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Capturing local knowledge of beach seine fishers in the north-western province of Sri Lanka

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Abstract

Local knowledge of fishers is considered to be useful in establishing effective dialogue between fishers and fishery managers to foster the sharing of power and responsibility between the government and local resource users. However, fishers' local knowledge is often considered anecdotal and consequently, these knowledge bases are largely underutilized for small-scale fisheries management. This study was an attempt to investigate whether local knowledge of beach seine fishers of the north western province of Sri Lanka could be used to assist in optimizing their harvests, to scientifically validate anecdotal local knowledge and to recognize this knowledge base as an important means for defining fisheries co-management strategies.

The beach seine fishers in nine fishing communities use their local knowledge to predict the occurrence of fish schools based on some indicators such as sea surface colour due to the presence of fish schools, turbulence of surface water in the presence of schools of larger fish species and behaviour of sea birds. Fishers were also aware that local weather conditions influence the occurrence of certain fish species. Accordingly, fishers select the appropriate cod end type to catch predicted species. Spatial and temporal variations of species composition were found to be in accordance with the fishers' local knowledge. Level of accuracy of fishers in all nine beach-seine fisher communities under the present study in selecting the appropriate cod end to be fixed to catch target species was high (64.9% - 82.9%). Psychometric approach adopted has shown that the mean harvest and mean daily income of fishing communities had significant positive correlations with fishers' knowledge about management-related aspects. Results of this study have shown that fishers' local knowledge is reasonably consistent and should therefore be incorporated for defining effective fisheries co-management.

Keywords: Likert scale; Local ecological knowledge; small-scale fisheries, fishers' perceptions; indigenous knowledge; folk oceanography

Introduction

Fishers' local ecological knowledge (LEK) consists of three facets: (i) perception of nature through knowledge of species and other environmental phenomena; (ii) use of nature for survival; and (iii) application of knowledge to manage human – environment/ natural resources relationship for the benefit of humanity (Berkes 2012; Begossi 2015). These knowledge bases are however largely underutilized for small-scale fisheries management. On one hand, LEK is considered anecdotal and "unscientific", thus inappropriate to be used in current "scientific" management strategies for fisheries but on the other hand, it has been increasingly recognized that local knowledge of fishers can be used to establish effective dialogue between fishers and fishery resource managers, which can in turn foster the sharing of power and responsibility between the government and local resource users (Johannes 1981; Moller et al. 2004; Silvano and Valbo-Jorgensen, 2008; Berkes 2009).

Beach seining is one of the traditional coastal fishing methods widespread in many parts of the world (Gabriel et al. 2005), and in many countries, traditional fisheries management mechanisms based on fishers' LEK are reported to exist. For example, in Gouyave, Grenada, beach seine fishers are reported to incorporate traditional customary rules in the formal legal procedures for resolving conflicts by defining fishing rights and benefit sharing (McConney and Baldeo 2007). Nevertheless, it is also common that fishery management authorities rarely consult fishers when management regulations are formulated (Tietze et al. 2011).

In many coastal communities of the world, local knowledge that has evolved through experience of fishers and empirical information about fish behaviour associated with environmental factors such as monsoons, lunar phases, and knowledge about marine physical environments and fish habitats, is known to be important in formulating fishery management strategies (Ruddle 1994a). Due to the differences in cultural norms among coastal communities however, empirically based and practically oriented bodies of local knowledge are often location-specific. The increasing recognition of LEK for coastal fisheries management induces investigation of beach seine fisheries in different geographical locations especially due to the fact that beach seining is a small-scale coastal fishing method which supports livelihood and food security in the coastal regions (Tietze et al. 2011).

In southern Sri Lanka, traditional beach seine fisher communities use their indigenous knowledge (IK) to predict the commencement of fishing season, and to identify and quantify the species composition within their fishing territory (Deepananda et al. 2015). In the present study, an attempt was made to investigate whether local knowledge of beach seine fishers of the north western province of Sri Lanka could be used to assist optimizing their harvests, and to scientifically validate anecdotal local knowledge of fishers with a view to recognizing this knowledge base as an important means for defining fisheries co-management strategies.

Materials and Methods

Beach seining in the north-western coast of Sri Lanka is seasonal, and is essentially carried out when the sea is calm. Fishing starts in September/October and lasts until

April/May of the following year. In the present study, the beach seine fishery in Chilaw area of the north-western province of Sri Lanka (Fig. 1) was investigated during the fishing season from November 2010 to May 2011. Nine beach seine sites (beach seine 'Padu') in Chilaw area were selected for the present study (Figure 1).

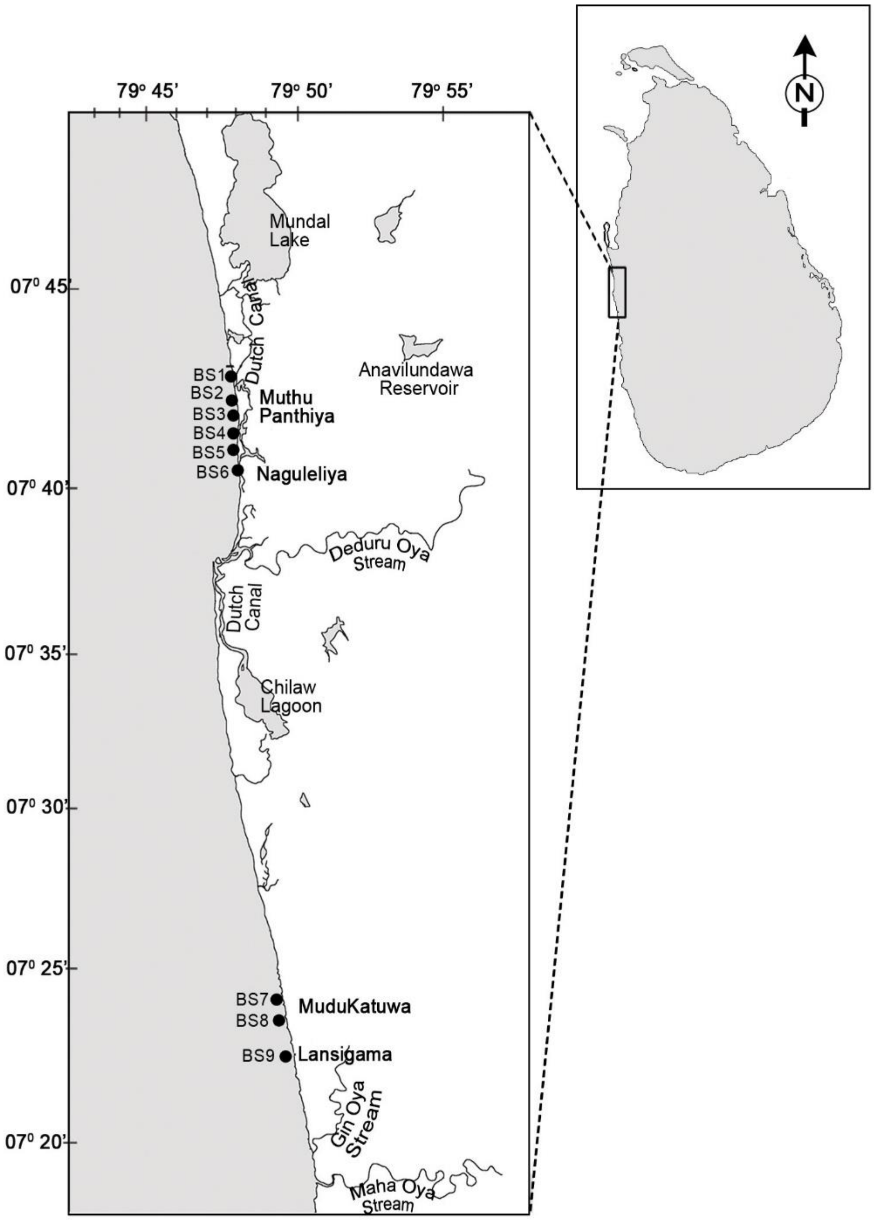

Figure 1. Locations of nine beach seine sites (BS1-BS9) studied in Chilaw area of north western province of Sri Lanka.

