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The interactions between livelihood capitals and access of local communities to the forest provisioning services of the Sundarbans Mangrove Forest, Bangladesh

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ABSTRACT

This study aims to understand the influence of livelihood capitals on access to provisioning services (PS) of the Sundarbans Mangrove Forest (SMF) including honey, crabs, mixed fish, shrimp, shrimp fry and fuelwood. The interactions among several livelihood capital components played significant roles in shaping the composite effect of respective livelihood capitals on the access to PS. The effect of human capital was significantly positive on people's access to fuelwood, shrimp fry and crabs consecutively; and negative on the access to honey, shrimp and mixed fish respectively. Physical capital was likely to increase access to shrimp, shrimp fry and crabs; and decrease access to fuelwood and honey. Natural capital (i.e., land area) significantly increased the access to shrimp fry and shrimp; and reduced access to honey. Financial capital played significant positive roles in access to crabs, fuelwood and honey; and negative role in accessing mixed fish respectively. Social capital was likely to enhance access to honey and fuelwood; obstructed access to crabs, shrimp fry and shrimp. Protection of any ecosystem from over exploitation and improved wellbeing of the dependent communities can be achieved by addressing the influence of the livelihood capitals through the integrated development approach.

1. Introduction

Access, broadly defined as the ability to benefit from material objects, persons, institutions and symbols, is a prerequisite to enjoying the benefits of any resource. It is complicated by the political economic aspect of the concept which evidently divides the access mechanism into 'access control' and 'access maintenance'. The issue of control refers to function or power of directing and regulating who can access a resource (Rangan, 1997). Maintenance of access is another issue that requires expending resources or powers to keep a particular sort of resource access open (Berry, 1989). Smith et al. (2013) described this as the opportunity to benefit from Ecosystem Services (ESS) and to maintain this benefit for future generations to attain a sustainable society. One important types of ESS is provisioning services (PS) which are the material benefits (e.g., food, medicines, raw materials, fresh water and so on) supplied by the ecosystem. The mechanisms of gaining access to PS vary between people depending on their available livelihood capitals (Ribot and Peluso, 2003). Livelihood capitals, which include natural, human, financial, physical and social capital (Table 1) are likely interact to influence how and when resources are accessed (Costanza et al., 2014; Fisher et al., 2014). For example, Bhandari (2013) reports that the size of cultivated land and livestock ownership significantly influence the livelihood activities of forest dependent people. However, elsewhere it has been stated that the availability of working age children and men also have a significant impact on livelihood strategies (Kibria et al., 2014; Rakodi, 1999). Any opportunity of income other than ESS extraction is likely to reduce the ecosystem destruction (Wunder, 2001).

Adequate access to forest resources would ensure greater community wellbeing and ecosystem conservation because forest dependent communities are mostly marginalized with little to no opportunities for alternative livelihoods (Angelsen et al., 2014; Naidu, 2011; Vedeld et al., 2007). While one way to assess the level of access (or ability to benefit) is by the income generated from a resource (Ribot, 1998; Ribot and Peluso, 2003), this notion of access to resources has not been adequately addressed as past studies often use 'property rights' to measure access rather than focusing on other ways people may access resources. As such, by defining access as the 'ability to benefit' from any resources of the forest we can inevitably draw attention to a wider range of material, economic and social elements that are gained from resources without solely focusing on property rights (Ribot and Peluso, 2003). While some research has examined the factors that lead to

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Table 1
Different types of livelihood capitals and their components.

Capitals	Definitions	Model variables measurement
Natural capital	Water, land, forests, air, hydrological cycle, pollution sinks and so on from which resources are generated and people can draw on their livelihood need	Size of shrimp farm (ha); Family land size (ha)
Financial capital	These are vital to build confidence in pursuing any livelihood strategy include cash, credit/debt, savings	Pirate's permit (1–5 scale: 1-easily affordable, 5-unaffordable); No. of chicken (No.)
Human capital	The skill, knowledge, good physical and mental health, number working age member and so on	Education level (1-Illiterate, 2-primary, 3-JSC, 4-SSC, 5-HSC, 6-BSc, 7-Postgraduate); Age (yr)
Physical capital	The basic infrastructure and the production equipment and technologies which enable people to derive benefits from any source	Mobile phone (1-no, 2-yes); TV (1-no, 2-yes); Boat (No.)
Social capital	This includes trust and solidarity, networks and connectivity, social cohesion and so on. This kind of capital ensures coordination and cooperation for mutual benefits	Livelihood group (No.); Co-op membership (No.); Togetherness (1–5 scale: 1-strongly agree, 5-strongly disagree), Close member (No.); Neighbours mostly trusted (1–5 scale: 1-strongly agree, 5-strongly disagree)

