An application of fuzzy inference system to marine fish landings for west coast of Malaysia

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Abstract: Malaysia marine fishery sector and its activities are prominent in Malaysia waters, contributing to the nation's gross domestic product (GDP) and providing sustenance and protein. Among these activities are the landings of different fisheries resources from different landing districts, collated on states level, and officially reported annually. However, contributions of these landings to GDP are not adequately reported; moreover, fuzzy terms used in some cases were not evenly represented. Therefore, in the context of marine geospatial data infrastructure (MGDI) decisions, these constitute fuzzy decision problems resulting from stakeholders' subjectivity and uncertainties. In this paper therefore, evaluations of reported landings from 2006–2010 for western coast of Malaysia were investigated using fuzzy inference system. Categorisation of these contributions to GDP appropriately analysed to assist stakeholders in making informed decisions. Additionally, this novel approach is yet to be reported in literature to cases of fisheries landings and GDP across Asia and beyond.

Keywords: Malaysia waters; marine fishery sector; gross domestic product; GDP; marine fishery landings; artificial intelligence; fuzzy logic; fuzzy inference system; FIS; fuzzy decision problems; marine geospatial data infrastructure; MGDI decisions; marine environment; coastal zones; Malaysia Department of Fisheries.

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1 Introduction

Waters around coastal regions, like Malaysia are today witnessing an unprecedented increased and numerous marine activities, with attendant complex sea use configuration (Kaur, 2014). Accordingly, these water bodies are used for different purposes as reported in previous studies (Kaur, 2014; Saharuddin, 1995, 2001; Kaur and Sharma, 2014; Basiron, 2014). Kaur (2014) highlighted the need for new opportunities that would strengthen the national economy while enhancing the current Malaysia' fisheries and aquaculture resources. The marine resources from the marine environment are therefore very important to national economy, by contributing to the gross domestic product (GDP) of the country. Not surprisingly, this is in accordance with the United Nations Environment Program's (UNEP) estimation of more than two percent average contribution of marine fisheries sectors to the GDP of countries in the Southeast Asian (SEA) region. Despite this, Dyck and Sumaila (2010) emphasised a relatively small contribution of less than 1% of the fishing industries to GDP, but could be more than 2.5% for developing countries.

There are different fish landings that are annually reported for Malaysia's waters by Malaysia Department of Fisheries (DOFM). These comprise landing quantities (measured in tonnes) of different categories and multi-species of fisheries stocks with their equivalent values in Malaysian currency (Ringgits). The Malaysian fisheries resources are harvested from two areas: the inshore areas (from shoreline up to less than 30 nm) and for the deep sea exploitation areas (from 30 nm seaward). Moreover, there are different types of fishermen and vessels used in these two regions for the fish landings. For instance, there were 134,110 fishermen on licensed fishing vessels in 2011 compared to 129,622 in 2010 for both local and foreign fishermen and vessels (DOFM, 2011).

Furthermore, DOFM (2010) report for 2010 highlighted the distributions of 73 fish landing centres across the states in Malaysia [Peninsular Malaysia (41) that is 56.2% spatial landings, while the remaining 43.8% were for Sabah (16), Sarawak (15), and Federal Territory of Labuan (1)]. Extra analysis of these figures show that the west coast had 23 landing centres that cover the states of Perlis, Kedah, Penang, Perak, Selangor, Negeri Sembilan, Malacca, West Johor. Meanwhile, there were 18 centres for the eastern peninsular that cover the following states: Kelantan, Terengganu, Pahang, and East Johor. The tropical nature of Malaysia makes the marine fisheries resources to be abundantly multi-species, making their landings to be multi-geared, multi-stock and therefore posited to be complex (Loneragan et al., 2005; UNEP, 2008; Islam et al., 2011a). In addition, effects of these different multi-criteria, geographic locations, and prevailing environmental conditions are being associated to the muddy and shallow nature of the fishing grounds, particularly in the west coast that make the region to be significantly exploited (Islam et al., 2011a; Alam et al., 2002; Reczkova et al., 2013).

