Journal of Tropical Biology and Conservation 14: 37-53, 2017 ISSN 1823-3902

Research Article

The Application of Citizen Science Approach in an Ichthyofaunal Survey at Tagal Sites in Upper Moyog River, Sabah, East Malaysia

Casey Ng Keat Chuan

Forever Sabah, HG01B Ground Floor, Hawaii Court Waikiki Condominium, Tanjung Aru 88100 Kota Kinabalu, Sabah, Malaysia
Corresponding author: casey@foreversabah.org

Abstract

This study explores and describes the effects of citizen science and the application of traditional ecological knowledge in data collection. A monthly survey of 10m transact were conducted in Kibunut Bawah and Notoruss tagal sites during the period of February to May 2016 to determine the fish species composition for setting the biological baselines for river monitoring purposes. A total of 279 individuals representing 8 species from 3 families were recorded and the dominant species was *Tor tambra*. Shannon Index of Diversity (H') in Kibunut Bawah and Notoruss was 0.747 and 0.825 respectively. Deeper waters were found to host higher abundance. Local participants' familiarity with local habitats and species were the key factors that influenced the sampling results. Some site observations and community responses are also discussed to guide future studies.

Keywords: Fish, *tagal*, citizen science, community-based, conservation

Received 20 June 2016
Reviewed 08 September 2016
Accepted 06 October 2016
Published 15 October 2017

Introduction

Traditional communities of Sabah have long recognized the perils of "tragedy of the commons" (Hardin, 1968). As a response, the *tagal* community-based conservation approach was conceived to ensure fish stock is not overfished in the rivers. Thus, through Section 58 of the Sabah Native Courts Rules of 1995 (Native Customary Law) and Sections 35, 36 and 37 of the Sabah Inland Fisheries and Aquaculture Enactment 2003, the *tagal* fish refugia system was introduced. Sometimes known as *managal* or *bombon* depending on local dialect, it aims to empower the local community to conserve and harvest fish stock from the *tagal* sites in a sustainable manner (Foo &Noor, 2012; Selvadurai, 2012; Halim et al., 2013). Section 35 recognizes indigenous practices for natural resource management and Sections 36-37 outline the Community Fisheries Zone framework to empower locally elected committees to manage *tagal* sites. Perpetrators who violate the *tagal* rulings can be penalized in accordance to the Sabah Native Courts Rules of 1995 (Native Customary Law).

A typical *tagal* site is demarcated by traffic light colours to depict the degree of prohibitions in *tagal* sites. Critical fish spawning grounds are designated as "red zone" while the "yellow zone" is allocated for periodical *buka tagal*, or a communal fish harvesting period, which is decided by the local *tagal* committee (Wong et al., 2009). There is no fishing restriction in the "green zone" but local communities usually forego this privilege to increase the fish population. Fishes acquired during *buka tagal*, usually a one day affair, are customarily divided equally among members of the local community.

In recent years, fish population is not only reduced by uncontrolled fishing, it is also affected by pollution in the rivers arising from human population growth and socio-economic activities. In Malaysia, 1,475,444 point sources of water pollution were identified by the Department of Environment (DOE, 2013) in 2013 alone. Left unchecked, there is a high possibility of *tagal* sites eventually losing their viability as refugia. Therefore, the process of fish diversity monitoring needs to be stepped up and it is timely that the local communities are included in the process. This can be attained by enriching the traditional *tagal* practice with modern scientific rigour based on the concept of citizen-science (Couvet et al., 2008; Dickinson et al., 2012).

The UK Environmental Observation Framework (UK-EOF) defines citizen science as a data collection exercise that involves local volunteers and it is expected to contribute to knowledge expansion of the natural environment (Tweddle et al., 2012). It is a valuable approach that combines research with environmental education for local communities who are involved in the study projects. The application of citizen science and participation of indigenous communities in conserving biodiversity is not new in Malaysia. It has been highlighted as early as 2004 (Nicholas & Lasimbang, 2004) and traditional ecological knowledge (TEK) (Berkes et al., 2000) is now widely practiced in fishery mapping and studies (Drew, 2005; MacLean et al., 2009). Naturally, local artisanal fishermen who exploit the species are the best informants. They are skilful assessors of fish composition and distribution patterns in relation to local hydrological variances. Without doubt, indigenous knowledge can enrich science and this study is inspired by such notions.

The Moyog River (5° 53' 59.8914", 116° 11' 29.544") is located at the western foothills of Crocker Range within the Penampang district that has a population of 122,388 (Department Of Statistics, 2010). Besides ichthyofaunal integrity, the river is selected based on its importance in supplying water to households, agriculture and industrial applications to nearby Kota Kinabalu city. Fish composition in Kibunut Bawah and Notoruss are expected to reflect the "best of what is left" (Karr, 1999). Therefore the objectives of this study are to generate a species list to set the biological baseline for river monitoring and to examine the implications of adopting citizen science and traditional ecological knowledge when collecting data in Moyog River.