Source: Nath and Inoue (2009); Putnam et al. (1993); Scoones (1998).

decisions about livelihoods of ecosystem dependent people, expanding this to consider livelihood capital as a means to understand a household's decision on livelihood strategy is a relatively new development. In fact, to our knowledge, there has been no study that has explained the composite effect of livelihood capitals in the decision making of households in terms of which ecosystem resources they will extract from a forest ecosystem (Bhandari, 2013; Cinner et al., 2009; Hua et al., 2017; Liu and Liu, 2016). This leaves a considerable knowledge gap in our wider understanding of the complex interactions of livelihood capitals. Revealing these interactions will benefit policy makers and development organizations by allowing them to better control access of local people to the ecosystem by manipulating livelihood capitals instead of imposing harsher regulation and thereby ensure sustainable conservation of the ecosystems.

Over 3.5 million people from surrounding areas rely on the Sundarbans Mangrove Forest (SMF) for their livelihoods leading to forest cover loss at an alarming rate of 0.04% per year (Abdullah et al., 2016; Iftekhar and Islam, 2004a). Growing population pressure, corruption and climate change have posed great threats to the integrity of the unique mangrove ecosystem (Roy et al., 2013). Miah et al. (2010) reported that over-exploitation is the most eminent threat to the biodiversity of SMF. As local villagers rely on the forest for PS to maintain their wellbeing, any reduction in access to these resources and services would put them under threat. In addition, competition for particular PS may jeopardize the integrity of the ecosystem and create challenges for sustainable management. This may be particularly true for the resources for which there is a lack of control in extraction leading to unsustainable harvesting and large-scale biodiversity loss. Such loss weakens traditional conservation values and diminishes the effectiveness of local institutions (Stewart, 2003). To better mitigate this loss and understand its true impact, it is crucial to recognise the underlying reasons behind the harvesting of certain PS and acknowledge the complex interactions among livelihood capitals of individuals (Costanza et al., 2014).

Given that the ability to benefit from PS is something which is determined by a range of livelihood capitals, the aim of this research is to investigate the relationship between livelihood capitals and access to PS of the villagers living around the SMF in Bangladesh. As the status of livelihood capitals of people determines their ability to consume any PS, understanding the interactions between the livelihood capitals and access to PS of these ecosystem dependent societies is key to achieving sustainability in natural resource management.

2. Methodology

2.1. Study area

Shyamnagar upazila was chosen as our study area based on its geographic location. The upazila is situated just beside the SMF and amongst a network of tidal rivers (Grant et al., 2015) located between 21°36′ and 22°24′ N and 89°00′ and 89°19′ E (Fig. 1). It is bordered by Kaliganj and Assasuni upazilas on the north, and the West Bengal state of India and the Bay of Bengal on the south. The average literacy of the area is 52% (male 45%, female 48%) and the majority of families live in extreme poverty (Bangladesh Bureau of Statistics (BBS), 2013). Villages along the coastal lines are very vulnerable due to frequent natural calamities in the monsoon season (Islam, 2003; Tamason et al., 2016). A major part of the SMF belongs to this upazila; hence, the forest is the only source of livelihood of many of the villagers in the vicinity of the SMF.