Moreover, the complexities are also attributable to the oceans geodynamic processes, marine activities, as well as stakeholders' subjectivity and uncertainties. Likewise, are the existing conflicts and competitions among neighbouring maritime states. Moreover, Loneragan et al. (2005) reiterated the complexities arising from varieties of fishing methods used and over-fishing, while at the same time emphasised the potential sources of bias and error in fisheries data that are also peculiar to those of prawns. The authors highlighted the causes of these bias and error in relation to issues on reliability and accuracy of fisheries data, particularly with respect to the following: landings evaluations through sub-sampling method, identification and categorisation strategies used to differentiate the species into groups, weights estimation for each category, particularly with respect to multi-species categorisation, as well as reporting errors of these various landings. These rendered the marine environment with multiple criteria decision-making (MCDM) problems; due to the observed complexities and conflicting criteria. As such, complexities in systems and observed phenomena need to be adequately handled; the artificial intelligent (AI) domain is one of the means of handling complexities in observed phenomena, particularly with respect to MCDM. The field of AI has different techniques, some of which are: fuzzy logic, neural network, artificial neural network, and genetic algorithms.

However, the reported annual fisheries statistics by DOFM (2011) over the years were observed not only to be embedded with linguistic terms that try to depict the contributions of the Malaysia's fisheries resources to GDP, but are also not adequately represented through the various fish landings. For instance, the fisheries sector's production and value for 2010 [DOFM, (2010), p.22] portrayed the inshore fisheries from the overall marine capture fisheries sub-sector to be the *major contributor*, with a production of 1,108,897 tonnes (77.61%), valued at RM5,362.97 million (73.98%), while that of the deep sea was 319,984 tonnes with a value of RM1,288.92 million; meanwhile others were not linguistically reported. Moreover, even though the overall marine capture fisheries sub-sector for both inshore and deep-sea fisheries were 1,428,881 tonnes, valued at RM6,651.89, with an increment of 2.56% to that of 2009, a contribution of 70.93% to the total national fish production was reported. The contributions of other resources were not linguistically reported except for the inland fisheries or freshwater capture fisheries sub-sector that were reported to be insignificant in 2010 with only 4,605.43 tonnes valued at RM44.67 million or 0.23% of the total fish production. These are also parts of the MCDM decision problems that constitute the crux of this paper, and the motivation is also coupled with the attendant complexities of identified marine activities (DOFM, 2010).

The objective of this paper therefore is to analyse the reported fish landings data by DOFM for a five year period from 2006–2010 using one of the AI techniques of fuzzy inference system (FIS) of fuzzy logic. Through this approach, the observed inadequacies could be properly categorised and reported for better decision making that would adequately depict the various contributions of different fisheries landings to national GDP. In this way, the FIS would handle the stakeholders' subjectivities and uncertainties. Such novel approach as used in this paper is yet to be reported in previous studies, thus making this paper to have an innovative and significant contribution with respect to marine fisheries landings and their contributions to national GDPs.

The paper is therefore organised as follows: related studies are covered in the next section, followed by the methodology adopted, then the results and discussions are presented, and next are the conclusions drawn.

2 Related studies and FISs

The landings of fisheries resources within Malaysian maritime delineation zones (MDZs) are usually reported for both the in-shore and deep sea sub-sector areas of the marine fish sector. The annual reported fisheries resources and landings within Malaysian waters contain different and multi-species fisheries stocks harvested from different coastal states of the Peninsular, Sabah and Sarawak. Accordingly, Mohd Taupek and Nasir (2003) highlighted the historical evolution of fisheries activities in Malaysia and posit that Malaysian waters are very productive due to conducive and excellent growth of aquatic organisms. These organisms are characterised by a host of different multispecies, multi-stocks and multi-gear varieties of tropical and marine resources of fish, fisheries, and other marine fauna that are of high commercial values (Islam et al., 2011a, 2011b, 2014a, 2014b; Alam et al., 2002; Reczkova et al., 2013; Mohd Taupek and Nasir, 2003; MSC, 2015a, 2015b; Teh et al., 2011) spanning through the shoreline to the EEZ areas particularly in the east coast of Malaysia (Mohd Taupek and Nasir, 2003). For this paper, the fish landings reported by Malaysian Department of Fisheries between 2006 and 2010 (DOFM, 2010) were used.

