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Research article

Public knowledge and perceptions of the impacts and importance of alien fish species in Malaysia: implications for freshwater biodiversity and conservation

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Abstract

A good understanding of the public's knowledge and perceptions of alien fish species can guide policymakers to gain support for conservation and management programs. Using online and hardcopy questionnaires (n = 304), this study investigated public knowledge and perceptions of the impacts and importance of alien fish species in Malaysia, as well as information about relevant practices related to keeping and consuming fish. We correlated items measuring respondents' knowledge, perception, and practices regarding alien fishes and associated these items with selected socio-demographic variables (education, ethnicity, gender and age). Significant relationships ($p < 0.05$) were found between different items measuring respondent knowledge *versus* perceptions regarding alien fishes, and between items measuring knowledge and perception *versus* practices regarding alien fishes. Seventy-six percent of the respondents considered alien fish species as economically valuable, while 91% knew their ecological impacts. Arapaima (*Arapaima* sp.) was the most well-known alien fish species among the public. Chi-square (χ^2) tests showed that education, ethnicity, gender and age were important factors influencing public knowledge and perceptions of alien fish in Malaysia. Information from this study can inform future planning of conservation programs for native fish species in Malaysia.

Key words: ecological impacts, alien species, public perceptions, public awareness, practices, prohibited fish

Introduction

Introduced species may cause significant negative impacts on the environment and socio-economy (Holmes et al. 2009; Novoa et al. 2017). Some alien fish species threaten the survival of native fish species through competition, predation, habitat disruption, and disease transmission (Mendoza et al. 2009; Khairul-Adha et al. 2013; Esmaeili et al. 2014; MNRE 2014; Zaid et al. 2018). Humans are highly instrumental in the successful establishment and spread of alien species in the aquatic environment (Nanayakkara et al. 2018). Moreover, human actions also can help curtail the further spread of these alien species if they are properly informed of the existing and potential negative impacts of these species through management

and policy actions (Estévez et al. 2015). To tackle the current and future problems that may arise from alien fish species' impacts on the environment and socio-economy, it is important to increase public awareness of and their involvement in the prevention of introductions and establishment of alien species (Verbrugge et al. 2013; Clusa et al. 2018; Potgieter et al. 2019).

A good understanding of the relationships that exist between humans and nature is vital for environmental management in general (Bauer et al. 2009; Walker-Springett et al. 2016), and also for management and conservation of freshwater ecosystems and fisheries (Cooke et al. 2013). Having insights into public knowledge and perception is not only important for predicting and understanding their actions, but can also serve as a guide for the development of effective management strategies useful in the maintenance, preservation, and improvement of biodiversity, ecosystem services, and human well-being (Bennett et al. 2016; Nanayakkara et al. 2018). Furthermore, conflicts of interest over alien species can be mitigated, while decision making can be prioritized (Shackleton et al. 2019).

Malaysia is not spared in the wave of fish introductions, occurring either intentionally or inadvertently as a result of human actions (Khairul-Adha et al. 2013). Alien fishes have been reported for natural and other freshwater habitats in the country, including streams, swamps, rivers, lakes, reservoirs, paddy fields, drainage areas, and mining pools (Samat et al. 2008; Khairul-Adha 2012; Khairul-Adha et al. 2013; Ng et al. 2017; Zakaria 2017, 2019; Radhi et al. 2017; Jalal et al. 2018; Zulkafli et al. 2018; Mohd-Sukeri et al. 2020). Moreover, some of the alien taxa have been prohibited from entry into Malaysia, and this prohibition has been empowered under Section 40 on Control of Live Fish, Fisheries Act 1985 (Act 317) (DOF 2007).

Previous studies related to public knowledge, perceptions, and practices regarding invasive alien species, including fish, have been carried out in other countries, mainly in North America and Europe. These include, for example, studies about the general knowledge, perceptions, and attitudes regarding alien and invasive species management in the San Marcos River, Texas, USA (Oxley et al. 2016), college students' knowledge and perceptions of invasive species in the USA (Waliczek et al. 2017), and knowledge and attitudes towards invasive alien species in the Netherlands (Verbrugge et al. 2013), Canada and the UK (Gozlan et al. 2013; Fischer et al. 2014).

To our knowledge, this study provides the first exploration of the public views regarding alien fish species in Malaysia. The objectives of this study are (1) to assess public knowledge, perceptions, and practices in relation to alien freshwater fish species in Malaysia, (2) to analyse the relationships between these three components, and (3) to make comparisons between groups with different demographic characteristics (including ethnicity, age, gender, and education). The findings can inform preventive and other management measures to limit the introduction, spread, and impacts of alien fish species in Malaysia.