The SMF is situated in southwestern Bangladesh, located between 21°30′ and 22°30′ N and 89°00′ and 89°55′ E extending over Khulna, Satkhira and Bagerhat districts (Fig. 1). The SMF in Bangladesh forms the single largest contiguous mangrove forest in the world and is a unique national asset to Bangladesh in terms of its economic importance (Salam et al., 2000). Its unique physical and physico-chemical environment has nurtured the growth of the most biodiverse mangrove in the world (Choudhury, 2001). Hence, the forest is of enormous importance ecologically and economically at local, national and global scales. In fact, it has been recognised for having such value that UNESCO declared the forest a World Heritage Site in 1999 (Hoq, 2007). It covers an area of 6017 km^2 among which the total land area is 4143 km^2 (includes exposed sandbars: 42 km^2) with the remaining 1874 km^2 area including rivers, canals and small streams (Iftekhar and Islam, 2004b; Wahid et al., 2007). The biodiversity of fauna and flora in the region is much higher than other large mangrove ecosystems (Wahid et al., 2007). The Sundarbans reserve forest offers a diverse resource base for local people by supplying PS including honey, fish, crabs, nypa leaf, fuelwood and timber (Abdullah et al., 2016).

This area is managed by four administrative ranges including, Sarankhola, Chandpain, Khulna and Satkhira. The whole SMF is divided into 55 compartments and it is under the control of Sundarbans Forest Circle. Commercial logging from SMF is banned (International Resources Group, 2010) and three wildlife sanctuaries facing the Bay of Bengal, were established in 1977 (Seidenstlcker and Hai, 1983). This valuable forest ecosystem, however, is currently experiencing numerous threats including illegal timber extraction, poaching of wildlife, sea-level rise, upstream water extraction/divergence, over fishing and harvesting of aquatic resources, plant disease, and river pollution (Aziz et al., 2013; Mohsanin et al., 2013; Roy et al., 2013).

2.2. Sampling design and data collection

Our sample households were drawn from the villages of Moukhali ($N = 10$), Burigoalini ($N = 10$), Gabura ($N = 10$), Kalbari ($N = 15$), Purbo Kalinagar ($N = 10$), Kadamtali ($N = 10$), Harinagar ($N = 13$), Datinakhali (14) and Dhankhali ($N = 12$), which are situated in the Satkhira district. A complete list of villages in the area was obtained