Reczkova et al. (2013) reviewed the state and average consumption rate of fish and fisheries status of Malaysians. In addition, the contributions of marine fisheries sector to GDP in Malaysia are also highlighted in earlier studies (DOFM, 2010, 2011, 2013; Reczkova et al., 2013; Teh et al., 2011; Wan, 1988). Likewise, there are issues of different forms that affect the marine fish, fisheries landing and management in Malaysia. Of these, the main challenges are over-exploitation, and illegal, unreported and unregulated (IUU) cases of fishing (Saharuddin, 1995; Islam et al., 2011a; Alam et al., 2002; Reczkova et al., 2013; Mohd Taupek and Nasir, 2003; Stobutzki et al., 2006a, 2006b; Yahaya, 1988; Teh and Sumaila, 2007; Sumaila et al., 2012). Moreover, despite the spate of increase in the general landings, the contributions of different species as reported were not evenly mentioned in the DOFM annual statistics (DOFM, 2010, 2011, 2013; Teh et al., 2011; Wan, 1988; Cunningham et al., 2009). Thus, there is need to find an adequate and scientific tool to capture the various contributions of the fisheries to GDP, which has not been given adequate research attention. Consequently, there is dearth of such studies wherein such contribution of GDP to Malaysia economy, except in Teh et al. (2011) for the case of the contributions of marine fisheries resources from Sabah to the national economy, and Abu Talib et al. (2003).

In this study therefore, due to the complexities highlighted, the marine environment characteristics, and the embedded fuzziness in these reports over the years, the FIS based on fuzzy logic triangular fuzzy number (TFN) and linguistic variables (LV) approach was implemented for the classification of these contribution of marine fisheries sector to the GDP. The fuzzy concepts are useful tools in dealing with systems with inherent subjectivity and uncertainties; FIS, TFN and LV have found application areas in previous studies (Tahriri et al., 2014; Büyüközkan and Çifçi, 2011;; Khaleie et al., 2012; Shaw et al., 2012; Balogun, 2014; Masumeh and Safar, 2012; Sakthivel et al., 2013a, 2013b; Naghadehi et al., 2009; Ilangkumaran et al., 2014; Ayag and Ozdemir, 2006; Khajeeh, 2010). For instance, Tahriri et al. (2014) applied fuzzy Delphi and FIS to the case of supply ranking and selection; highlighting the interpretative capability of FIS and ease of encoding a priori knowledge as parts of its main advantages over others. Moreover, the TFN was used in expressing the decision makers' preferences in their choice of appropriate models for automobile cars. In addition, Kahraman et al. (2015) highlighted the state-of-the-art review of fuzzy consideration to MCDM research areas.

Such approach is yet to be given research attention to cases and application in the areas of fisheries resources and landings. In exploring this important approach, the fuzzy logic concepts which is based on fuzzy logic theories were used to categorise the cases of fish landings for different states in the west coast of Malaysia based on the available data. It is expected that an awareness of the various contributions would improve the sustainable management of these marine resources for viabilities.

2.1 Marine geospatial data infrastructure

The marine geospatial data infrastructure (MGDI) is an initiative, whose goals among others is to satisfy the seamless geospatial data requirements of the marine environment and the water-oriented stakeholders for different applications (GeoConnections, 2002).