Materials and methods

Questionnaire development

An existing questionnaire from Gozlan et al. (2013) was adapted and extended based on the research objectives stated above. The questions were intended to gather information on the public's knowledge, perceptions, and practices regarding alien fish species in Malaysia. Questions included dichotomous (yes/no), open-ended (without any defined answering categories; e.g. species examples), Likert-type (from 1 = "strongly disagree" to 4 = "strongly agree"), and multiple-choice questions. The questionnaire consisted of four parts in two sections: demographics (four questions), knowledge (11 questions), perceptions (three questions), and practices (four questions) (Appendix 1).

The four questions which gathered responses on the socio-demographic characteristics of the respondents asked about their gender, age group, ethnicity, and education (section A, Q1 to Q4). Five Likert-type statements on a scale ranging from strongly disagree (1) to strongly agree (4) asked about the publics' knowledge of characteristics and ecological impacts of alien fishes (section B, Q1 to Q5), and two Likert-type questions (section B, Q6 to Q7) measured their perceptions of the economic importance of alien fishes. In addition, one Likert-type question measured the public's knowledge of existing legislation regarding alien fish species in Malaysia (section B, Q8), and one measured perceptions of the general benefits of alien fish species as opposed to the disadvantages (section B, Q9). One dichotomous question measured respondents' awareness of alien fish species (section B, Q10), while one multiple choice question measured the public's knowledge of alien fish species by numbers (section B, Q11). Five open-ended questions asked respondents to give specific examples of alien fish species they know (section B, Q12), the type of fish they preferred for consumption (section B, Q13), their hobbies (section B, Q14), what they do with their aquarium fishes when they grow too large (section B, Q16), and examples of fishes prohibited from import into Malaysia (section B, Q18). Finally, two dichotomous questions asked whether respondents had a functional fish aquarium in their homes (section B, Q15) and whether they had any knowledge of prohibited alien fishes in Malaysia (section B, Q17).

To test the validity of the questionnaire, three expert academics in the area of fish ecology and biostatistics were consulted. The instrument was revised based on their recommendations, before testing the survey in a pilot of 40 postgraduate students from Universiti Putra Malaysia. After the pilot, some minor grammatical changes were made and some questions were reordered.

Data collection

Data were collected from the general public in two phases. An online version was created using Google Forms (https://docs.google.com) and was

Table 1. Factor loadings from Principal Components Analysis (PCA) of items about perceptions of economic importance and knowledge of ecological impacts of alien fishes in Malaysia.

	C1	C2
Eigenvalues	2.55	1.60
Variance explained (%)	42.49	26.65
Cumulative %	42.49	69.14
Belong	**0.632**	−0.071
Consume	**0.837**	0.035
Compete	**0.859**	0.004
Disrupt	**0.785**	−0.190
Profitable	−0.043	**0.905**
Contribute	−0.079	**0.907**

open to responses for five months (April–September 2019). A link to the online survey was shared via Facebook and WhatsApp groups in April 2019. These included the WhatsApp group of the official Malaysian Fisheries Society and the Malaysian Freshwater Fish Facebook page with more than 25,000 members. These groups consist of government officials, environmentalists, students, fishermen, businessmen, and fish hobbyists. The online survey generated 245 responses.

To account for the potential bias that may arise from an online questionnaire (i.e. higher educated people or those with an internet connection), hard copies of the questionnaire (both English and Malay versions) were administered to aquarium store owners and the hobbyists who visit these stores in different parts of Klang Valley, Malaysia. The respondents were encouraged to fill in the questionnaires on the spot. A total of 60 questionnaires were returned and adequately filled in, from 150 that were distributed (40% response rate), in addition to the 245 responses from the online questionnaire. Therefore, a total of 305 responses were available for the analyses.

Data analyses

We used Principal Components Analysis (PCA) to cluster and differentiate responses to the Likert-type questions and calculated Cronbach's alpha to test their reliability (Taber 2018). Next, we used Spearman's rank correlation to identify relationships between knowledge, perception, and practice items, and Chi-square tests to compare the knowledge, perception, and practices based on demographic characteristics. Basic descriptive analyses were carried out using Microsoft Office Excel. Inferential statistical analyses (including Spearman's rank correlation and Chi-square test of association) and PCA (including reliability tests) were conducted using Statistical Package for Social Sciences (SPSS) (version 22; Armonk, NY).

The PCA clustered six out of nine items measuring public knowledge of ecological impacts and perceptions of economic importance into two components that cumulatively explained 69% of the variation (Table 1). The extraction was based on eigenvalues of ≥ 1 and items with rotated component matrix values < 0.4 were eliminated. The first component included