Beach seine

The structure of the beach seine net used in Sri Lankan coastal fisheries is basically similar to those used in many countries (Tietze et al. 2011). A beach seine net consists of the seine body also termed as cod-end, wings, ground rope, head rope and hauling ropes. In the beach seines used in the coastal fisheries of Sri Lanka, cod-end can be detached from the wings, and fishers decide fixing of the appropriate cod-end type targeting the fish species occurring in the fishing area. The beach seine sites ('padu') are established by fishers depending on shelter from winds and absence of bottom impediments to fishing operations, and are registered in the Department of Fisheries and Aquatic Resources. The beach seine is laid by a permanent crew of 10-15 members working on a beach seine boat. Beach seine is hauled by several (30-50) unskilled labourers of beach seine crew.

Fisheries production and allied data

Daily fish production data from nine beach seine sites were collected from November 2010 to May 2011 using the log-sheet approach (Sparre 2000), where a book-keeper was assigned from the crew of each beach seine, who was provided with a structured data-sheet prepared in the local language of fishers, '*Sinhalese*.' The fishery-related data gathered using this approach were *inter alia*, size of the beach seine used, cod-end type fixed (Table 1), species-wise landings and number of crew members participated in each beach seine operation. All book keepers were trained for accurate data recording and taught about the importance of providing reliable and consistent data for scientific management of the fishery for its sustainability. From time to time, nine beach seine locations were visited for cross-checking the data collection procedure of book keepers. Book-keepers have recorded species-wise data using vernacular names and the scientific names were determined during field visits on the basis of De Bruin et al. (1994). This approach was proven to be a reasonably accurate procedure of data collection on the beach seine fishery of Chilaw area.

As market values of different species caught in beach seine fisheries are thought to be different both spatially and temporally, for comparison of fishers' income derived from beach seine operations, value of daily landings was estimated on the basis of average price per kg of different fish species recorded in log-sheets.

Local weather conditions

Due to nature of operation of beach seines, it was considered that the sea roughness, which would be brought about by temperature, rainfall and the wind speed, is the main factor influencing beach seine catches. Therefore, data on rainfall, wind speed and daily maximum and minimum temperature were obtained from the Department of Meteorology. Daily data recorded from the meteorological sub-station at Chilaw and the main station at Puttalam were used for the analysis. Here, the wind speed was considered as the main indicator of the sea roughness.

Table 1. Local names of beach seines with different cod-end types to target various species. * Not used during the present fishing season.

Local name of beach seine	Thread thickness	Cod-end mesh size (cm)	Main target fish types
Maha Dela or *Ma Dela*	21 ply	1.6	*Lates calcarifer, Parastromateus niger, Taeniura lymma, Sphyraena jello, Otolithes ruber, Lethrinus nebulosus, Rastrelliger kanagurta, Hemiramphus* sp., and *Lactarius lactarius*
Suda Dela	9 ply	1.6	*Sardinella albella, Sardinella gibbosa, Sardinella fimbriata, Escualosa thoracata, Stolephorus indicus* and *Lepturacanthus savala*
Pura Dela	9 ply	1.2	*Selaroides leptolepis, Nematalosa nasus* and Shrimps
Murukku Dela or *Masukku Dela*	6 ply	2.0	*Leiognathus equulus, Gazza minuta, Leiognathus splendens* and *Dendrophysa russelli*
Halmasso Dela	6 ply	1.2	*Stolephorus commersonii*
*Thora Dela**	75 ply	6.4	*Chirocentrus dorab* and *Scomberomorus commerson*

Fishers' perception and knowledge on management

Of the 294 crew members in the nine beach seine sites, 143 fishers were interviewed using a pre-tested questionnaire to gather their perceptions and knowledge on the fisheries management related aspects. Here, the aspects to be included in the questionnaire were determined on the basis of preliminary information collected during a reconnaissance survey. For quantitative analysis of information, Likert scale (Likert 1932) was employed. Traditional norms and practices of each of the nine beach seine communities were also gathered from the most experienced fisher in each community, locally known as '*Mannadi Rala*,' who is responsible for making all decisions with regard to beach seine operations.

Fisheries data analysis

Fisheries data analysis in the present study was aimed at investigating relative accuracy of beach seine fishers' LEK about the aspects given in Table 2. Based on the information collected from *Mannadi Rala*, standard uni-variate and multi-variate statistical methods were used with a view to providing scientific explanations for beach seine fishers' LEK.

Table 2. Assigning of beach seine fishers' perceptions and knowledge about the fisheries management related aspects to four different Likert score categories.

Likert score category	Aspect	Sub-criteria
Category 1	Influence of the physical status of the 'padu' on the beach seine yield	The catches of the beach seines vary with the nature of the bottom Physical status (open/closed) of the nearest lagoon mouth has no impact on the beach seine catch
Category 2	Influence of the local weather conditions on the beach seine yield	Local rainfall has less influence on the species-wise variations in the beach seine yield Air temperature (hot/cold) has high influence on species-wise variations in the beach seine catches Wind speed (sea roughness) has negative influence on the species-wise variations in the beach seine catches. Occurrence of *Gazza minuta*, *Leiognathus equulus*, *Nematalosa nasus*, *Sardinella longiceps* in the beach seine catches is influenced by temperature Occurrence of *Dendrophysa russelli*, *Leiognathus splendens*, *Penaeus spp*, *Stolephorus indicus* in the beach seine catches is negatively influenced by wind speed (sea roughness)
Category 3	Seasonal occurrence of the species in the beach seine landings	Small pelagic species i.e. *Stolephorus commersonii*, *Sardinella albella*, *Sardinella gibbosa* and *Dendrophysa russelli* are mostly caught. Least dominant species are *Lates calcarifer*, *Sardinella fimbriata*, *Hemiramphus* sp. and *Lepturacanthus savala*. *Dendrophysa russelli*, *Otolithes ruber*, *Rastrelliger kanagurta*, *Sardinella albella*, *Sardinella gibbosa* and *Selaroides leptolepis* are common and non-seasonal. *Escualosa thoracata*, *Gazza minuta*, *Leiognathus equulus* and *Nematalosa nasus* are highly seasonal.
Category 4	Influence of the cod-end type	Cod-end type of the beach seine net has significant effect on the catch composition "Blind seining" is less effective than "Shoal seining" to enhance beach seine yield

Note: "Blind seining" is the fishing operation carried out without identifying specific fish schools present, and "Shoal seining" is the beach seine operation carried out in order to surround an identified fish school.