Previous studies on MGDI initiatives abound in literature (MSDIWG, 2009; Vaez and Rajabifard, 2012; Pepper, 2009), at different levels of the MGDI hierarchies that is similar to those of spatial data infrastructure (SDI) for effective and informed decisions making. SDI hierarchy as exemplified in Williamson et al. (2003) were based on hierarchical reasoning. MGDI is been overseen at the International Hydrographic Organization (IHO) 'marine spatial data infrastructure working group (MSDIWG, 2009)'. Thus, MGDI is the component of national SDI (NSDI) that encompasses marine geographic and business information in its widest sense. This would typically include seabed topography, geology, marine infrastructure (e.g., wrecks, offshore installations, pipelines and cables, etc.); administrative and legal boundaries, areas of conservation and marine habitats and oceanography (MSDIWG, 2009).

2.2 Fuzzy inference systems

The FISs are used to map given input to an output by using fuzzy sets theory. The Mamdani-style fuzzy inference process is one of the most commonly used FIS and comprised of the following four steps: fuzzification of the input variables, rule evaluation, aggregation of the rule outputs, and finally defuzzification (Negnetivisky, 2005; Shin and Xu, 2009); it is a form of a four multi-input multiple-output (MIMO) FIS (Tahriri et al., 2014). Moreover, Cheng (1999) highlighted the benefits of FIS in terms of its interpretation capability as well as the ensuing simplicity in encoding a priori knowledge, though it lacks learning capabilities. Some of the required fuzzy set theory for FIS are further explained in subsequent sub-sections.

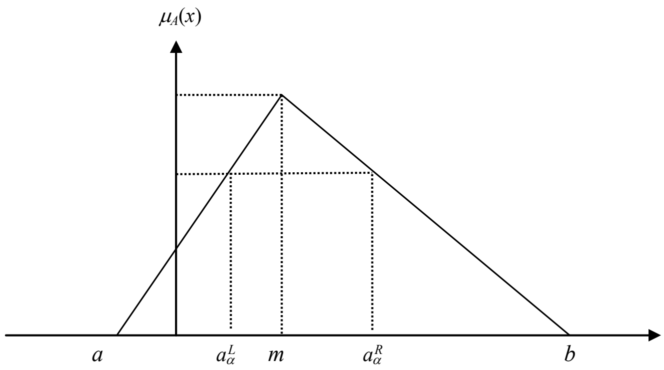
2.2.1 Triangular fuzzy number

This is based on the fuzzy set theory to resolve and evaluate the fuzziness among experts particularly when based on diverse scales of judgment (Tahriri et al., 2014). A TFN is one of the special types (Bector and Chandra, 2005) of fuzzy number whose membership function is defined by three real numbers (a, m, b) and can be written mathematically (Bector and Chandra, 2005; Nguyen and Walker, 2006; Torfi et al., 2010; Vahidnia et al., 2009; Yang and Hung, 2007) as shown by equation (1) and Figure 1:

$$\mu_A(x) = \begin{cases} 0, & \text{if } x \le a, \\ \dfrac{x-a}{m-a}, & \text{if } x \in [a,m] \quad \text{i.e., } a \le x \le m \\ \dfrac{b-x}{b-m}, & \text{if } x \in [m,b] \quad \text{i.e., } m \le x \le b \\ 0, & \text{if } x \ge b, \end{cases} \tag{1}$$

Here, (x) represents a fuzzy input variable of discourse (X), the output which has a fuzzy interval with grades that lies between 0 and 1, which could be expressed by the linguistic set $\mu_A(x)$.