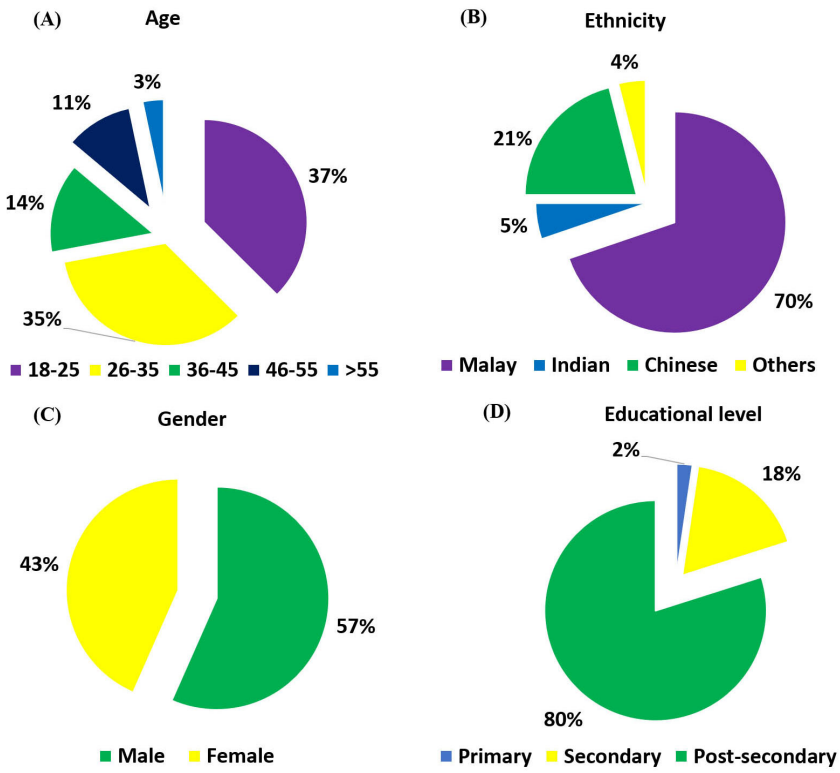

Figure 1. Summary of respondents' socio-demographic characteristics including (A) age, (B) ethnicity, (C) gender, and (D) educational level.

two items related to economic value (i.e. profitability and contribution to economic development). The second component included four items about ecological impacts (i.e. alien fishes do not belong/consume other fish/ compete with other fish/disrupt aquatic environments). Cronbach's alpha values of 0.78 and 0.79 for the perception of economic value and knowledge of ecological impacts, respectively, reflected acceptable reliability of the instrument.

Results

Socio-demographic profiles

An overview of the socio-demographic characteristics of our sample is shown in Figure 1. The majority of our respondents were Malay (70%) with other ethnicities including Chinese and Indian. We received more responses from males (57%) compared to females (43%) and most of the respondents were educated at the post-secondary level (80%). Regarding age, more than two-thirds of the respondents were in the age group of 18–35, while the age groups of 46–55 and above 55 had the lowest percentages. Except for the educational level, where post-secondary level was overrepresented, our sample generally shares demographic similarity with the general Malaysian population (DOS 2020).

Knowledge, perceptions, and practices

The majority of the respondents (76%) agreed or strongly agreed that alien fish species were economically valuable, while only 10% strongly disagreed

