action Plan on Invasive Alien Species 2021-2015 which is to strengthen information sharing among relevant stakeholder.

CONCLUSION

The use of FISK v2 has allowed the detection of the range of invasiveness of a non-native freshwater. The present application of FISK v2 on *C. gariepinus* demonstrates the potential for this risk screening method to be applied to any non-native aquatic species proposed for introduction to Sarawak. Hence, it is possible to create a database for non-native fishes specifically for Sarawak. As a part of Goal 2 in the National Action Plan on Invasive Alien Species 2021-2025, questions that were left unanswered need to be updated to obtain new scores and classification when the information becomes available. FISK v2 has given positive indication as promising screening tool kit to be applied in Sarawak as it has vastly gained popularity in the world. Hopefully, this study on the practicality and accuracy of FISK v2 will contribute to the development of a comprehensive model in risk analysis of non-native fish in Malaysia.

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