Figure 1 Triangular membership function



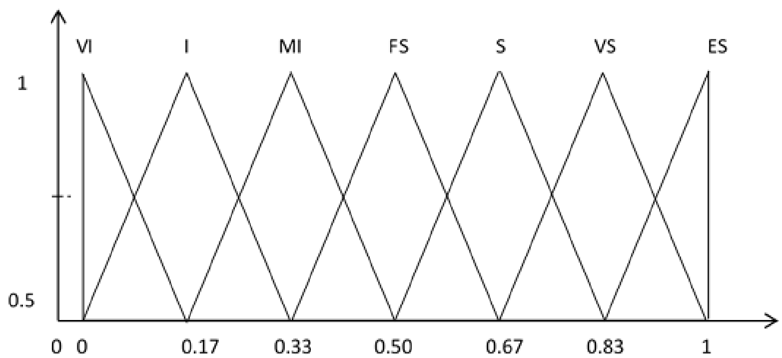
Source: Adapted from Bector and Chandra (2005)

Based on equation (1), the TFN can be expressed by five to eight or more numbers, each representing a linguistic value that expresses the contributions in view; the transformation of which could be achieved by using fuzzy membership function (FMF). Thus, the FMF could be transformed and expressed generally with the usual five and six FMF but could also be seven or eight. For this paper, the seven TFN and FMF were used as shown respectively in Table 1 and Figure 2.

Table 1 Transformation of linguistic values of seven fuzzy triangular membership function to corresponding fuzzy numbers

Linguistic variables	*Abbreviation*	*Sub-criteria grade*	*Fuzzy numbers*
Very insignificant	VI	1	(0.00, 0.00, 0.17)
Insignificant	I	2	(0.00, 0.17, 0.33)
Medium insignificant	MI	3	(0.17, 0.33, 0.50)
Fairly significant	FS	4	(0.33, 0.50, 0.67)
Significant	S	5	(0.50, 0.67, 0.83)
Very significant (major)	VS	6	(0.67, 0.83, 1.00)
Excellently significant	ES	7	(0.83, 1.00, 1.00)

Figure 2 Triangular FMF with seven linguistic values



2.2.2 Interval arithmetic/interval of confidence

This is represented as a closed interval in a set of real numbers $\mathbb{R}$ as it limits the uncertainty of data to an interval (Bector and Chandra, 2005). The elements of $\mathcal{F}(\mathbb{R})$, that is, the fuzzy subset of $\mathbb{R}$ are fuzzy quantities (Nguyen and Walker, 2006). Thus, if $A = [a_1, a_2, a_3]$ and $B = [b_1, b_2, b_3]$ are two closed interval in $\mathbb{R}$, then the following are possible fuzzy arithmetic as shown in equations (2) to (11) and adapted from Bector and Chandra (2005), Torfi et al. (2010), Yang and Hung (2007), Feng and Xu (1999), Liou and Chen (2006), Önüt and Soner (2008), Prakash and Uday (2008), Wang et al. (2006), Li (2013) and Lin et al. (2008), representing the basic fuzzy arithmetic:

1 Fuzzy addition denoted by either $\oplus$ or $A(+)B$:

$$A \oplus B = [a_1, a_2, a_3] \oplus [b_1, b_2, b_3] = [a_1 + b_1, a_2 + b_2, a_3 + b_3]. \tag{2}$$

2 Fuzzy subtraction denoted by $\ominus$ or $A(-)B$:

$$A \ominus B = [a_1, a_2, a_3] \ominus [b_1, b_2, b_3] = [a_1 - b_1, a_2 - b_2, a_3 - b_3]. \tag{3}$$

3 Image of A, denoted by $\overline{A}$ is given by:

$$\overline{A} = \overline{[a_1, a_2, a_3]} = [-a_3, -a_2, -a_1]. \tag{4}$$

4 Fuzzy multiplication denoted by either $\otimes$ or $(\cdot)$:

$$A(\cdot)B = [a_1, a_2](\cdot)[b_1, b_2] = [\min(a_1b_1, a_1b_2, a_2b_1, a_2, b_2), \max(a_1b_1, a_1b_2, a_2b_1, a_2, b_2)]. \tag{5}$$