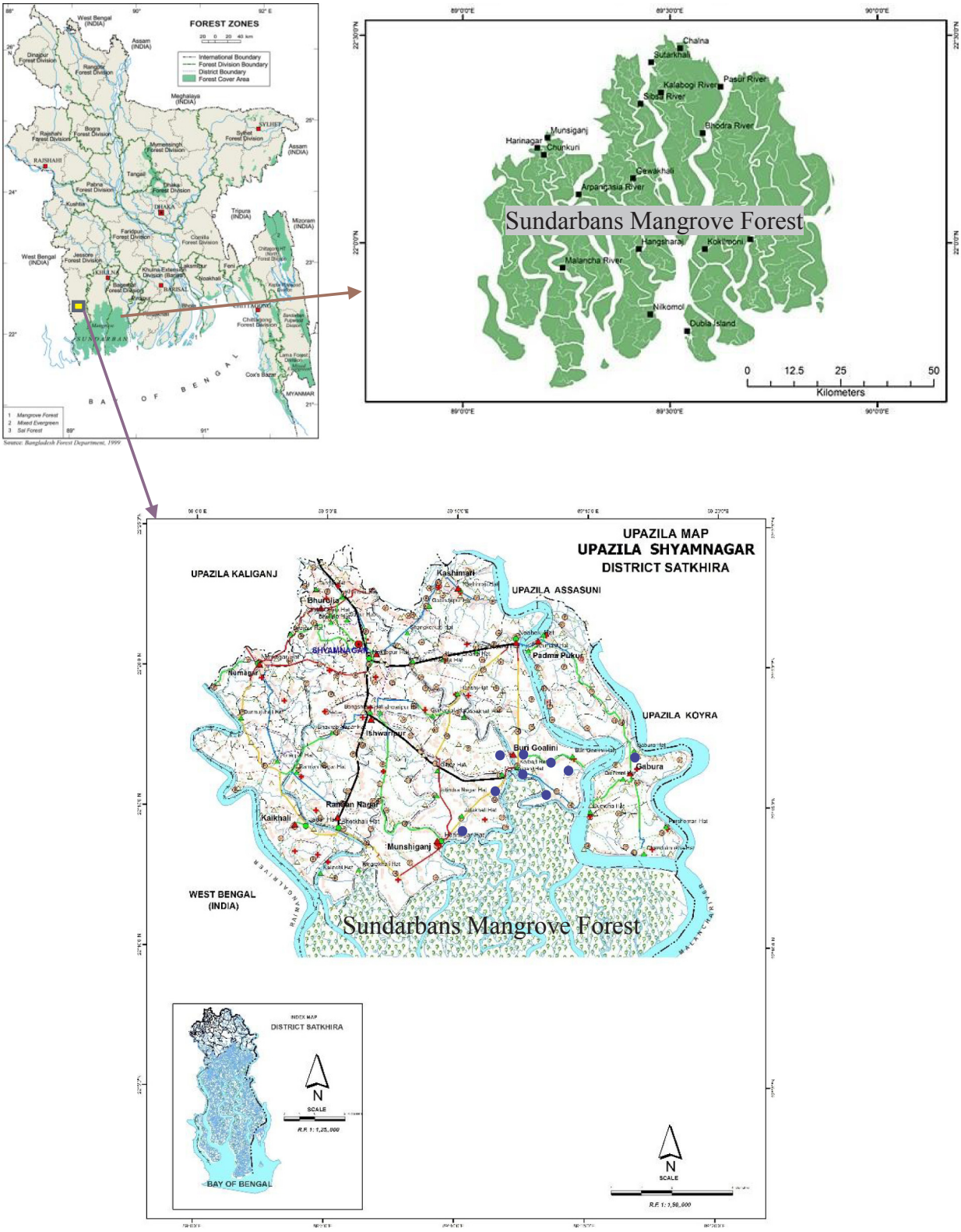

Fig. 1. Map of: (a) the forest zones of Bangladesh (Bangaldesh Forest Department, 1999) cited in (Roy et al., 2013), (b) Sundarbans Mangrove Forest (Hossain et al., 2015), (c) Shyamnagar upazila of Satkhira district marked with the study villages in blue dots (Local Government Engineering Department, 2017).

from a local NGO office (Centre for Natural Resource Studies or CNRS, Bangladesh) and from that list we randomly selected a total of 104 households. The head of each selected household was interviewed using a face-to-face interview. The interviewees were predominantly male (100 men and four women) because women were generally not engaged in collecting PS from the forest, rather they stayed at home to take care of the family. In some cases (e.g., crab collection, fuelwood collection) women may accompany men, thus while interviewing men about this,

the views of women were also often noted. One widow was part of our initial sample, but as her eldest son was the primary PS collector they were both interviewed. For consistency, the same interview method was used to interview all household heads regardless of their locality and gender.

In each village we also conducted a focus group discussion, and interviewed key informants and elderly people by using open ended questions in order to explore background information on PS collection including the collection process, marketing, benefit sharing and challenges in each village that included members of all PS collecting groups. The whole process from 'collection permission' to 'consumption' was extensively discussed in each session. Key informants were selected based on their knowledge on the study subject and familiarity with local people. Additional qualitative and/or quantitative data also were collected by asking additional questions about interesting issues that emerged from the original interviews. People were asked to identify the capitals influencing a particular PS. At the beginning of every group discussion session, respondents were adequately briefed about the livelihood capitals and influences on collecting PS. People were asked to select influencing components from each livelihood capital type for each PS they collected (Table 1). Livelihood capital variables were then selected based on the consensus among group members which were the most important for the collection of the six identified PS. These were also checked during individual household interviews. Two social capital variables in the regression models (trust, togetherness) were also identified based on direct observations during field visits and interviewing with households. The lead author facilitated the selection of livelihood factors and finally categorized the factors under different livelihood capitals (Table 1). Seven visits were also arranged to observe PS collection activities and explore the factors influencing their collection.

We identified six types of PS that were collected by households from group discussions and key informant interviews. These included: honey, crab, shrimp fry, shrimp, mixed fish and fuelwood. Although nypa leaf is one of the major PS harvested from the Sundarbans forest elsewhere (Uddin et al., 2013), we did not analyse it here as only a few villagers engaged in nypa leaf collection in our study. In collecting data on income from a particular PS by the households we considered income from both sold and consumed items.