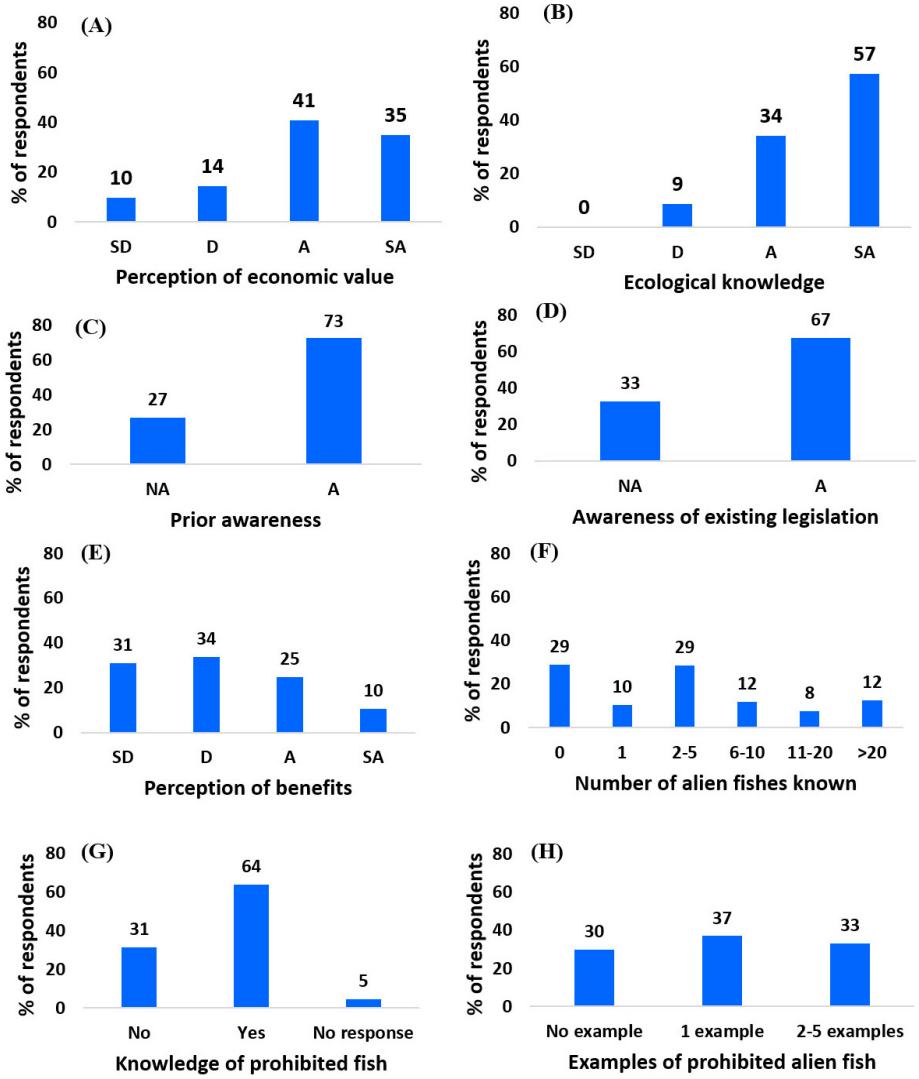

Figure 2. Summary of responses by percentage for (A) perceptions of economic value, (B) knowledge of ecological impacts, (C) prior awareness of alien fish species, (D) awareness of existing legislation regarding alien fishes, (E) perceptions of the benefits of alien fishes, (F) number of alien fishes known, (G) knowledge of prohibited fishes, and (H) number of examples of alien fishes present in Malaysia given by respondents. SD = strongly disagree, D = disagree, A = agree, SA = strongly agree. A = aware, NA = not aware.

with this statement (Figure 2A). Most of the respondents also reported they had knowledge of the ecological impacts of alien fish (91%) (Figure 2B).

Most respondents also had prior awareness (73%) of alien fishes (Figure 2C) and were aware of existing legislation on alien fishes (67%) (Figure 2D). About one-third of the respondents (31%) strongly disagreed with the statement that alien fish were generally more beneficial than detrimental and only 10% of them strongly agreed with this statement (Figure 2E). About one-third of the respondents (32%) indicated they had knowledge of more than six alien fish species (Figure 2F). Most of the respondents (64%) indicated knowledge of prohibited fishes (Figure 2G). More so, about 33% of the respondents gave 2–5 correct examples of alien fish species, while 30% gave no correct example (Figure 2H).

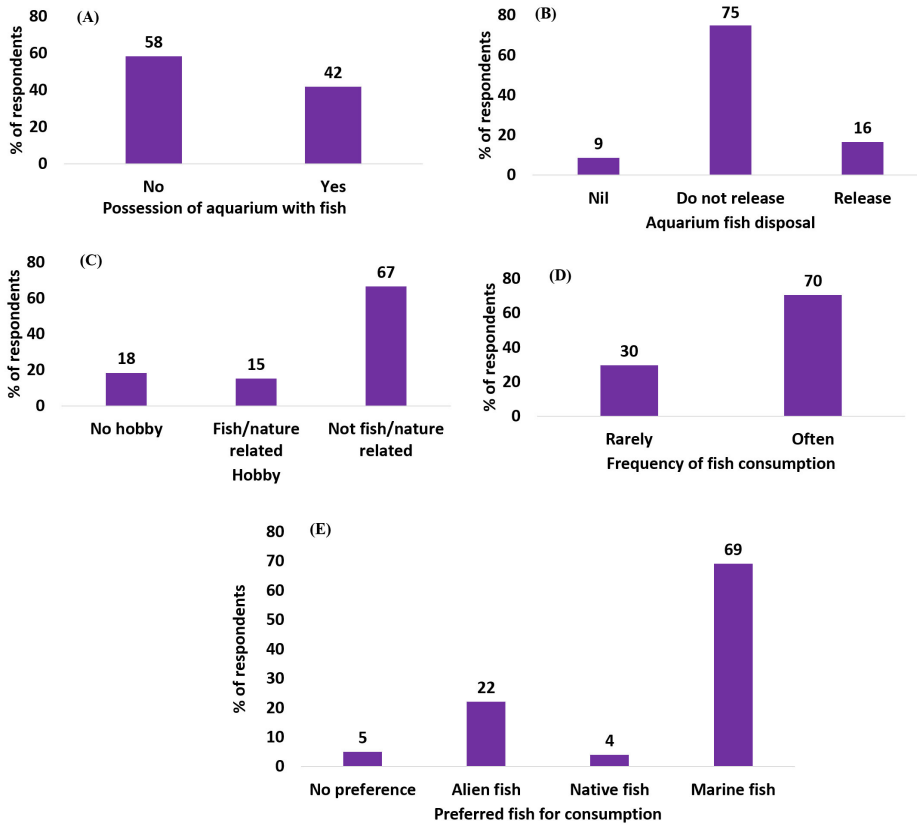

Figure 3. Summary of responses by percentage for some practices regarding alien fishes in Malaysia including, (A) possession of a working fish aquarium, (B) manner of unwanted aquarium fish disposal, (C) type of hobby, (D) fish consumption frequency, and (E) fish consumption preference.