Due to the mode of operation, the relative fishing power in the beach seine is better represented by area covered by net. As such, assuming that the beach seine covers approximately a half-circle in the fishing area, catch per unit area (CPUA) covered by net was estimated as,

$$CPUA = 2C\pi/L^2$$

where C is catch per haul, L is the length of the ground rope of beach seine and π = 3.14159 (i.e., the ratio of the circumference to the diameter of a circle). As CPUA is known to be log-normally distributed (Gulland 1983), data were ln (CPUA+1) transformed to reduce non-normality.

To investigate the spatial and temporal variation of species composition in the landings of the nine beach seines during the study period, species-wise ln (CPUA+1) in all samples was ordinated by principal component analysis (PCA). Similarly daily meteorological data during the study period, after square root transformation, were also ordinated employing PCA. Principal component (PC) scores of meteorological parameters were then correlated with PC scores of species composition to investigate possible influence of meteorological parameters on the occurrence of different species in the landings.

Fishers' knowledge on fisheries management related-aspects

In the Likert scale for psychometric analysis of fishers' knowledge, a five-level scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used (see below).

Example: Fishers' knowledge about species co-occurrence was quantified as follows:

Question:	Do you agree that wind speed (sea roughness) has negative influence on the species-wise variations in the beach seine catches?	
Responses:	Strongly agree	- 5
	Agree	- 4
	Neutral	- 3
	Disagree	- 2
	Strongly disagree	- 1

Based on the five-level Likert Scale, fishers' knowledge and perception about the effective means of management of beach seine fishery on the aspects given in Table 2 was quantified. The mean value of the Likert score of responses for each aspect was then calculated. The mean Likert value for all five aspects given in Table 2 was also determined for each beach seine community and the level of fishers' knowledge and perception with regard to management of beach seine fishery was arbitrarily determined according to the following three levels.

Score 1.00-2.33	: Little Knowledge
Score 2.34-3.66	: Moderate Knowledge
Score 3.67-5.00	: Good Knowledge

To investigate the relative accuracy of LEK of beach seine fishers, results of the fishery data analyses described above, were compared with Likert scores calculated for the nine beach seine fisher communities separately. Finally, the levels of significance between the Likert score categories and the mean CPUA and mean income derived from the beach seine fishery were determined by coefficient of determination.

Results

Geographic locations of the nine beach seine sites ('padu') investigated, number of fishing days sampled during the study period, number of hauls, total weight of the landings from each beach seine and area covered by each beach seine are given in Table 3.

Table 3. Summary of log-book records of beach seining in 9 selected beach seine sites. Codes of beach seine sites (BS code) are as shown in Figure 1.

BS code	GPS coordinates of beach seine sites	Number of fishing days	Total numb er of hauls	Total catch recorded (kg)	Area covered by each beach seine (x1000 m^2)
BS1	7°42'10"N; 79°47'49"E	101	142	98,196.7	104.75
BS2	7°41'47"N; 79°47'53"E	95	128	81,897.5	102.18
BS3	7°41'36"N; 79°47'55"E	48	60	34,361.0	104.75
BS4	7°41'26"N; 79°47'56"E	90	126	40,716.0	102.18
BS5	7°41'14"N; 79°47'56"E	81	92	36,075.5	107.35
BS6	7°40'55"N; 79°47'24"E	77	91	26,151.0	106.30
BS7	7°23'14"N; 79°49'15"E	94	120	75,021.0	97.15
BS8	7°23'04"N; 79°49'18"E	94	155	27,583.2	107.35
BS9	7°22'40"N; 79°49'22"E	122	203	41,554.3	107.35

During the study period, sampling of beach seine landings was performed in 802 occasions. There were 47 species belonging to 21 families landed from the beach seines operated in all nine sites during the study period. Of these, only 25 species/species groups formed significant proportions of the landings and the contribution of rest of the species (by-catch) was negligible. The highest contribution to the beach seine landings was from *Stolephorus commersonii* and the lowest, apart from those which had negligible contributions (by-catch), was registered from *Lates calcarifer* (Table 4).

According to PCA, the first nine principal components had eigen value of >1 explaining a cumulative variance of 67.2%. This indicates the multi-dimensional nature of spatial and temporal variation of species composition in the beach seine landings. The three-dimensional plot of ordination of 802 beach seine samples during the study period is shown in Figure 2. The first three principal components explained 19.9%, 9.5% and 7.1% of the variance respectively.

Table 4. Mean CPUA±SE and range of catch per operation of commercially important species caught in the beach seine fishery of Chilaw area. Note: Here all penaeid shrimp species caught were grouped and considered as *Penaeus* spp. Average market prices per kg of different species during the study period are also given here. LKR – Sri Lankan Rupees. In May, 1 USD ≈ LKR 146.9.

Species Code	Species Name	Mean CPUA ± SE (kg km^{-2} haul^{-1})	Maximum catch per haul (kg)	Average price per kg (LKR)
SP1	*Chirocentrus dorab*	4.26 ± 0.96	770.0	67.00
SP2	*Dendrophysa russelli*	118.23 ± 6.17	1371.0	45.00
SP3	*Escualosa thoracata*	9.84 ± 3.26	621.0	44.00
SP4	*Gazza minuta*	7.35 ± 1.96	268.0	37.00
SP5	*Hemiramphus far*	4.08 ± 0.77	65.0	72.50
SP6	*Lactarius lactarius*	3.67 ± 0.62	700.0	110.00
SP7	*Lates calcarifer*	3.32 ± 0.35	1.5	385.00
SP8	*Leiognathus equulus*	10.03 ± 2.46	1000.0	345.00
SP9	*Leiognathus splendens*	18.73 ± 3.53	735.0	36.00
SP10	*Lepturacanthus savala*	3.4 ± 0.46	52.0	105.00
SP11	*Lethrinus nebulosus*	3.35 ± 0.43	667.0	42.00
SP12	*Nematalosa nasus*	7.96 ± 3.45	1232.0	24.00
SP13	*Otolithes ruber*	47.33 ± 3.64	437.0	106.00
SP14	*Parastromateus niger*	4.01 ± 0.81	1150.0	330.00
SP15	*Penaeus* spp.	16.02 ± 2.91	5354.0	260.00
SP16	*Rastrelliger kanagurta*	197.88 ± 2.29	1794.0	270.00
SP17	*Sardinella albella*	54.58 ± 5.27	1120.0	49.00
SP18	*Sardinella fimbriata*	3.52 ± 0.58	142.0	29.00
SP19	*Sardinella gibbosa*	101.77 ± 5.55	1926.0	53.00
SP20	*Sardinella longiceps*	19.34 ± 4.36	593.0	28.00
SP21	*Selaroides leptolepis*	49.46 ± 2.5	337.0	475.00
SP22	*Sphyraena jello*	3.67 ± 0.65	90.0	90.00
SP23	*Stolephorus commersonii*	21.84 ± 5.55	5666.0	114.00
SP24	*Stolephorus indicus*	4.57 ± 0.95	260.0	320.50
SP25	*Taeniura lymma*	3.74 ± 0.68	90.0	90.00