Material and Methods

Prior to the study, a series of traditional *sumuku* sessions, or communal consultation gatherings, were carried out to ensure that free, prior and informed consent (FPIC) (FAO, 2014) were obtained from the villagers. Field data was collected by the selected artisanal fishermen and elders from the local communities between February and May in 2016 (covering a period of four months). They were chosen by showing them fish images and assessing whether they knew and could identify the species with vernacular names. Their responses indicating familiarity of fish habitats, seasonality and feeding guilds were also taken as traditional ecological knowledge competency. No two persons were spoken to at the same time to ensure one informant could not influence the answers of the other.

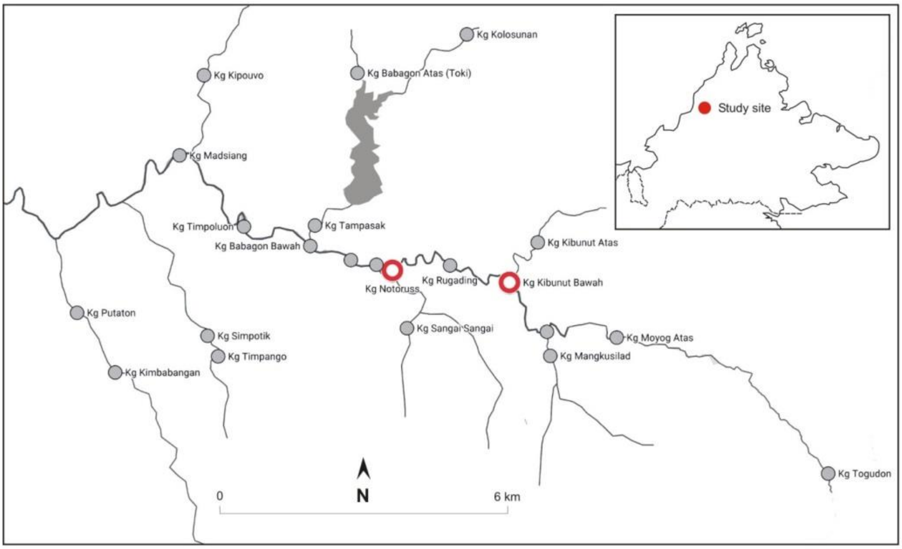


Figure 1. The study sites Notoruss and Kibunut Bawah and other *tagal* sites around them.

Sampling was supervised by the author and physically executed by selected locals during the day along 10m length transects at four locations in each *tagal* site on a monthly basis (Figure 1 & 2).

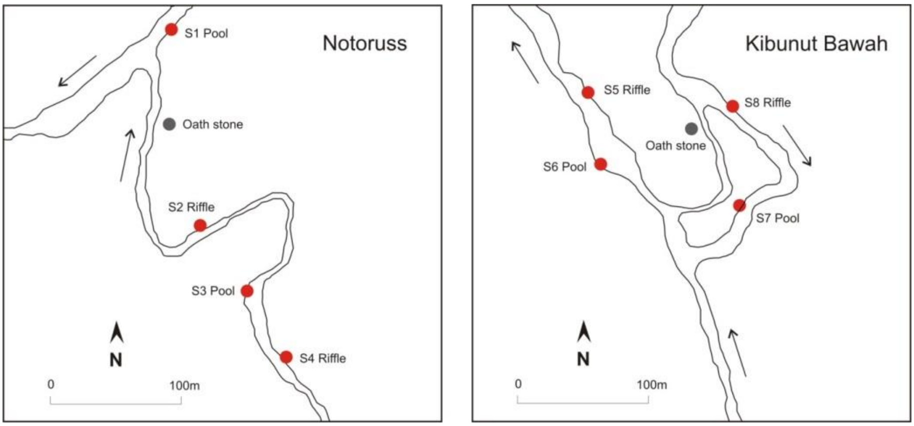


Figure 2. GPS coordinates of sampling transacts are as follow, S1= N 5° 53' 56.868", E 116° 11' 55.5714"; S2= N 5° 53' 48.2994", E 116° 11' 57.8034"; S3= N 5° 53' 45.636", E 116° 11' 59.2434"; S4= N 5° 53' 42.54", E 116° 12' 0.504"; S5= N 5° 53' 49.02", E 116° 13' 13.6194"; S6= N 5° 53' 47.076", E 116° 13' 14.484"; S7= N 5° 53' 46.1394", E 116° 13' 17.832"; S8= N 5° 53' 48.3354", E 116° 13' 17.04". Kibunut Bawah and Notoruss are located 124m and 98m above sea level respectively.

Sampling transacts in each *tagal* site were also stratified to two fast-turbulent unidirectional shallow riffles and two non-turbulent deeper pools to examine which hydraulic-habitat hosts a higher abundance. Respecting the *tagal* custom, non-depletive sampling practices were applied and specimens were released back to the river unharmed after assessment.