In case these intervals are in $\mathbb{R}_+$, the non-negative real line, the multiplication formula gets simplified to:

$$A(\cdot)B \cong [a_1a_2, b_1, b_2], \tag{6}$$

Therefore, for:

$$A(\cdot)B = [a_1, a_2, a_3](\cdot)[b_1, b_2, b_3] \cong (a_1b_1, a_2b_2, a_3b_3), \quad a_1 \geq 0,\ b_1 \geq 0 \tag{7}$$

5 Scalar multiplication and inverse $k \cdot A$:

$$k \cdot A = [k, k](\cdot)[a_1, a_2] = [ka_1, ka_2]. \tag{8}$$

6 Fuzzy inverse:

$$A^{-1} = [a_1, a_2]^{-1} = \left[\frac{1}{a_2}, \frac{1}{a_1}\right], \tag{9}$$

provided $0 \notin [a_1, a_2]$.

7 Fuzzy division:

$$\frac{A}{B} = \left(a_1 / b_3, a_2 / b_2, a_3 / b_1\right), \qquad a_1 \geq 0,\ b_1 \geq 0 \tag{10}$$

8 The vertex method is defined to calculate the distance between the two sets *A* and *B* (Torfi et al., 2010; Yang and Hung, 2007; Feng and Xu, 1999):

$$d(A,B) = \sqrt{\frac{1}{3}\left[\left(a_1 - b_1\right)^2 + \left(a_2 - b_2\right)^2 + \left(a_3 - b_3\right)^2\right]} \tag{11}$$

9 Using Singh and Benyoucef (2011) equation for defuzzification techniques, through which the fuzzy numbers are converted to real numbers, the equation is given by:

$$x = \frac{a_1 + 2a_2 + a_3}{4} \tag{12}$$

Based on the four steps earlier mentioned for Mamdani FIS, equation (1) and Figure 1 therefore represents the fuzzification of the input crisp values that are later transformed to fuzzy sets. Meanwhile, equations (2) to (11) are the basic fuzzy arithmetic used in this paper for the rule and aggregation of their fuzzy output; while equation (12) is required in converting the fuzzy output from equation (1) to scalar output.

3 Methods

The study area for this paper is the western coast peninsular Malaysia. The region is near the equator with coordinates 1°N, 104°20’E in the east, to 6°30’N, 100°E; and bordered to the north-western with Thailand, with Singapore on the south-eastern part and Indonesia on the western part while Sabah and Sarawak were bordered by Indonesia and Brunei (Loneragan et al., 2005). The data used was from the annual fishery landings for Malaysian waters as reported in DOFM (2010). As stated earlier, the reported data made mentioned of contribution of the marine seaweed, and landing of freshwater fishery for public water bodies to be an ‘insignificant contributor’ to GDP in 2010 without adequately referencing others. This forms part of the research problems being addressed in this paper. The data used as shown in Table 2 is made up of the quantities landed and their equivalent values. Since these two variables are not having the same units and because of other prevailing circumstances, such as varying exchange rates, ex-vessel prices, and to prevent the co-linearity among them, they were both normalised for the years per states. Thereafter, the stages highlighted in Section 2.2 for FIS were adopted in order to compute the various contributions.

Table 2 Annual series of Malaysian marine fish landings for 2006–2010

State	*2006*		*2007*		*2008*		*2009*		*2010*	
	Quantity (tonnes)	*Value (RM)*	*Quantity (tonnes)*	*Value (RM)*	*Quantity (tonnes)*	*Value (RM)*	*Quantity (tonnes)*	*Value (RM)*	*Quantity (tonnes)*	*Value (RM)*
Perlis	163,038	384,366,523	193,800	467,627,913	189,358	449,668,658	178,247	805,640,168	165,298	711,100,751
Kedah	67,122	398,606,822	83,922	476,855,289	95,940	465,356,320	106,486	614,680,958	74,266	441,625,779
Penang	33,112	196,010,591	37,773	218,933,355	43,627	252,435,570	42,790	254,041,412	45,182	337,610,809
Perak	209,153	746,871,291	239,653	890,083,237	219,066	862,451,186	258,086	1,155,477,524	303,509	1,376,107,063
Selangor	146,388	378,993,370	116,138	348,942,341	124,224	318,368,252	131,350	471,556,535	144,440	509,473,223
Negeri Sembilan	375	3,773,002	426	4,725,089	376	4,457,792	610	7,731,460	690	9,194,177
Malacca	1,829	18,037,313	1,801	19,050,806	1,790	20,126,715	1,691	18,054,463	1,666	18,243,596
West Johore	19,026	119,251,599	19,472	136,339,074	19,331	156,977,824	10,298	65,968,951	20,775	173,218,377
Total	640,043	2,245,910,511	692,985	2,562,557,104	693,711	2,529,842,318	729,558	3,393,151,472	755,826	3,576,573,775