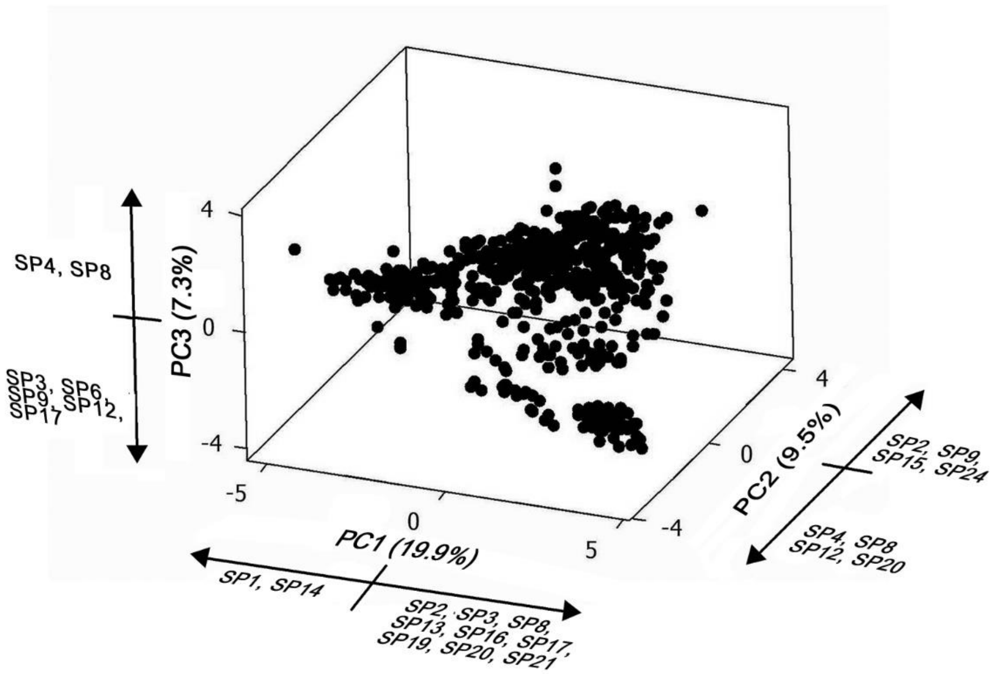

Figure 2. PCA plot of first three principal components. Percentage variances explained by three PC components and major species in the beach seine landing responsible for PC score loading are also indicated here. Species codes are as given in Table 4.

As can be seen from Table 5, the first principal component (PC1) was positively loaded by *Dendrophysa russelli* (SP2), *Escualosa thoracata* (SP3), *Leiognathus equulus* (SP8), *Otolithes ruber* (SP13), *Rastrelliger kanagurta* (SP16), *Sardinella albella* (SP17), *Sardinella gibbosa* (SP19), *Sardinella longiceps* (SP20), *Selaroides leptolepis* (SP21) and negatively loaded by *Chirocentrus dorab* (SP1), *Parastromateus niger* (SP14). In the second principal component (PC2), positive loading was from *Dendrophysa russelli* (SP2), *Leiognathus splendens* (SP9), *Penaeus. Spp* (SP15), *Stolephorus indicus* (SP24) while negative loading was due to *Gazza minuta* (SP4), *Leiognathus equulus* (SP8), *Nematalosa nasus* (SP12), *Sardinella longiceps* (SP20). The third principal component (PC3) was positively loaded by *Gazza minuta* (SP4), *Leiognathus equulus* (SP8) and negatively loaded by *Escualosa thoracata* (SP3), *Lactarius lactarius* (SP6), *Leiognathus splendens* (SP9), *Nematalosa nasus* (SP12), *Sardinella albella* (SP17).

Table 5. PC score loading of the first three components of species composition. Major positive loadings are indicated by bold values and major negative loadings are indicated as bold italics. Variables are species caught in beach seine catches. For species codes refer to Table 4.

	PC1	PC2	PC3
Eigen value	4.9641	2.3757	1.8176
Cumulative proportion explained	0.199	0.294	0.366
Variables			
SP1	***-0.139***	-0.047	-0.016
SP2	**0.308**	**0.238**	0.151
SP3	**0.204**	-0.091	***-0.471***
SP4	0.180	***-0.123***	**0.558**
SP5	-0.019	0.199	-0.067
SP6	0.007	0.140	***-0.101***
SP7	-0.035	-0.037	0.037
SP8	**0.261**	***-0.353***	**0.300**
SP9	0.117	**0.445**	***-0.246***
SP10	-0.055	-0.044	0.033
SP11	-0.001	-0.010	-0.016
SP12	0.197	***-0.344***	***-0.410***
SP13	**0.341**	0.138	0.117
SP14	***-0.136***	-0.096	0.007
SP15	0.144	**0.462**	0.119
SP16	**0.228**	-0.034	-0.041
SP17	**0.361**	-0.056	***-0.134***
SP18	-0.033	0.009	-0.012
SP19	**0.351**	0.000	-0.037
SP20	**0.321**	***-0.290***	-0.084
SP21	**0.338**	0.165	0.082
SP22	-0.020	0.054	0.017
SP23	-0.048	-0.100	0.200
SP24	0.002	**0.203**	-0.035
SP25	-0.065	-0.051	-0.055

The PCA ordination of the daily values of local weather condition (rainfall (RF), temperature (minimum (T_{Min}) and maximum (T_{Max}) and wind speed (WS)) recorded during the study period indicated that 71.5% of cumulative variance was explained by the first two principal components (Figure 3; Table 6). The first principal component was positively loaded by T_{Max} and T_{Min}, while negatively loaded by WS. The second principal component was positively loaded by RF and T_{Min} and negatively loaded by T_{Max} (Table 6).

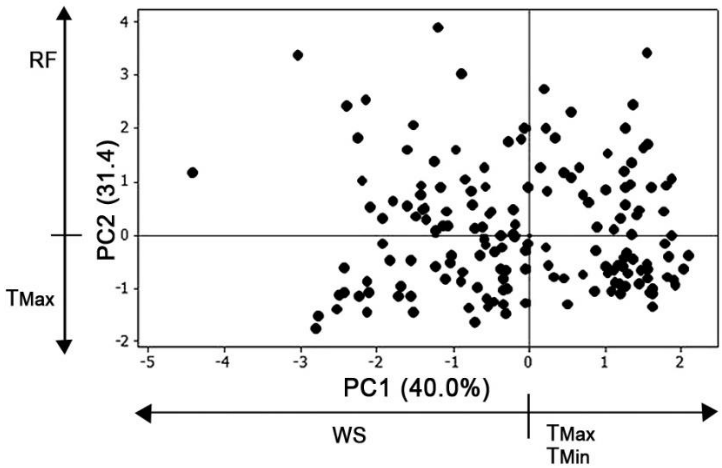

Figure 3. PCA plot of first two principal components. Percentage variances explained by two PC components and major weather factors responsible for PC score loading are also indicated here. Abbreviations of variables are as given in Table 6.