Only freshly caught adults with mature morphology were photographed to ensure that the natural colours and body patterns were recorded. Specimens were captured manually using 0.5m diameter round handnets (mesh size 5mm) and 2.5m diameter *rambat* (castnet mesh size 15mm). Publications by Martin-Smith & Tan (1998), Inger & Chin (1962), Tan (2006) and Ambak et al. (2012) were referred to when identifying specimens caught to species level, when possible. *Tagal* sites' hydrological characteristics were also mapped and documented to assist in result interpretation.

The Simpson index (D) is calculated as;

$$D = \Sigma p_i^2$$

where p_i is the faction of individuals corresponding to the *i*th species (Simpson, 1949). In this study, the Simpson index is expressed as 1-D to limit the value between 0 (poor) to 1 (excellent) to indicate diversity.

The Shannon index (H') is calculated as;

$$H' = -\Sigma p_i \ln p_i$$

where p_i is the ratio of individuals corresponding to the *i*th species (Shannon &Weaver,1949; Magurran, 2004).

Results and Discussion

A total of 288 individuals were caught representing eight species and three families. Food species *Tor tambra* is the dominant species in Kibunut Bawah and Notoruss (Table 1).

Table 1. List of species encountered during the study period. View appendix for images of specimens.

Family / Species	Kibunut Bawah	Notoruss
GASTROMYZONIDAE		
1. *Gastromyzon* cf. *introrsus*	13	23
CHANNIDAE		
2. *Channa striata*	0	4
CYPRINIDAE		
3. *Lobocheilos ovalis*	18	21
4. *Nematabramis borneensis*	3	7
5. *Paracrossochilus acerus*	4	27
6. *Barbodes sealei*	11	17
7. *Rasbora* cf. *rheophila*	25	26
8. *Tor tambra*	32	48
Total number of individuals	106	173
Relative abundance of *Tor tambra*	30.2%	27.7%
Simpson Diversity Index (1-D)	0.804	0.837
Shannon Diversity Index (H’)	0.747	0.825
Pielou Evenness Index (J’)	0.884	0.913

An independent sample t-test reveals there is a significant difference for abundance, $t(30) = 3.13$, $p = 0.004$, with Notoruss ($M = 10.44$, $SD = 4.13$) hosting a higher fish population than Kibunut Bawah ($M = 6.62$, $SD = 2.58$). As both sites are roughly just 2km apart, abundance data are combined and results show a mean population of 8.53 (n=32, $SD = 3.90$) per transect of 10m. This can be regarded as the population density of upper Moyog River based on the two *tagal* sites sampled.

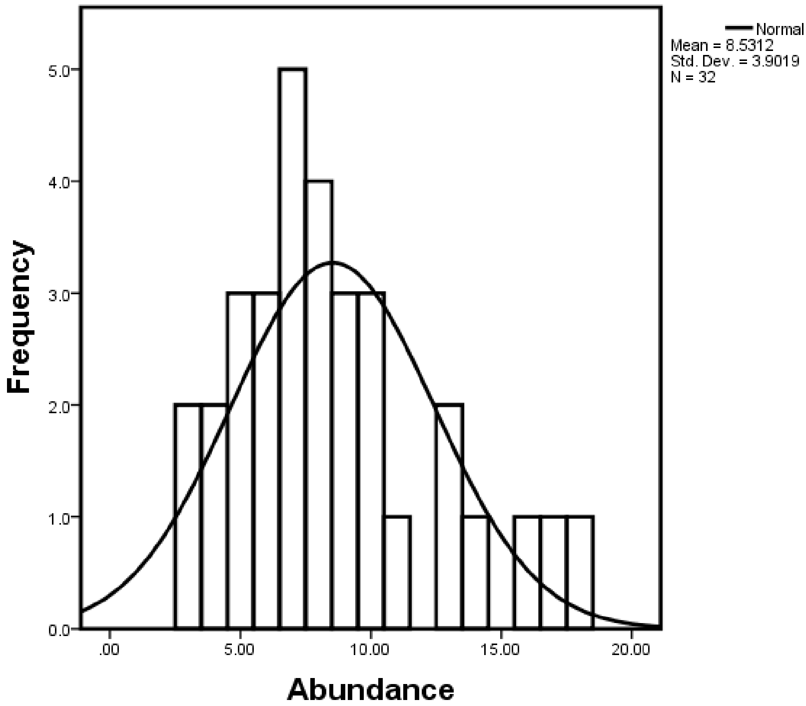


Figure 3. Histogram of combined abundance data of all species sampled in Kibunut Bawah and Notoruss.

Not surprisingly, the distribution curve is noticeably left-skewed (Figure 3). More low values were recorded and this was expected. In nature, tropical fishes are not evenly distributed for many reasons. Native species in small tributaries have evolved to be highly adaptable in their micro-habitats to prevent predation. It was observed that they tend to hide under rocks and underwater snags, especially the smaller species.