2.3. Data analysis

To determine the level of access to PS in the SMF the gross average annual income of the households was calculated for each PS. The income from PS includes the income from both self-consumption and sold items. Rather than focusing on just one PS, each family engaged in collecting several types of PS, hence, trade-offs had to be made among the PS collections. A Pearson Correlation Matrix was developed to understand these trade-offs. As our study defined access gain as both 'access control' and 'access maintenance', the way each livelihood capital influenced different mechanisms of gaining access was observed by using both qualitative and quantitative data. After exploring the influence of livelihood capitals we also identified the influence of specific components of livelihood capitals on the level of access to PS in the SMF. OLS (Ordinary Least Squares) regression analysis was then performed to explore the effects of these livelihood capitals on the level of access to each individual PS. The models were prepared according the following equation (Eq. (1)) (Dranove, 2012):

$$Y = \beta_0 + \beta_1\chi_{i1} + \beta_2\chi_{i2} + \beta_3\chi_{i3} + \ldots\ldots\ldots + \beta_n\chi_{in} + \varepsilon_i \quad (1)$$

Here, Y = ability to benefit from a PS; β_0 = intercept of the regression equation; $\beta_1, \beta_2, \beta_3 \ldots\ldots \beta_n$ = regression co-efficient; and $X_1, X_2, X_3 \ldots\ldots\ldots X_n$ = independent variables; ε = the regression residual; $i = 1,2,3,\ldots\ldots\ldots n$.

A Variation Inflation Factor (VIF) identified multi-collinearity among the independent variables. As it is acceptable for VIFs value to be < 5 (Craney and Surles, 2002; Rogerson, 2001; Slinker and Glantz, 1985; Vu et al., 2015), we removed some of the violating predictors from the model until each of the VIF value was very low at < 2.75). To combine the effects of each respective dependent variables of each livelihood capital on the outcome variable, a single composite effect size was measured. The composite effect measurement is made up of the effect size of two or more variables which are related to one another. Thus, a composite effect is an estimate based on the multiple effect sizes found using descriptive statistics. The individual effects of the variables making up a composite variable may be single, scales, global ratings or categorical values (Gunter, 2015; Song et al., 2013). One of the most precise methods for computing the 'composite effect size' of a set of predictor variables on an outcome variables comes from a single regression model that uses an arithmetic mean of standardized regression coefficients (Eq. (2)) (Gunter, 2015; Hedges and Olkin, 2014; Song et al., 2013).

$$Composite\ effect = \frac{\sum_{i=1}^{N} b_i}{N} \quad (2)$$

Here, b_i = standardized co-efficient value of ith variable, N = number of significant variables of the respective capital.

3. Results and discussion

3.1. Level of access and trade offs

Average annual income from PS received by the collectors was measured to understand the 'ability to benefit' or 'level of access' to each PS (Table 1). Most families engaged in crab catching, although families generally made less than US$255 yr^{-1} from it with only 1% earning more than US$1020 yr^{-1}. The majority of households (75%) received up to US $255 yr^{-1} from mixed fish collection while only 2% of fishermen were able to catch enough to make between US$1020 yr^{-1} and US$1275 yr^{-1}. The income from shrimp fry collection was below or equivalent to US $255 yr^{-1} for 75% of families with only very few (1.5%) earning US $765 yr^{-1} to US$1020 yr^{-1}. Households (84%) who were engaged in shrimp catching generally made up to US$255 yr^{-1}. Only 5% collectors were able to make US$510 yr^{-1} to US$765 yr^{-1}. The income from honey averaged US$255 $yr^{-1}collector^{-1}$ which was received by 90% of the villagers. Fuelwood was collected for household consumption only; hence the money saved by the fuelwood was up to US$255 yr^{-1}; hence there was no competition for securing higher access to fuelwood. It was observed that across the village earning over US$765 yr^{-1} from a PS was very rare (Table 2). These results highlight the fact that very few families make a significant amount of money from PS collection with most PS providing up to US$255 yr^{-1}. In the SMF, people gained access to the PS which were the most easily available and had the least amount of associated risk in collection (i.e., from pirates or wildlife attack (e.g., Tiger), disease, food shortage, or physical sickness). Those families that could either increase capital investment or were able to take more risks for gaining greater access to the most profitable PS (e.g., mixed fish) (Bebbington, 1999; Kamanga et al., 2009).