Table 6. Eigen values, proportions of variation explained and cumulative variation explained by each principal component (PC) for local weather factors. Major positive loadings are indicated by bold values and major negative loadings are indicated as bold italics. RF - Rainfall; T_{Max} - Maximum temperature; T_{Min} - Minimum temperature; WS - Wind speed.

	PC1	PC2
Eigen value	1.6007	1.2573
Cumulative variance	0.400	0.715
Variables		
RF	0.109	**0.780**
T_{Max}	**0.460**	***-0.549***
T_{Min}	**0.602**	**0.301**
WS	***-0.643***	0.022

The results of PCA of species-wise ln (CPUA+1) (Figure 2; Table 5) indicated that PC1 explained relatively low variance (40%) and therefore both PC1 and PC2 scores were used in the present analysis to explain the trends of spatial and temporal patterns of species composition in the beach seine landings. The correlation of PC1 scores of species-wise ln (CPUA+1) with PC1 scores of the local weather conditions (Figure 4A) is insignificant. However PC2 scores of the species-wise ln (CPUA+1), which were positively loaded by *Dendrophysa russelli* (SP2), *Leiognathus splendens* (SP9), *Penaeus* spp. (SP15), *Stolephorus indicus* (SP24) were negatively correlated with PC1 scores of the local weather conditions which are negatively loaded by wind speed variables (Figure 4B), and therefore the occurrence of above species is negatively influenced by wind speed. Similarly temperature variables which brought about the positive loadings of PC1 values for local weather data may influence the species catches of *Gazza minuta* (SP4), *Leiognathus equulus* (SP8), *Nematalosa nasus* (SP12), *Sardinella longiceps* (SP20) which have negatively loaded the PC2 scores of species data.

Due to spatial and temporal differences in the occurrence of fish species in the nine beach seine sites, their species composition showed remarkable variations (Figure 5). Also, market price variability of different species (Table 4) landed in each beach seine site resulted in variability of mean daily income from the beach seine landings (Table 7).

The accuracy of fisher's decision to fix the appropriate cod-end type (Table 1) to target the species that they predict using LEK (Table 8), indicated that percentage accuracy ranged from 64.9% in BS8 to 82.9% in BS7.

The four Likert scores of the nine beach seine communities, related to mean daily beach seine landings (Figures 6A to 6D), and to mean daily income (Figures 7A to 7D) separately showed their positive significant influence ($p<0.05$) on daily landings and mean daily income of beach seine operations. The overall Likert scores also had positive significant influences ($p<0.05$) on mean daily beach seine yield (Fig. 6E) and on mean daily income (Figure 7E). The Likert scores pertaining to all four management-related aspects and overall Likert scores in the nine beach seine communities ranged from 2.78 in BS8 to 3.61 in BS1 (Figures 6 and 7) indicating the members of all nine fishing communities had either moderate or good knowledge about fisheries management-related aspects.

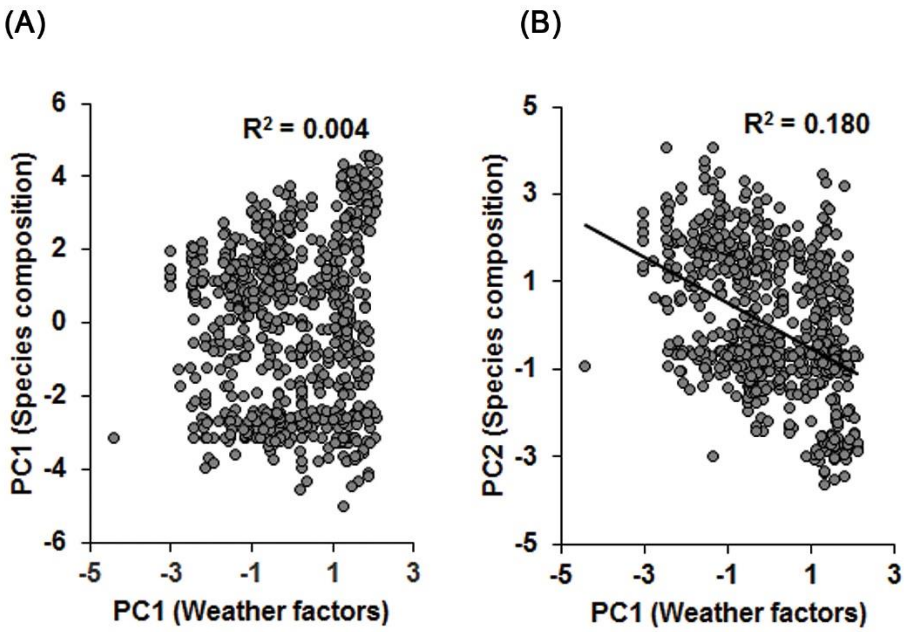

Figure 4. Relationships between (A) PC1 of weather factors and PC1 of species composition and (B) PC1 of weather factors and PC2 of species composition. For details, see text.

The decision to fix appropriate cod-end type to target various fish species is made by the *Mannadi Rala* according to his knowledge and experience about the occurrence of various pelagic fish schools in the fishing area. Generally, predictions of the occurrence of certain fish species in the fishing ground are made according sea surface colour due to the presence of fish schools (e.g., reddish brown colour of water when schools of sardines and Indian anchovies are present), turbulence of surface water in the presence of the schools of larger fish species such as Indian mackerel and scads, and behaviour of sea birds (e.g., flying of common tern (*Sterna hirundo*) with head down over the water surface indicating the exact location of fish school, diving into water to catch small fishes such as sardines and anchovies). Experienced fishers were also aware that in the occasions of high surface water temperature, schools of small pelagic species such as *Sardinella albella* and *S. longiceps* would be present in the fishing area.