Fishes also gather in spots which provide more feeding opportunity. For example, frugivores will gather in waters underneath a fruiting tree that grows on the water edge. Therefore, the aggregating behaviours may skew the distribution curve and contradict with the fundamental of statistical analysis which generally calls for distribution homogeneity. Because it is by no means an easy task to capture the fishes, undoubtedly, here lies the advantage of adopting local community participation and traditional ecological knowledge. If it was not for the persistency and skills of locals in searching and capturing the fishes, the distribution curve would have been more left-skewed.

Correspondingly, it is often in such short-term exercises that the sampling results are possibly biased toward species that are bigger and easier to catch in open waters, for example *Tor tambra*. Because these are typically food species, locals have more relevant experience in finding their habitats and capturing them. Evidently, this shows that indigenous knowledge and species familiarity have an effect on fish assessment results. Additionally, nocturnal and benthic (which prefer crevices under rock, or with burrowing habit) species may be under-represented in this study.

Table 2. Data recorded in Notoruss

Month	Sampling point	Flow (m/s)	Depth (m)	Abundance (Number of individuals captured)
February	S1	0.76	1.89	14
	S2	1.48	0.45	7
	S3	0.55	2.22	18
	S4	1.68	0.54	6
March	S1	0.56	1.93	10
	S2	1.35	0.65	8
	S3	0.62	2.13	13
	S4	1.74	0.8	7
April	S1	0.71	2.2	10
	S2	1.64	0.73	8
	S3	0.34	2.5	17
	S4	1.52	0.65	6
May	S1	0.66	1.93	16
	S2	1.58	0.62	7
	S3	0.61	2.32	13
	S4	1.81	0.82	7

Table 3. Data recorded in Kibunut Bawah

Month	Sampling point	Flow (m/s)	Depth (m)	Abundance (Number of individuals captured)
February	S5	1.43	0.7	5
	S6	0.51	2.34	9
	S7	0.54	2.68	11
	S8	1.84	0.54	6
March	S5	1.24	0.67	4
	S6	0.64	1.93	8
	S7	0.52	2.12	10
	S8	1.64	0.58	5
April	S5	1.21	0.34	5
	S6	0.64	1.83	7
	S7	0.42	2.39	9
	S8	1.69	0.45	3
May	S5	1.63	0.64	3
	S6	0.61	1.83	9
	S7	0.68	2.12	8
	S8	1.74	0.72	4

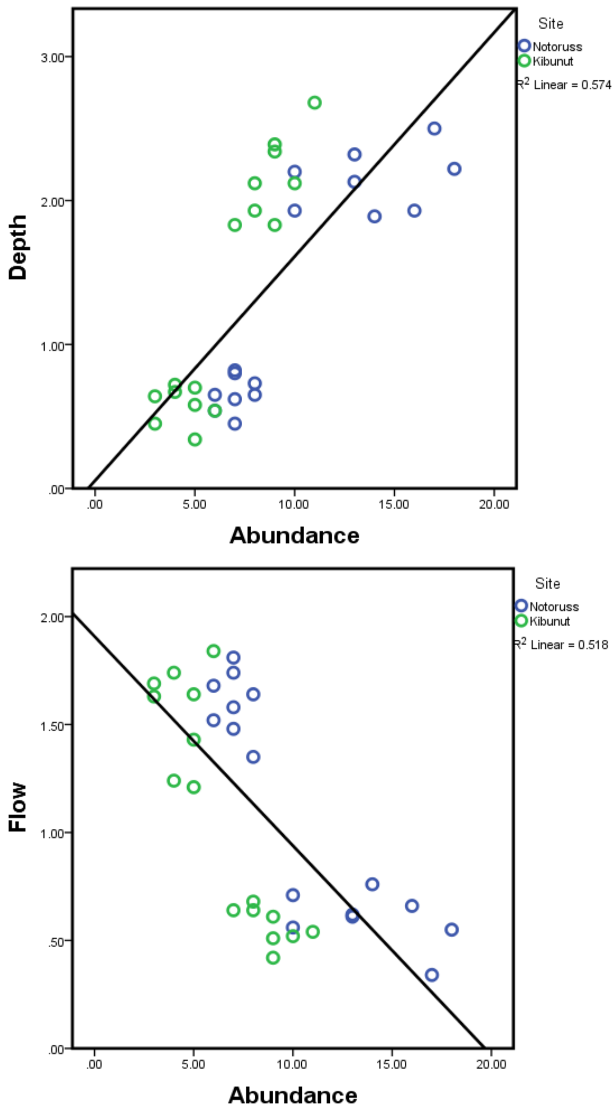


Figure 4. Two clusters are presented in the scatter plots to demonstrate correlation between abundance with river depth (m) and flow (m/s). This is expected because sampling points were intentionally stratified to two riffles and two pools in each sampling points for reasons explained in methods.