4 Results and discussion

Normalised relative landings and values for the data in Table 2 are shown in Table 3, which also represent the weights that serve as the input for the FIS procedure. Thereafter, using equations (1) to (9), the fuzzy relative average data per state over the years were computed based on highlighted FIS algorithms, as shown in Table 4. In addition, based on these results, the computed fuzzy weights for the marine fisheries landings for the five years considered for western coast of Peninsular Malaysia is shown in Table 5. The row sum of Table 4 was computed and used to calculate the weights of the fuzzy number shown in Table 5 by using equations (10) and (11) for fuzzy division. This represents the various transformation of the physical fish landings and values using the theory and fuzzy logic concepts to depict the various contributions of fisheries landings of each state of the west coast of Malaysia to the GDP.

Furthermore, using equation (12), the various defuzzified weights for the west coast of the Peninsular were computed. When this region is considered alone, the 'fairly significant' contribution of the State of Perak is almost 28%. This was followed by that of Perlis with about 17% 'medium insignificant' contribution, closely followed by an almost 16% contributions from Selangor, while other states are just a bit above 6%. Interestingly, while the highest contribution from Perak is in agreement with that in Loneragan et al. (2005) for the case of the total landings of prawns in west coast of Malaysia, Selangor was on third position in this study whereas it was next to the first in Loneragan et al. (2005).

Out of these eight states, four of them (Negeri Sembilan, Malacca, West Johor, and Penang), recorded a linguistically 'very insignificant' contribution to the GDP. However, these should not be seen as being undervalued production compared to that of the total contribution to overall national contribution to the GDP. Such was also peculiar to Negeri Sembilan and Malacca in Loneragan et al. (2005). These were followed by an 'insignificant' contribution attributable to Kedah and Selangor, whereas Perlis had a 'medium insignificant' contribution, while a 'fairly significant' contribution could be attracted to the state of Perak. These results are also consistent with those reported in Teh et al. (2011) for the state of Sabah' fishing sector that was considered not to be a 'major contributor' to their economy, An understanding of these forms of contributions would therefore be handy to different stakeholders, so that their fisheries productions could be achieved for sustainable management.

Since there is dearth of scientific research on the application of FIS to marine fishery landings in Malaysia and beyond, the empirical study by Teh et al. (2011) portrayed the motivation for this novel approach as used in this paper. This is based on the practical remarks made in their conclusion that despite the rigorous method adopted, their approach in estimating the historical and present socio-economic contributions of fisheries 'entails uncertainty and a certain degree of subjectivity'. Such fuzziness are readily handled using any of the AI techniques, as demonstrated in this research.

Moreover, the IUU and other challenges on the overexploitations of the fisheries resources as earlier highlighted (Saharuddin, 1995; Islam et al., 2011a; Alam et al., 2002; Reczkova et al., 2013; Mohd Taupek and Nasir, 2003; Stobutzki et al., 2006a, 2006b; Yahaya, 1988; Teh and Sumaila, 2007; Sumaila et al., 2012) are also peculiar, which if not checked would be affecting the overall landings and eventually the contributions to the GDPs.