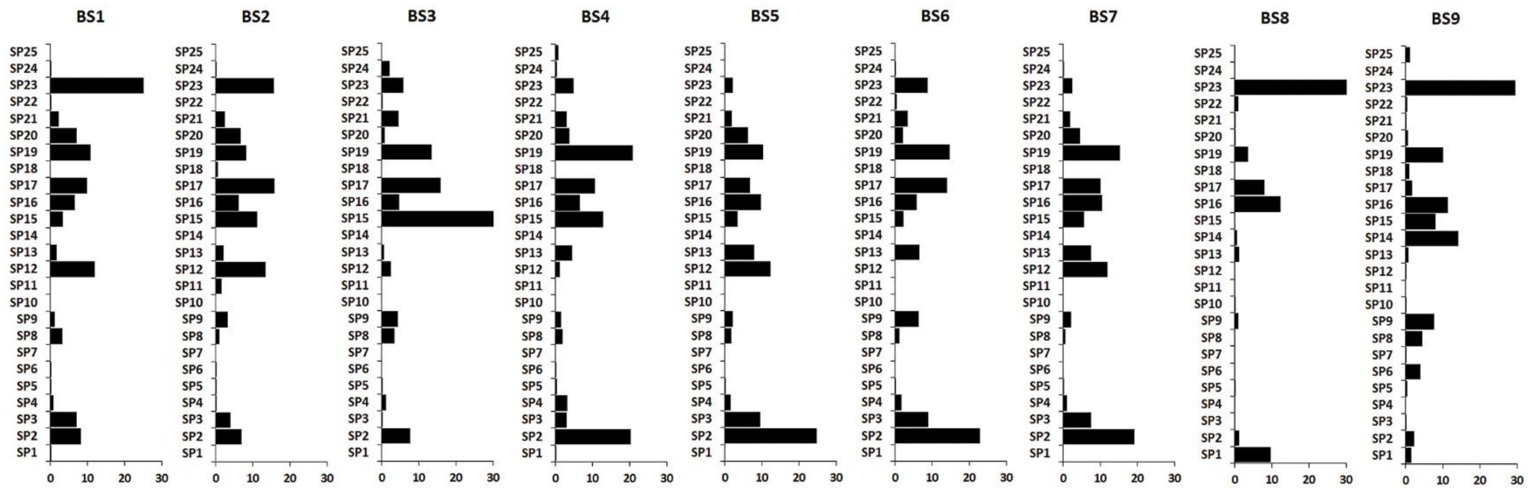

Figure 5. Overall species composition of the landings of nine beach seine sites during the study period. The codes of the beach seine sites as indicated in Figure 1. Species codes are as given in Table 4.

Table 7. Mean daily income in the nine beach seine sites. Codes of beach seine sites are as indicated in Figure 1. In May 2016, USD 1 ≈ LKR 146.9.

Beach seine site	Average daily income (LKR)
BS1	27,051.50
BS2	26,777.70
BS3	16,680.30
BS4	11,675.80
BS5	10,404.50
BS6	6,369.40
BS7	21,171.60
BS8	7,107.10
BS9	16,228.00

Table 8. Use of different cod-end types and the percentage of accuracy. Codes of cod-end types are as given in Table 1.

Beach seine site	Number of operations with each cod-end type					Total	Incorrect use of cod-end	Correct use of cod-end	% accuracy
	T1	T2	T3	T4	T5				
BS1	4	36	20	22	19	101	21	80	79.2
BS2	8	35	18	20	14	95	23	72	75.8
BS3	4	15	10	14	5	48	12	36	75.0
BS4	11	31	2	40	6	90	20	70	77.8
BS5	7	22	13	38	1	81	23	58	71.6
BS6	2	28	1	40	6	77	15	62	80.5
BS7	4	29	19	39	3	94	16	78	82.9
BS8	31	35	0	0	28	94	33	61	64.9
BS9	51	33	3	8	27	122	38	84	68.8

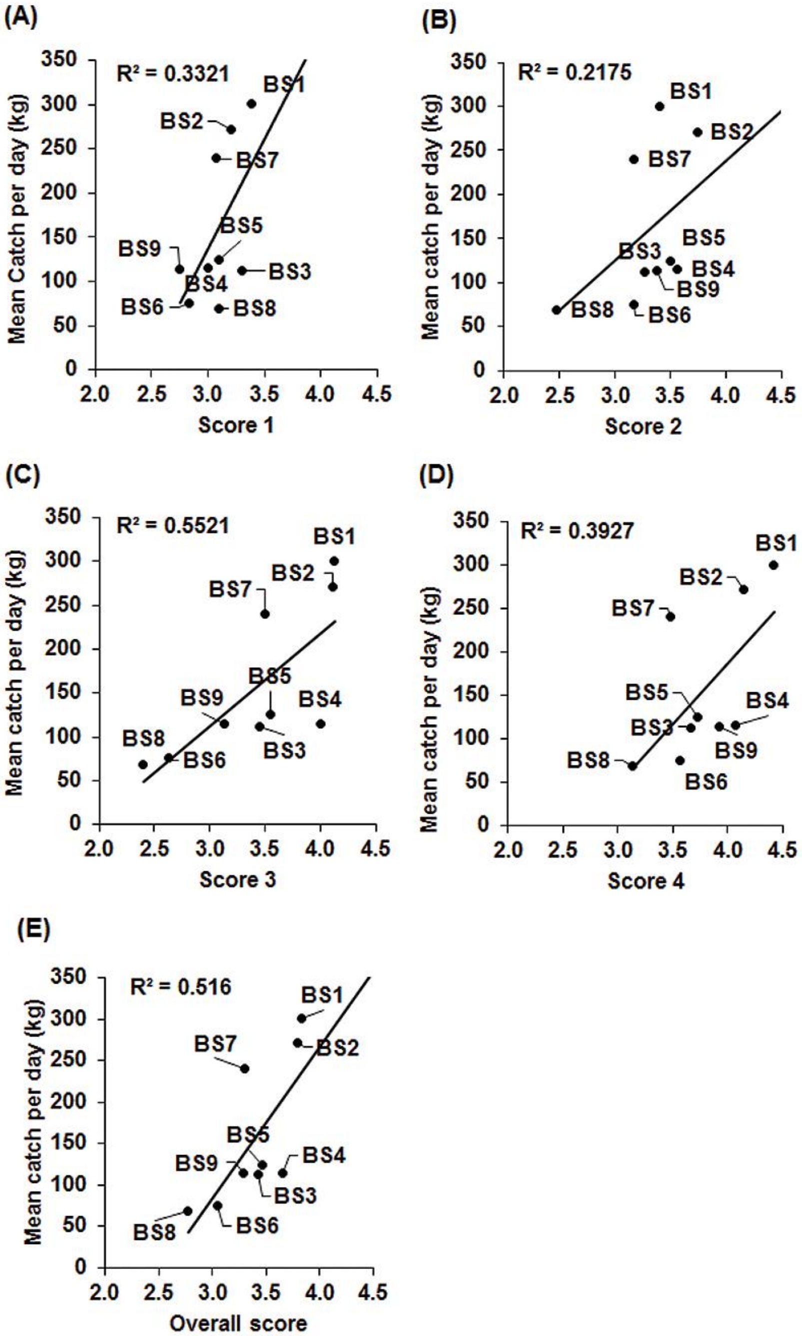

Figure 6. Likert scores of four categories (see Table 2) and overall Likert scale the nine beach seine communities related to mean daily beach seine landings.