A Pearson product-moment correlation analysis was conducted between population abundance with river flow speed and depth. As shown on Figure 4, there is a strong positive correlation between abundance and depth (r = .758, n = 32, p < .001) and strong negative correlation between abundance and flow speed (r = -.720, n = 32, p < .001). Relationships showed linear trends and this implies that habitats with deeper and slower waters are more favourable in sustaining higher population. However, this study does not suggest that fast-turbulent shallow riffles should be excluded when assessing species inventory. In fact, riffles are a natural feature of most hillside rivers and Sabah is home to many torrent specialists such as *Gastromyzon* spp., *Protomyzon* spp. and *Paracrossochilus* spp. Riffles must be assessed to yield the best result to reflect species diversity of a particular site.

When interviewed and shown the results, Vitalis Galasun felt vindicated. He is the founder of the Notoruss *tagal* initiative in 1994, possibly the first formalized *tagal* site in Sabah. When the *tagal* scheme was first planned for Notoruss, he insisted that pool areas must be conserved as oral tradition dictates that deep pools are ecological refugia in times of monsoonal flooding. The move faced fierce opposition because pools were well known as the best fishing grounds. Local villagers perceived that such a move would reduce their fishing yield per effort. Eventually, traditional wisdom, and now empirical evidence, have shown everyone in the villages that their elders and forefathers were right. It is a best practice to designate pool areas for spawning and therefore a strictly non-fishing area (red zone) at *tagal* sites. This is consistent with many other studies which have found long held oral tradition embedded in indigenous society to be a plausible source of guidance for fishery conservation (UNESCO, 2007; Eicken, 2010; Berkes, 2012; Roy et al., 2012; Thornton & Maciejewski Scheer, 2012).

For the record, on 12th March 2016, Kibunut Bawah's *buka tagal* (a one-day open fishing event) yielded 168kg of fishes. Surprisingly, sampling results in the following month April 2016 did not show a substantial drop in abundance. Hydrologically, Kibunut Bawah is connected to upriver *tagal* sites of Kibunut Atas, Moyog Atas and Moyog Bawah. At downriver, Kibunut Bawah is connected to *tagal* sites of Notoruss and Tinopikon. Moreover, the Moyog River is interlinked with multiple tagal sites (Figure 1).

This implies that the Moyog ecohydrological unit has high integrity and allows a free flow of metapopulation dynamics to occur. When a site experiences depletion, the void is quickly repopulated by fishes from neighbouring *tagal* sites. This tells us that the speed of population recovery can be taken as a biology indicator for ichthyofaunal metapopulation rigour and resilience.

During the *buka tagal* event, locals interviewed also claimed that an eel with a distinctive mottled body pattern was encountered. This fits the description of *Anguilla marmorata* (Arai & Ryon, 2012). However, because the eel is not regarded as a food species, it was released without photographic records. This may warrant further investigation to ensure that the latest local fish checklist does not miss out any possible species.

The *Anguilla* genus consists of 18 species/subspecies and are all catadromous (Tesch, 1977; Aoyama, 2009). Although the adults live in freshwater, they migrate to spawning areas in the ocean. Juveniles grow up in stages in estuaries, mangroves and slowly make their way back to freshwater as adults. The coast is roughly 28km from Kibunut Bawah. If the eel was indeed *A. marmorata,* it raises the question of how the upper parts of Moyog River are still somehow ecologically linked to sea although a weir is present in Babagon Bawah (Figure 1). The Petagas-Putatan rivermouth is also considered polluted due to surrounding dense human settlement and would likely inhibit migration of catadromous species. Are *A. marmorata* specimens captured in March 2016 the last of their kind after the Babagon Bawah weir was constructed? Can the residual population be saved? Due to the awareness created from participating in this study, local communities are interested to keep a close watch on *A. marmorata* presence.

Other endemic species namely *Barbodes sealei, Nematabramis borneensis, Gastromyzon* cf. *introrsus* and *Lobocheilos ovalis* were also recorded in both *tagal* sites. When interviewed, locals did not know they were rare or endemic species. This was not surprising as the key motivation for *tagal* implementation in the villages was to conserve food species. Small and non-food species were typically overlooked. Owing to the short duration, this study is not exhaustive and the local community has plans to continue searching for more species to update their checklist. This includes organizing night searches to look for nocturnal species. Nets with finer mesh should also be used to capture smaller species.

Indeed, there were many insights that are interesting to science. More investigations are needed in the future as a follow up. As a spin off, the citizen-science approach has widened the local communities' perspective and managed to spur critical thinking. On the other hand, science has also learned and benefited from local traditional ecological knowledge. This is a desirable outcome because an ecology-friendly "collective thinking" within the communities and scientists is needed to create resilience to counter the perils of "tragedy of the commons". Locals who participated in this study are also beginning to appreciate the notion that the freshwater ecosystem and species composition should be interlinked and balanced. Big or small, rare or common, all species are important.