Table 2
Household percentage involved in collecting different PS of the Sundarbans Mangrove Forest.

Collectability (US $ yr^{-1})	% of households					
	Honey	Crabs	Fuel	Shrimp fry	Shrimp	Mixed fish
0–255	89.9	53.9	100	75.2	83.9	75.0
255–510	8.7	22.1	–	9.9	9.8	15.4
510–765	–	18.3	–	11.1	5.2	3.8
765–1020	1	3.8	–	1.5	1.1	3.8
1020–1275	–	1	–	–	–	1.9
> 1275	–	1	–	2.3	–	–

Table 3
Correlation between the access levels to the PS of the Sundarbans Mangrove Forest.

Name	Pearson correlation (r)					
	Crabs	Honey	Shrimp	Mixed fish	Fuelwood	Shrimp fry
Crabs	1					
Honey	0.080	1				
Shrimp	−0.116	0.274	1			
Mixed fish	−0.285	−0.352	−0.359	1		
Fuelwood	0.056	0.025	−0.114	0.040	1	
Shrimp fry	0.026	0.110	0.001	0.429	0.351**	1

Note: **denotes correlation significant at the 95% level (2-tailed).

Each household collects more than one type of PS; hence, there are always trade-offs among PS collections. We only found one slightly significant correlation between PS with shrimp fry and fuelwood. People collected shrimp fry in the river along the forest and at the same time they also collected fuelwood from the forest edge. These two activities were the least risky livelihood activities because pirates were mostly active deep inside the forest. Villagers reported that the presence of pirate groups was a key decisive factor in trade-off decisions between accesses to different PS (Table 3).

3.2. Access mechanism: control and maintenance

Fig. 2 represents the access mechanism of the stakeholders to the PS of the SMF. Gaining access (control and maintenance) required people to use their human, natural, financial, physical and social capital. Villagers, merchants, pirates, forest department (FD), police, rapid action battalion (RAB), and the coast guard were involved in access control and maintenance to forest resources. The FD falls under the Ministry of Environment and Forest, while police, RAB and coast guard are controlled by the Ministry of Home Affairs. The police were primarily responsible for dealing with the confiscated person/s by the FD officials. The coast guard patrols along the coast line to stop any illegal activities while RAB occasionally runs operation for capturing the forest-pirates hiding inside the forest.

Administratively the FD is responsible for managing the forest. Villagers had to buy a permit from the FD to collect any resource, which cost US$3.2 $week^{-1}$ $person^{-1}$. Without this permit people were not able to legally collect any resource or even enter the forest. In reality, however, many people sneaked into the forest without permits to avoid paying the fees. If they were caught by FD officials, most of them admitted to paying a small bribe to escape. Forest pirates also illegally sold permits to collectors, which were reported to occur because pirates bribed the local police station to continue their activities. Villagers were always dependent on the local merchants for money and physical objects including boats, nets, drums and so on. After collecting PS they would either sell to the merchants or share benefits with them based on their agreement. Merchants would then sell to urban traders who would eventually sell to customers elsewhere in the country. Some products such as shrimp and crab were also exported to the international market.

PS collecting groups also had to buy a permit from a pirate group to secure their collection; hence, their browsing range remained limited within the respective group's territory. However, they were also sometimes caught by a group other than their permit issuing group and had to pay a ransom of US$130–US$380 to the pirates with the exact amount often depending on the appearance of the hostage (i.e., if he