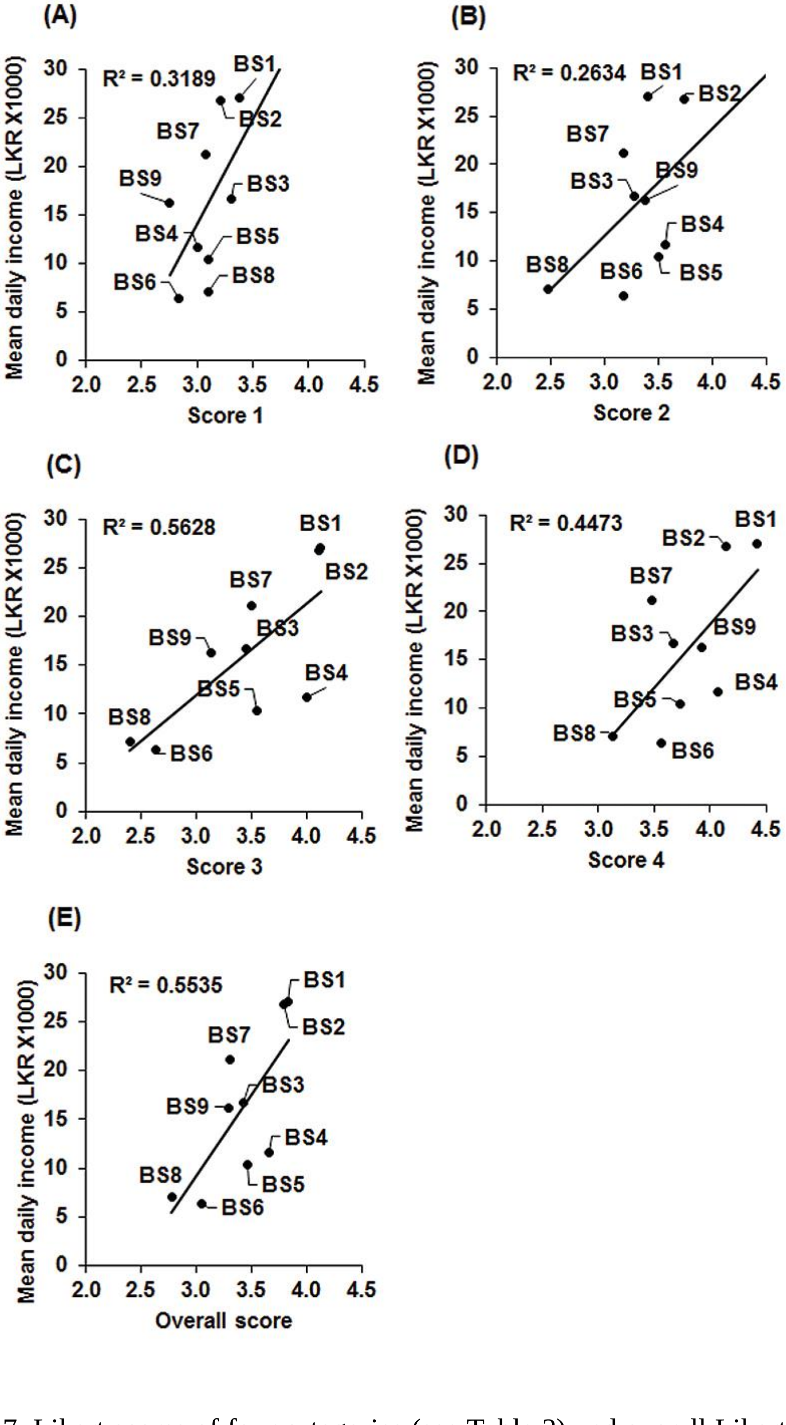

Figure 7. Likert scores of four categories (see Table 2) and overall Likert scale the nine beach seine communities related to mean daily income of beach seine landings.

Water current and direction are often determined examining floating objects, and this information is used by *Mannadi rala* to decide the exact starting point and the encircling direction of beach seine operation in the fishing site. Almost all fishers interviewed expressed that high wind speed would negatively influence successful beach seine operations.

Experienced fishers are also aware of the pelagic species of seasonal occurrence and non-seasonal occurrence (see Table 2). As such, *Mannadi rala* was able to decide which cod-end type should be fixed in the beach seine operations.

During the questionnaire survey, it was also revealed that in all nine fishing communities, there was a high 'team-working spirit', which was essential for beach seine operations. Fishers interviewed were of the opinion that this was due to identical cultural norms acquired through long tradition of co-operative attitudes of beach seine fishing communities.

Discussion

Many pelagic fish stocks in the tropical seas exhibit spatial and temporal variation of species occurrence (Fréon and Misund 1999; da Rocha et al. 2010; Kaplan et al. 2014; Saraux et al. 2014). As such, effectiveness of the fishing operations targeting such species is invariably dependent on the fishers' knowledge and experience about the seasonal occurrence of various target species. It is a fact that in many small-scale coastal fisheries in the tropical belt, fishers use appropriate gear types such as correct mesh size in gillnetting and correct hook size in hook-and-line fishing (McGoodwin 2001). In the beach seine fishery of north western coastal area of Sri Lanka, spatial and temporal patterns of species occurrence was evident as shown in the present analysis. As such, fishers' LEK to predict the occurrence of different species of pelagic fish schools is important for achieving high harvests, especially due to the reason that *Mannadi rala* in each beach seine community decides over fixing of the cod-end type of the appropriate mesh size. In the present study, it was revealed that beach seine fishers in all nine communities are engaged in 'shoal fishing' i.e., to target the species that are occurring in the fishing ground at the time of fishing operation, rather than 'blind fishing' i.e., a 'trial-and-error' type of fishing without knowledge about the species occurrence.

The experienced fishers in the beach seine communities in the present study use various indicators such as colour and turbulence of surface water brought about by schools of different fish species, and surface water temperature to which, according to their experience, some species have affinities. Such ecological knowledge of fishers is known as 'folk oceanography' (Grant and Berkes 2007; Berkes 2015). Conventional fisheries management systems however, do not appreciate fishers' ecological knowledge because such knowledge is often treated as 'anecdotal'. Nevertheless, the present study has shown that fishers' ecological knowledge about the prediction of the occurrence of schools of various fish species was scientifically accurate. Berkes et al. (2001) observed that most of the assessment efforts in the world's fishery resources have been devoted to resource-oriented approaches such as stock assessment and to some extent on economics. They also observed that these approaches had not addressed the socio-economic needs of fisher communities or the benefits of participatory management. On the other hand, traditional indigenous knowledge for resources management is proven to be important for resource management especially in coastal fisheries in many parts of the world due to the fact that such knowledge is accumulated among resource users as a result of their intimate contact with the surrounding environment which supports their livelihood (Ruddle 1994b; Berkes and Folke 1998).

The income derived from the fishing operations is equally shared among crew members, as practised in the beach seine communities of southern Sri Lanka (Deepananda et al. 2016). Locally crafted norms and practices evolved through fishers' local knowledge results in increased harvest and high financial returns in beach seine communities (Deepananda et al. 2016), which motivates individual fishers to comply with the traditional mechanisms of self-governance.

The traditional living styles of Sri Lankan people consist of unique socio-cultural characteristics to help each other for their mutual benefits. The coastal fishing communities also possess this important co-operative relationship especially in beach seining, which is necessarily a group activity. In the beach seine operations, the net is dragged with the incoming wave. During the outgoing wave, the net should be kept stable so that strong grip of the hauling rope is essential. The team working spirit is therefore essential for the success of fishing operation. The customary beliefs, which are essentially an integral part of rural living driven by religious and traditional norms, appear to be the bonding substances in the fishing communities with co-operative attitudes. It is known that many resource-use decisions in developing countries are based on traditional norms (Amarasinghe et al. 1997; Quinn et al. 2007). It is also a fact that greater participation and increased commitments of resource-users are necessary for the governance of community-based management systems (Kabir et al. 2013; Sutton and Rudd 2015). Hence, team working spirit, traditionally evolved in the beach seine fishing communities plays a major role in the community-based resource governance.