Conclusion

In line with the objectives outlined earlier, this study has produced a basic species inventory checklist with the application of citizen science. Subsequently, the study also revealed the advantages and issues in adopting citizen science. Although citizen science is a plausible tool for collecting data, it may not always be the best approach to take due to some biases as highlighted in this study. Data collected during the study can only be regarded as a preliminary baseline and it should be further supported with empirical study that includes the appropriate taxonomy and molecular analysis. Any absence or presence of species in the future can be used to indicate levels of integrity of the Moyog River system. Rivers and streams where we stand to lose the most aquatic biodiversity to anthropogenic pressure are currently under-researched in Sabah. It is hoped that this study will spark off a strong and continuous citizen-science movement to resolve the predicament. Traditional wisdom has vast potential and it should be further explored in a systematic manner to unearth more hidden knowledge. Certainly, questions arising from this study suggest that we still have much to learn.

Acknowledgements

The author is thankful to Shared Earth Foundation for funding this study. Special appreciation also goes to the Penampang District Office, Department of Fisheries (Penampang), Penampang Tagal Association, Kg Kibunut Bawah and Kg Notoruss tagal committees for the kind support and partnership. The author is especially grateful to Dr. Tan Heok Hui and the anonymous reviewers who have kindly assisted in improving the manuscript.

References

Ahmad A, Nek ASR, Ambak MA. 2006. Preliminary study on fish diversity of Ulu Tungud, Meliau Range, Sandakan, Sabah. *Journal of Sustainability Science and Management* **1(2):**21-26

Ambak MA, Mat Isa MM, Zakaria MZ, Ghaffar MA. 2012. *Fishes of Malaysia, 2nd edition*. Terengganu: Penerbit UMT

Aoyama J. 2009. Life History and Evolution of Migration in Catadromous Eels (Genus Anguilla). *Aqua-BioScience Monographs* **2(1):**1-42

Arai T, Siow R. 2013. First Documented Occurrence of the Giant Mottled Eel, *Anguilla marmorata* in Peninsular Malaysia, Malaysia. *World Applied Sciences Journal* **28 (11):**1514-1517

Berkes F, Coldings J, Folke C. 2000. Rediscovery of Traditional Ecological Knowledge as Adaptive Management. *Ecological Applications* **10:**1251-1262

Berkes F. 2012. Implementing ecosystem-based management: evolution or revolution? *Fish and Fisheries* **13:**465–476

Couvet D, Jiguet F, Julliard R, Levrel H, Teyssedre A. 2008. Enhancing citizen contributions to biodiversity science and public policy. *Interdisciplinary Science Reviews* **33(1):**95-103

Department of Environment, Malaysia 2013. *Environmental Quality Report 2013* [Online]. Available at: https://enviro.doe.gov.my/view.php?id=15791

Department Of Statistics, Malaysia 2010. *Population And Housing Census Of Malaysia.* Available at: https://www.statistics.gov.my/mycensus2010/images/stories/files/Laporan_Kiraan_Permulaan2010.pdf

Dickinson JL, Shirk J, Bonter D, Bonney R, Crain RL, Martin J, Phillips T, Purcell K. 2012. The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment.* **10(6):**291-297

Drew JA. 2005. Use of Traditional Ecological Knowledge in Marine Conservation. *Conservation Biology* **19:**1286-1293

Foo J, Noor HM. 2012. Local community respond to indigenous management of aquatic resources: The case of Tagal system. *Malaysia Journal of Society and Space* **8(2):**30-37

Food and Agriculture Organization of the United Nations, 2014. *Respecting free, prior and informed consent, Governance Of Tenure Technical Guide No. 3.* Rome: United Nations

Eicken H. 2010. Indigenous knowledge and sea ice science: What can we learn from indigenous ice users? *SIKU: Knowing our ice - documenting Inuit sea-ice knowledge and use*, New York: Springer

Halim AA, Jawan JA, Ismail SR, Othman N, Masnin MH. 2013. Traditional Knowledge and Environmental Conservation among Indigenous People in Ranau, Sabah. *Global Journal of Human-Social Science* **13(3)**

Hardin G. 1968. The Tragedy of the Commons. *Science, New Series* **162 (3859):**1243-1248

Inger RF, Chin PK. 1962. *The freshwater fishes of North Borneo*. Kota Kinabalu: Natural History Publications

Karr JR. 1999. Defining and measuring river health. *Freshwater Biology* **41:**221–234

MacLean M, Breeze H, Doherty P. 2009. Using Fish Harvesters' Local Ecological Knowledge (LEK) in Support of Identifying Ecologically and Biologically Significant Areas (EBSAs) on the Offshore Eastern Scotian Shelf. Oceans and Habitat Report 2009. *Fisheries and Oceans Canada*, Nova Scotia