Table 3 Normalised relative fish landings and values of annual series of Malaysia for 2006–2010

State	*2006*		*2007*		*2008*		*2009*		*2010*	
	Tonnes	*RM*	*Tonnes*	*RM*	*Tonnes*	*RM*	*Tonnes*	*RM*	*Tonnes*	*RM*
Perlis	0.25	0.17	0.28	0.18	0.27	0.18	0.24	0.24	0.22	0.20
Kedah	0.10	0.18	0.12	0.19	0.14	0.18	0.15	0.18	0.10	0.12
Penang	0.05	0.09	0.05	0.09	0.06	0.10	0.06	0.07	0.06	0.09
Perak	0.33	0.33	0.35	0.35	0.32	0.34	0.35	0.34	0.40	0.38
Selangor	0.23	0.17	0.17	0.14	0.18	0.13	0.18	0.14	0.19	0.14
Negeri Sembilan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Malacca	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
West Johore	0.03	0.05	0.03	0.05	0.03	0.06	0.01	0.02	0.03	0.05
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 4 Fuzzy normalised relative fish landings and values of annual series of Malaysia for 2006–2010

State	*2006*		*2007*		*2008*		*2009*		*2010*	
	Tonnes	*RM*	*Tonnes*	*RM*	*Tonnes*	*RM*	*Tonnes*	*RM*	*Tonnes*	*RM*
Perlis	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)
Kedah	(0.00, 0.00, 0.17)	(0.00, 0.17, 0.33)	(0.00, 0.00, 0.17)	(0.17, 0.33, 0.50)	(0.00, 0.00, 0.17)	(0.17, 0.33, 0.50)	(0.00, 0.00, 0.17)	(0.17, 0.33, 0.50)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)
Penang	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)
Perak	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)
Selangor	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.17, 0.33)	(0.00, 0.00, 0.17)	(0.00, 0.17, 0.33)	(0.00, 0.00, 0.17)	(0.17, 0.33, 0.50)	(0.00, 0.00, 0.17)
Negeri Sembilan	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)
Malacca	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)
West Johore	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)	(0.00, 0.00, 0.17)

Table 5 Fuzzy linguistic contributions of states fish landings to GDP for 2006–2010

State	*Row sum*	*Fuzzy number weights*	*Fuzzy contribution type*	*Defuzzified weights*	*%*
Perlis	0.00, 1.70, 3.30	0.00, 0.22, 1.29	Medium insignificant	0.43	16.52
Kedah	0.68, 1.32, 3.02	0.03, 0.17, 1.18	Insignificant	0.39	14.80
Penang	0.00.00, 0, 1.70	0.00, 0.00, 0.67	Very insignificant	0.17	6.40
Perak	1.70, 3.30, 5.00	0.08, 0.42, 1.96	Fairly significant	0.72	27.51
Selangor	0.17, 1.52, 3.15	0.01, 0.19, 1.24	Insignificant	0.41	15.57
Negeri Sembilan	0.00, 0.00, 1.70	0.00, 0.00, 0.67	Very insignificant	0.17	6.40
Malacca	0.00, 0.00, 1.70	0.00, 0.00, 0.67	Very insignificant	0.17	6.40
West Johore	0.00, 0.00, 1.70	0.00, 0.00, 0.67	Very insignificant	0.17	6.40
	2.55, 7.84, 21.27		Total	2.62	100

5 Conclusions

Despite the spate of reported fisheries resources in Malaysia waters annually, their contributions to national GDP have not been adequately reported. These are coupled with some of the identified challenges that pose the marine environment to be in complex situations. The FIS of fuzzy logic was demonstrated to handle these observed oversights from stakeholders, providing both empirical and practical application of the FIS in the realms of marine fisheries landings, their distributions and respective contributions to the GDP. It is believed that this study would assist the various marine stakeholders in the planning and implementation of the various fisheries resource exploitations. This will also be useful to catchment districts where these fisheries are being sourced.

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