As the present analysis indicates that local knowledge exists among beach seine fishers of Chilaw area in the north western province of Sri Lanka, which are of potential use for resources management, it is possible to incorporate this knowledge in defining fisheries co-management. In fisheries co-management, mechanisms should be in place for the centralized management authorities to consult the resource users for making management decisions (Sen and Nielsen 1996). Based on the present analysis, the mechanism illustrated in Figure 8 is recommended to be adopted by the fisheries authorities. In the Fisheries and Aquatic Resources Act No. 2 of 1996, and the Fisheries Operations Regulations of 1996 in Sri Lanka (http://www.fisheriesdept.gov.lk/ fisheries_beta/index.php/fisheries-act-fisheries-management; accessed on 27.05.2016), there are legal provisions to adopt fishers' local knowledge in formal resource management schemes.

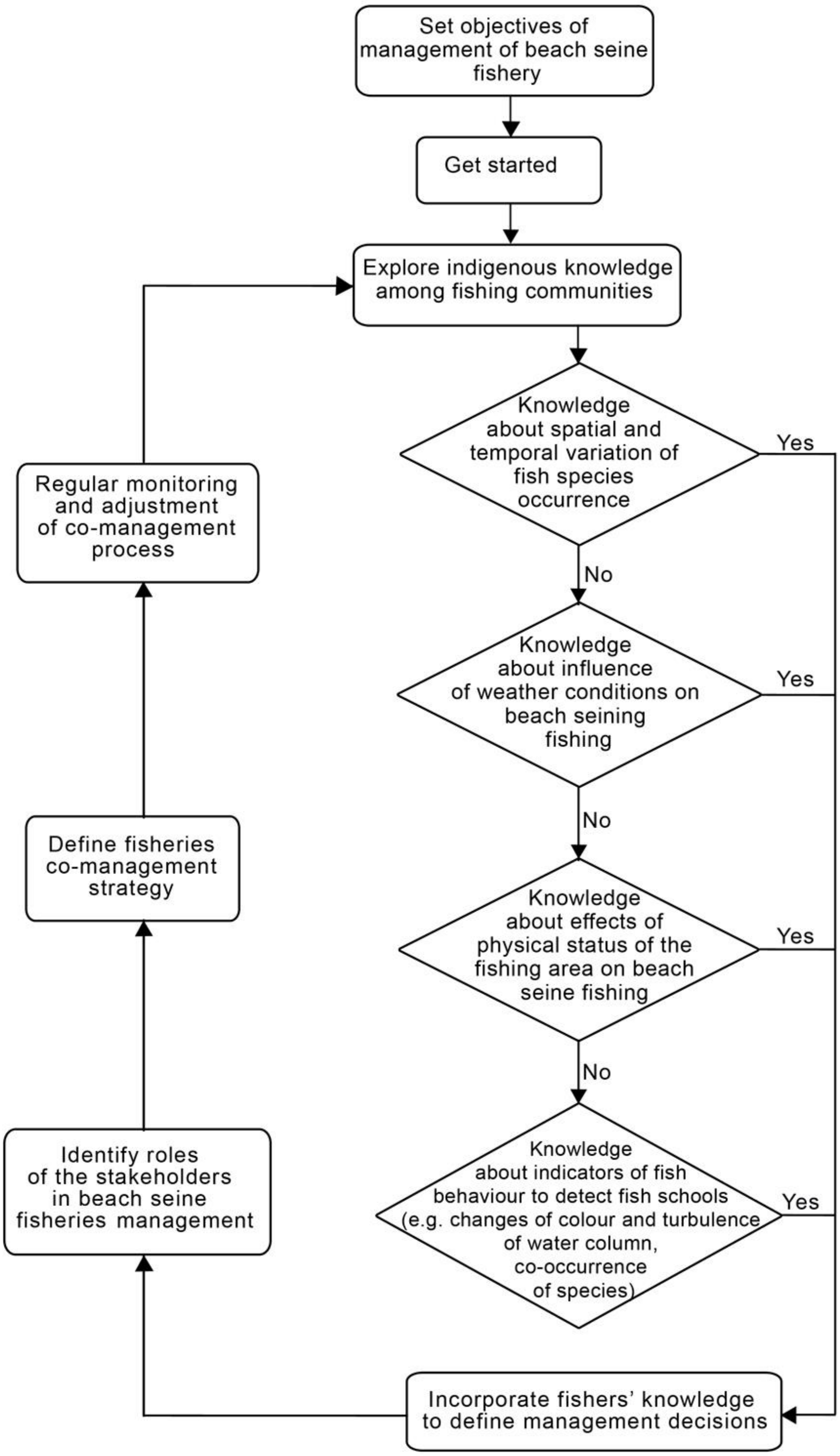
Set objectives of management of beach seine fishery
Get started
Explore indigenous knowledge among fishing communities
Knowledge about spatial and temporal variation of fish species occurrence
Yes
No
Knowledge about influence of weather conditions on beach seining fishing
Yes
No
Knowledge about effects of physical status of the fishing area on beach seine fishing
Yes
No
Knowledge about indicators of fish behaviour to detect fish schools (e.g. changes of colour and turbulence of water column, co-occurrence of species)
Yes
Incorporate fishers' knowledge to define management decisions
Identify roles of the stakeholders in beach seine fisheries management
Define fisheries co-management strategy
Regular monitoring and adjustment of co-management process

Figure 8. Flow diagram of the mechanism which is recommended to be adopted by the fisheries authorities.

Conclusion

In the beach seine fishery of Chilaw area in the north western province of Sri Lanka, fishers apply their local knowledge to predict occurrence of various fish species in the fishing area using various indicators such as colour and turbulence of surface water brought about by schools of different fish species, and surface water temperature to which, according to their experience, some species have affinities. Accordingly, fishers decide fixing the cod-end of appropriate mesh size to the beach seine to maximize their harvests. However, fishers' local knowledge is not appreciated by the centralized management authorities for defining management decisions possibly due to the reason that fishers' local knowledge is often considered 'anecdotal'.

In the present study, it was found that the spatial and temporal variations in species composition are influenced by local weather factors. Also, fishers' decisions to fix the appropriate cod-end to the seine net had high rate of accuracy in all nine beach seine communities studied. Furthermore, the local knowledge of fishers, quantified using a psychometric approach revealed that beach seine harvest and mean income are positively correlated with fishers' local knowledge about the fisheries management-related aspects. These analyses indicated the unambiguity of fishers' local knowledge and its potential to be adopted for defining beach seine fisheries management strategies.

However, in spite of the existence of legal provisions in fisheries regulations, mechanisms are not yet in place for the centralized fisheries authorities to consult resource-users for defining fisheries co-management strategies. It is therefore recommended that beach seine fishers' local knowledge be captured for defining effective co-management of the fishery.

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