Magurran A. 2004. *Measuring Biological Diversity*. Oxford: Blackwell Publishing Company

Martin-Smith KM, Tan HH. 1998. Diversity of freshwater fishes from eastern Sabah: annotated checklist for Danum Valley and a consideration of inter- and intra-catchment variability. *The Raffles Bulletin of Zoology* **46(2):**573-604

Ministry of Natural Resources and Environment, Malaysia. 2016. *Riparian Guideline* [Online]. Available at: http://www.nre.gov.my/ms-my/PustakaMedia/Penerbitan/National%20Policy%20on%20biological%20Diversity%202016-2025%20Brochure.pdf [Accessed: 24 May 2016]

Nicholas C, Lasimbang J. 2004. *Biodiversity And Indigenous Knowledge Systems In Malaysia*. Subang Jaya: Center for Orang Asli Concerns (COAC)

Roy HE, Pocock MJO, Preston CD, Roy DB, Savage J, Tweddle JC, Robinson LD. 2012. *Understanding Citizen Science & Environmental Monitoring. Final Report on behalf of UK-EOF*. NERC Centre for Ecology & Hydrology and Natural History Museum. UK Environmental Observation Framework

Shannon CE, Weaver W. 1949. *The mathematical theory of communication*. Illinois: University of Illinois Press

Simpson EH, 1949. Measurement of diversity. *Nature* 163-688

Tan HH. 2006. *The Borneo Suckers*. Kota Kinabalu: Natural History Publications

Tesch FW. 1977. *The Eel, Biology and Management of Anguillid Eel*s. London: Chapman & Hall

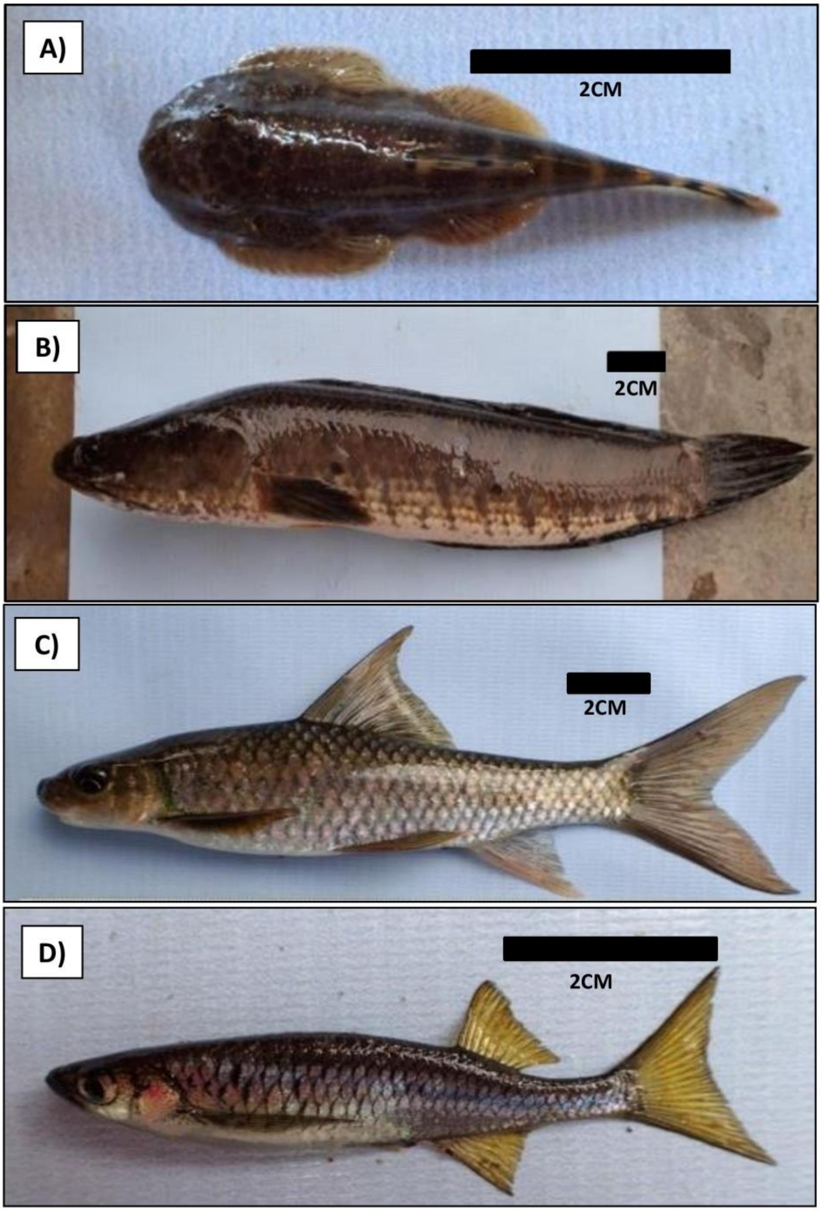
Thornton TF, Maciejewski Scheer A. 2012. Collaborative engagement of local and traditional knowledge and science in marine environments: A review. *Ecology and Society* **17(3):**8