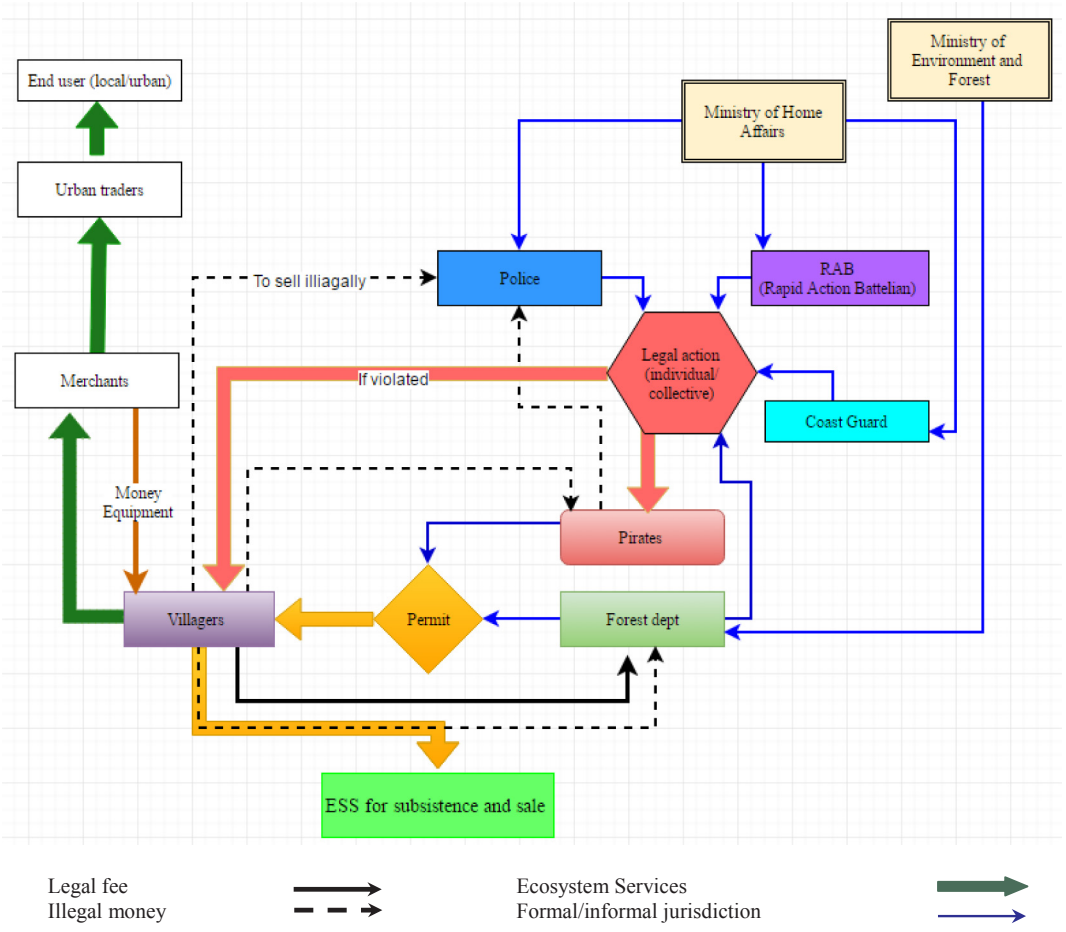

Fig. 2. Access mechanisms and flow of capital among different stakeholders.

looks economically solvent, then they demand the maximum). Inside the forest, pirates maintain their territories by fighting each other. It was reported by the villagers that to safeguard themselves pirates also killed some endangered Royal Bengal Tiger (*Panthera tigris tigris*) and other wildlife including marsh crocodile and various types of snakes. Local people informed us that the pirates earned huge money by selling those animals or their body parts in the black market.

Access to most of the PS required the formation of collecting groups i.e., people employed their livelihood capitals to gain access to the PS. The collection of honey, for example, required a group of about 10 people along with a variety of tools. Collecting crabs however was generally performed by two members of a family and required little capital investment, but large scale extraction requires more capital and a group of 4–5 persons. There were two different types of shrimp fries captured locally called 'Chati renu' (*Macrobrachium rosenbergii*) and 'Bagda pona' (*Penaeus monodon*). People could catch them without any restriction as these were available in the river outside the forest. Mixed fish were obtained in the deeper part of rivers or the river-ocean meeting area, which needed 7–8 days to reach by boat. Fishing required large boat and big nets; hence the members who had boat or net always played an important role while forming the group. Different merchant groups were active for different products and they were the main source of financial capital. Wholesalers or wealthy people provided loans either on interest or on an inter-locking credit agreement. Although merchants were the wealthiest part of the society, they always had to behave well and keep promises with the collecting groups to attract them into taking loans. As there was no written agreement signed, everything depended on mutual trust.