Out of the 127 respondents with functional aquaria in their homes (Figure 3A), about 16% reported release of unwanted aquarium fish into the wild, including streams, rivers, and lakes (Figure 3B). Hobbies related to nature as recorded in this study include fishing, sport-fishing, fish keeping, and hiking, but most of the respondents (67%) had hobbies that were not nature related (Figure 3C). The majority (70%) often consumed fish either weekly or monthly (Figure 3D) and preferred to consume marine fishes (69%) followed by alien freshwater fishes (22%) (Figure 3E).

Correlational comparisons

We found significant relationships ($p < 0.05$) between knowledge, perception and practice variables. For example, prior awareness of alien fishes was correlated with knowledge of ecological impacts ($r = -0.445$), the number of alien fishes known ($r = -0.634$), and the number of alien fishes mentioned ($r = -0.557$). The number of alien fishes mentioned correlated significantly with knowledge of ecological impacts ($r = -0.473$) and the number of alien fishes known ($r = 0.687$). Similarly, knowledge of prohibited fish correlated with examples of prohibited fish ($r = 0.452$) (Table 2).

We also found significant relationships ($p < 0.05$) between items measuring respondents' knowledge and awareness *versus* practices regarding alien fishes.

Table 2. Correlational comparisons of respondents' knowledge and perceptions of alien fishes among respondents in Malaysia.

Variables	PEcon_val	KEcol_impa	KLegislatio	PBenefits	Prior_aware	Num_know	AFish_ment	kFish_prohi	exFis_prohi
PEcon_val	1.000	0.050	**0.210**	**0.201**	0.016	0.026	0.077	−0.058	0.039
KEcol_impacts		1.000	−0.109	**−0.294**	**−0.445**	**0.308**	**0.473**	**0.140**	0.046
KLegislation			1.000	**0.114**	−0.010	0.069	−0.028	**0.113**	0.153
PBenefits				1.000	**0.239**	**−0.124**	**−0.171**	−0.067	0.038
Prior_aware					1.000	**−0.634**	**−0.557**	**−0.189**	−0.129
Num_known						1.000	**0.687**	**0.247**	**0.319**
AFish_ment							1.000	**0.181**	**0.383**
KFish_prohi								1.000	**0.452**
ExFis_prohi									1.000

PEcon_val = perception of economic value, KEcol_impacts = knowledge of ecological impacts, KLegislation = knowledge of existing legislation, PBenefits = perception of general benefits, Prior_aware = prior awareness, Num_known = number of alien fish species known, AFish_ment = number of alien fish species mentioned, KFish_prohi = knowledge of prohibited fish species, ExFis_prohi = examples of prohibited fish species given. Values in bold represent significant relationships at $p < 0.05$.

Table 3. Correlational comparisons of respondents' knowledge and perception *versus* practices regarding alien fishes among respondents in Malaysia.

Variables	Eatn_pref	Dispos_aqfish	Hob
PEcon_val	−0.062	−0.007	0.102
KEcol_impacts	**0.177**	**−0.443**	**0.316**
KLegislation	**−0.117**	0.067	**−0.165**
PBenefits	**−0.117**	0.154	−0.084
Prior_aware	**−0.113**	0.159	−0.065
KFish_prohi	0.039	−0.065	**−0.175**
Eatn_pref		−0.004	**0.120**
Dispos_aqfish			0.057

PEcon_val = perceptions of economic value, KEcol_impacts = knowledge of ecological impacts, KLegislation = knowledge of existing legislation, PBenefits = perception of general benefits, Prior_aware = prior awareness, KFish_prohi = knowledge of prohibited fish species, Eatn_pref = preferred fish for consumption, Dispos_aqfish = aquarium fish disposal, Hob = hobby. Numbers in bold indicate significant relationships at $p < 0.05$.

Knowledge of ecological impacts correlated significantly with fish eating preference ($r = 0.177$), disposal of aquarium fish ($r = -0.443$), and hobby of respondents ($r = 0.316$). Respondents' knowledge of legislation regarding alien fishes correlated significantly with fish eating preference ($r = -0.117$) and their hobby ($r = -0.165$). Respondents' perception of the benefits of alien fishes correlated significantly with fish eating preference ($r = -0.117$), while their prior awareness of alien fishes correlated significantly with their fish eating preference ($r = -0.113$). Finally, respondents' hobby correlated significantly with their knowledge of prohibited fish ($r = -0.175$) and their fish eating preference ($r = 0.120$) (Table 3).

Knowledge, perceptions and practices regarding alien fish species by socio-demographics

The summary of Chi-square (χ^2) comparisons of knowledge, perceptions, and practices regarding alien fishes in Malaysia based on socio-demographics is included in Table 4. We found that the level of education was a significant predictor ($p < 0.05$) for all items related to knowledge and perceptions of alien fish species, except for knowledge of legislation. Higher educated

Table 4. Chi-square (χ^2) comparisons of knowledge, perceptions, and practices regarding alien fishes in Malaysia by socio-demographics.