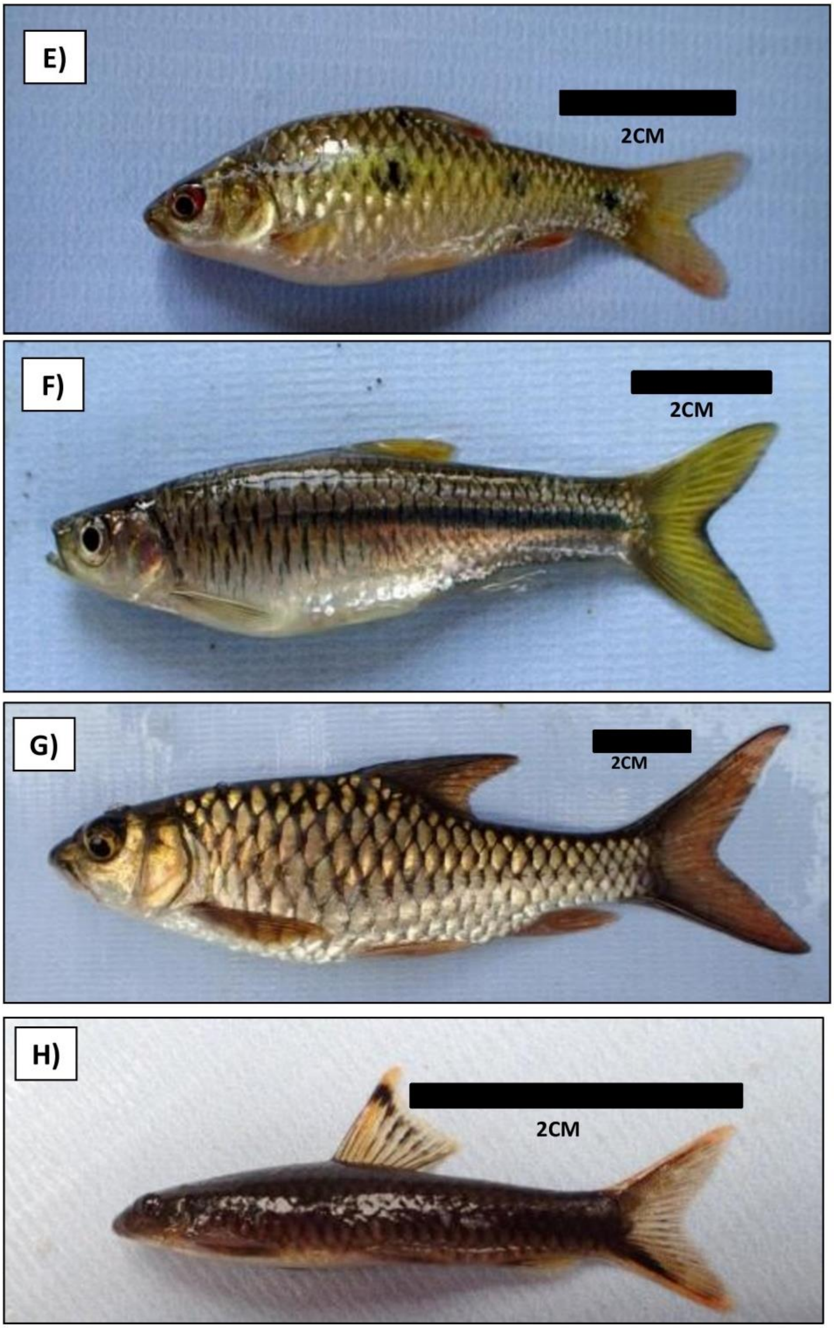
Tweddle JC, Robinson LD, Pocock MJO, Roy HE. 2012. *Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. Natural History Museum and NERC Centre for Ecology & Hydrology for UK-EOF

United Nations Educational, Scientific and Cultural Organization (UNESCO) 2007. *Fishers' Knowledge in Fisheries Science and Management*. Bonchamp-lès-Laval: UNESCO Publishing

Wong JZ, Etoh S, Sujang AB. 2009. Towards Sustainable Community-based Fishery Resources Management: The Tagal System of Sabah, Malaysia. *Fish For People*. Southeast Asian Fisheries Development Center. Available at: http://www.mahseertrust.org/downloads/Scientific_Publications/Wong%20et%20al%202009.pdf [Accessed: 8 September 2016]

Appendix





A) *Gastromyzon* cf. *introrsus* **B)** *Channa striata* **C)** *Lobocheilos ovalis*
D) *Nematabramis borneensis* **E)** *Barbodes sealei* **F)** *Rasbora* cf. *rheophila*
G)*Tor tambra* **H)** *Paracrossochilus acerus*