	Items	Education	Ethnicity	Gender	Age
Knowledge and perceptions	Perception of economic value	$p < 0.001$	$p < 0.001$	NS	NS
	Knowledge of ecological impacts	$p < 0.001$	$p < 0.001$	0.008	0.001
	Perception of general benefits	$p < 0.001$	0.001	NS	NS
	Awareness of legislation	NS	NS	NS	NS
	Knowledge of prohibited fish	0.002	NS	0.003	0.001
	Example of prohibited fish	0.001	NS	NS	NS
	Prior awareness	0.001	0.008	NS	NS
	Number of aliens known	0.003	0.001	0.001	0.025
	Number of aliens mentioned	$p < 0.001$	$p < 0.001$	0.001	0.004
Practices	Fish disposal	0.02	NS	NS	NS
	Fish eating preference	NS	NS	NS	NS
	Hobby	0.001	$p < 0.001$	$p < 0.001$	$p < 0.001$

NS = not significant.

respondents (with post-secondary education) showed higher levels of agreement with the items on perceptions of economic value and on knowledge of economics. Higher proportions of this group reported to have knowledge of prohibited fish (32%) when compared to secondary and primary education levels (13% and 14% respectively). About 15% of this group could mention six species examples or more, while this was only 0–2% for the respondents with secondary or primary education (Table S1).

Significant ($p < 0.05$) relationships based on ethnicity were found for selected items related to knowledge and perceptions of alien fish species. Higher proportions of all ethnic categories either agreed (Indian, Chinese, and others) or strongly agreed (Malay) to the statements on the economic importance of alien fishes, while the largest proportion of all ethnic categories consider alien fishes to pose ecological impacts. Regarding awareness of prohibited fish species and prior awareness of alien fishes, respondents in all ethnic groups mostly answered "yes" to the questions. Apart from the Malay respondents who mostly knew (31%) and were able to mention 2–5 alien fish species (32%), most of the respondents in the other three ethnic categories knew none and were not able to mention examples of alien fish species (Table S2).

Knowledge of ecological impacts, knowledge of prohibited fishes, number of alien fish species known, and number of alien fish species mentioned were significantly related to gender ($p < 0.05$). A higher proportion of females (97%) were knowledgeable of the ecological impacts of alien fishes. However, more males (72%) were aware of prohibited fish species, while two in three male respondents knew more than 10 alien fish species and could mention 2–5 alien fishes (Table S3).

There were significant ($p < 0.05$) associations among the age groups for items related to knowledge and perceptions of alien fish species. Most of the respondents in the age of 18–25 and 26–36 categories knew 2–5 alien fish species, while most of the respondents in the age category of 36–45 knew more than 10 alien fish species. Contrarily, most of the respondents in the

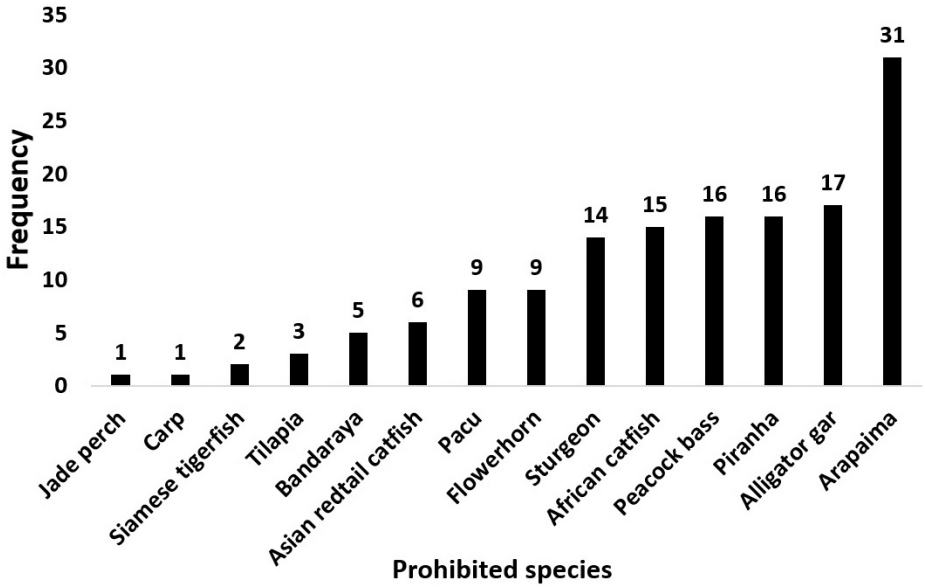

Figure 4. The number of times (frequencies) that prohibited alien fishes were mentioned by survey respondents. Please note that tilapia, African catfish, carp, jade perch, and pacu are among commonly cultured food fishes in this country. "Bandaraya" is the local name for all Loricariid catfishes.

age groups of 46–55 and > 55 indicated knowing no alien fish species. When looking at the number of examples given, we found that most of the respondents in the 18–25 and 26–36 age categories mentioned no alien fish species. Most of the respondents in the 36–45 age category mentioned 2–5 alien fish species, while most of those in the age groups 46–55 and > 55 did not mention any alien fish species (Table S4).

Finally, significant ($p < 0.05$) associations were found in the respondents' practices concerning alien fishes. Fish disposal practices were related to the level of education and hobby by education, ethnicity, gender and age (Table S5 and Table S6).

Frequently mentioned species

Arapaima (*Arapaima* sp.) was the most frequently mentioned species (n = 31) by the respondents as an example of a prohibited alien species, followed by alligator gar *Atractosteus spatula* (Lacépède, 1803) (n = 17), peacock bass (*Cichla* sp.) (n = 16), piranha (family Serrasalmidae) (n = 16), and African catfish *Clarias gariepinus* Burchell, 1822 (n = 15) (Figure 4).

Discussion

This study investigated the relationships between public knowledge and perceptions of the impacts and importance of alien fishes in Malaysia. In addition, we used socio-demographic profiles to make comparisons between groups and identified which alien fish species were well known among the public.

Knowledge and perception

We found negative relationships between public knowledge regarding ecological impacts *versus* awareness of alien fish, and perception of economic importance. This is an indication that being aware of alien fishes may not necessarily translate to having much knowledge about their potential ecological threats. Furthermore, those with knowledge about the possible ecological impacts do not perceive alien fishes to be of high economic importance. Those who think that alien fishes are economically valuable may have been influenced by the benefits they gain from certain alien fishes that serve to provide food, income, or as a source of aesthetics and recreation (Ellender and Weyl 2014).

Similar to the findings of this study, a high level of knowledge regarding alien species was reported for different stakeholder groups in the Donãna social-ecological system in Spain, and for knowledge of alien species in the Netherlands (García-Llorente et al. 2008; Verbrugge et al. 2013). The inability of some respondents to give specific examples of non-native fish species they claimed to know may be due to their lack of familiarity with specific alien fishes or uncertainty of the specific taxonomy of these species. Despite the high level of knowledge, there may be a need for further enlightenment of the general public to step up their knowledge, in order to influence their attitudes and practices regarding conservation of aquatic biodiversity, for example through knowledge of the current and potential impacts of alien fishes.

To our surprise, a large number of respondents strongly disagreed that alien fishes are generally more beneficial than detrimental. This implies that although they may benefit from alien fishes through their engagements either as ornamental fish store owners, fish farm owners, sport fishers, hobbyists, and consumers, they tend to be aware of their negative impacts. The negative relationship existing between respondents' disposal of aquarium fishes and their knowledge of ecological impacts shows that knowledge will likely influence people's actions concerning the conservation of native fish resources.

Socio-demographic comparisons

Despite the greater interest of males in nature-related hobbies like sport-fishing, hiking, and aquarium hobby, our findings show that females had more knowledge about the ecological impacts of alien fish species compared to males. Previous studies have identified a different general pattern, for example, Waliczek et al. (2017) who assessed college students' knowledge and perceptions of invasive species at a university and community college in Texas, USA, found that males are more knowledgeable compared to females with regards to alien species.

In this study, educational level of respondents seemed to be the most important factor influencing the public's knowledge and perceptions of

alien fish. This was expected because those with a more educated background are more likely to have had the opportunity to attend or access lectures, symposia, seminars, or articles about the need for conservation (Clusa et al. 2018). It further suggests that the more educated may provide greater support for management compared to the less educated (Verbrugge et al. 2013; Waliczek et al. 2017). In this study, people, by educational levels, seem to be equally informed about the existence of legislation regarding alien fishes, but differ regarding their knowledge and perceptions.

The outcome of this study showed that ethnicity is the second most important factor influencing knowledge and perception regarding alien fish. This finding is similar to Waliczek et al. (2017) for college students in Texas, USA, and Oxley et al. (2016) for public opinions on invasive species and their management in the San Marcos River, Texas, USA. They found a significant difference by ethnicity in the scores regarding respondents' knowledge and attitudes, with regards to invasive animal and plant species. It is important to note that the largest percentage of participants in this survey were Malays. This may have influenced the observed significance, therefore, future research may consider engaging in quota sampling by ethnicity or focusing on recognized social groups to give a better representation and more accurate information.

Practices

In this study, a low proportion of the respondents stated that they release their unwanted aquarium fishes into the wild. Disposal of fish into public water bodies is one of the important human-assisted dispersal pathways (Strecker et al. 2011). Since most of the freshwater aquarium fishes in Malaysia are alien, it is a likely introduction pathway into local waters. People who engage in this are likely to be unaware of the possible ecological impacts. Also, this study revealed that most of the respondents prefer to consume marine fish. This is in line with other studies that found that marine fish remains one of the most frequently consumed foods amongst Malaysian adults (Norimah et al. 2008; Ahmad et al. 2016). Concerning freshwater fishes, alien freshwater fishes were preferable to the respondents in this study than native freshwater fishes. This points to the dietary and economic importance of these fishes.

Well-known alien fish species

Arapaima and alligator gar were the most well-known alien fish species among the public, followed by peacock bass, piranha, and African catfish which may actually be of higher invasion risks judging from their history of establishment in other countries of the world (Froese and Pauly 2019). The high frequency of arapaima and alligator gar is probably due to the greater publicity of these species by the media due to their naturally large sizes. The freshwater ecosystems of Malaysia shelter many alien fishes such

as African catfish, peacock bass, striped catfish *Pangasianodon hypophthalmus* (Sauvage, 1878), Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758), Mozambique tilapia *O. mossambicus* (Peters, 1852), arapaima, piranha, and sailfin catfishes including suckermouth catfish *Hypostomus plecostomus* (Linnaeus, 1758), Amazon sailfin catfish *Pterygoplichthys pardalis* (Castelnau, 1855) and vermiculated sailfin catfish *P. disjunctivus* (Weber, 1991) (DOF 2007; Samat et al. 2008; Khairul-Adha 2012; Naji et al. 2014; Radhi et al. 2017; Zulkafli et al. 2015, 2018; Jalal et al. 2018). Most of these fishes have successfully adapted to the local environment, grow rapidly, and feed on indigenous species (Chong et al. 2010; NWGIAS 2014). There have been reports of their negative impacts in the wild. Unfortunately, these reports are not based on empirical studies. For example, the butterfly peacock bass *Cichla ocellaris* Bloch & Schneider, 1801 reportedly predates on smaller native fishes. About 50,000 fries of tinfoil barb *Barbonymus schwanefeldii* (Bleeker, 1854) were attacked by this species in the Timah Tasoh Lake, Perlis (Isa et al. 2012; Zulkefli 2017). Also, over 10 tonnes of the vermiculated sailfin catfish have been caught from the Skudai River, Johor, indicating that they have likely outcompeted the native fish species due to their hardy features (Tan 2019). Hobbyists, ornamental fish retailers, and fish farmers need to have access to information that can help to understand the challenges of invasion, as well as to identify the prohibited species (Azevedo-Santos et al. 2015; Magalhães et al. 2017). In addition, more efforts should be directed towards raising the consciousness of younger generations from the classroom regarding the impacts of releasing unwanted ornamental fish. This would give them a good understanding at a very early stage with opportunities to propagate the message as they grow older.

Limitations of the study

We compared the samples from our two recruitment strategies (i.e. online and hardcopy questionnaire) using Chi-square (χ^2) tests and found significant differences ($p < 0.05$) in their socio-demographic characteristics. Unlike respondents to the online questionnaire, who belong mainly to the post-secondary category (94%), most respondents to the hardcopy questionnaire belong to the secondary category (78%). Since the more educated are likely to use technology better (Riddell and Song 2017), it is possible that these results reflect a generally high proportion of respondents who are educated at the post-secondary level. Therefore, the inclusion of a proportionate number of hardcopy filled questionnaires in future studies may be valuable in capturing a greater range in education backgrounds.

Finally, the sampling method employed in this study targeted individuals with an existing interest in nature and fish related issues. As such, we believe that the sample and its size is more representative of people in this category rather than the generality of Malaysian citizens. Also, the hardcopy surveys were collected from one location (Klang Valley)

and this may result in bias as well. Therefore, hardcopy surveys should cover different representative locations in future studies.

Conclusion

This was the first study on public knowledge and perceptions of alien fish species in Malaysia. Our findings show that members of the public have considerable knowledge of the negative impacts of alien fish in Malaysia, but also that they perceive alien fish as economically important, and this may have positively influenced some of their practices especially the disposal of aquarium fishes into local waters. Moreover, public knowledge and perceptions differed between people from different ethnic groups and with different education levels. This study provides useful insights for future planning of conservation programs of native fishes in Malaysia.

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Supplementary material

The following supplementary material is available for this article:

Appendix 1. Questionnaire on knowledge and perceptions of ecological impacts and socio-economic importance of alien fishes in Malaysia.
Table S1. Chi-square (χ^2) comparisons of knowledge and perceptions of alien fish species in Malaysia by level of education.
Table S2. Chi-square (χ^2) comparisons of knowledge and perceptions of alien fish species in Malaysia by ethnicity.
Table S3. Chi-square (χ^2) comparisons of knowledge and perceptions of alien fish species in Malaysia by gender.
Table S4. Chi-square (χ^2) comparisons of knowledge and perceptions of alien fish species in Malaysia by age.
Table S5. Chi-square (χ^2) comparisons of practices regarding alien fish species in Malaysia by ethnicity and education.
Table S6. Chi-square (χ^2) comparisons of practices regarding alien fish species in Malaysia by gender and age.

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