3.3. Livelihood capitals and access to PS

3.3.1. Human capital

Table 4 shows that education levels of both sons and daughters were found to be significantly related to honey collection. Education level of the eldest daughter resulted in household heads collecting significantly more honey because schooling daughters was costlier than schooling sons. Moreover, families required a fair amount of money to arrange the wedding of daughters. In a group discussion in Kadamtali village a person reported that "*If the daughter does not have at least the basic education, she would suffer entire life. During marriage having primary education is also very important. On top of that, we need money for arranging wedding party and dowry. Although government discourages dowry, nowadays nobody agrees to marry without that.*" All the participants unanimously agreed to this statement discussion and interview sessions. Without creating safe and secured employment opportunities at the local level, female education apparently would drive people to more PS extraction which might lead to more environmental degradation. The primary intention of the families to educate their daughter was to marry her to an educated man who could better provide for her (Lichter et al., 1995), as there were very few woman-friendly job opportunities. Contrary to this, an increase in the education of eldest son had the opposite effect that is significantly reduced PS extraction. This was explained to occur as the eldest son was culturally meant to take responsibility for the family expenses; as such families often sacrificed income from the forest to educate the eldest son for a better job, which thereby reduced the vulnerabilities of the family.

We found that physical weakness significantly reduced access to honey and shrimp. Catching shrimp was solely dependent on a period locally called 'Gon' which is a period of 3–5 days that occurs once in every 15 day interval during the full and new moon when the spring tides increase the tidal heights. Widespread inundation during this lunar cycle enables collectors to harvest shrimp. It was mentioned that fishermen had to stay awake for long periods to catch shrimp, which requires a considerable amount of physical stamina. Access to shrimp fry was significantly determined by the education level of the eldest son, which may be because of their cultural responsibility to the family as mentioned above. The total family size also had significant positive effect on access to shrimp fry collection, as this was the least risky job and did not require any formal permissions meaning that more people could engage in the activity at low risk or cost (Table 4).

Composite scores of effect size suggest that human capital had a

Table 4
Livelihood capitals and level of access to the PS of Sundarbans Mangrove Forest.

Capitals	ESS	Variables	Coefficients	Std. Error	VIF
Human					
	Honey	Physical weakness	−16.415	10.290	1.948
		EL of son-1	−31.329***	8.977	1.568
		EL of daughter-1	31.649***	12.595	2.336
	Crabs	Physical weakness	49.553	28.695	2.050
		EL of son-1	−2.936	23.638	1.599
		EL of daughter-1	17.429	31.417	2.107
		Age of housewife	−3.658	3.819	1.505
	Shrimp	Physical weakness	−36.649***	14.109	1.045
		EL of Son-1	23.038	17.128	1.154
		EL of HH	−29.693	24.190	1.079
	Shrimp fry	Total family member	119.791***	44.669	1.201
		EL of son-1	−321.108***	60.681	1.960
		EL of daughter-1	−53.527	26.808	2.029
	Mixed fish	Physical weakness	30.324	20.375	1.262
		Total family member	−44.195	23.671	1.116
		EL of son-1	−29.289	21.624	1.064
	Fuelwood	No. of female member	1.090	1.024	1.943
		Total family member	0.110	0.735	2.06
		EL of daughter-1	0.158	0.482	1.291
Financial	Honey	Pirate's permit	−29.007***	14.284	1.182
		Wage	0.013***	0.005	1.410
	Crabs	Pirate's permit	113.562***	38.336	1.187
	Mixed fish	Pirate's permit	−101.112***	31.671	1.111
	Fuelwood	No. of chicken	0.648***	0.226	1.117
Natural	Honey	Size of shrimp farm	−0.884***	0.382	1.664
		Family land size	1.483	1.270	1.569
	Shrimp	Family land size	5.560***	2.461	1.107
	Shrimp fry	Family land size	63.826***	22.095	2.74
Physical	Honey	Mobile phone	−10.695	39.296	1.243
	Crabs	Mobile phone	−224.792***	104.832	1.310
		TV	424.047***	91.767	1.343
		No. of boat	−18.336	64.873	1.295
	Shrimp	No. of boat	94.383***	46.338	1.085
	Shrimp fry	No. of boat	−355.112***	125.451	1.821
	Fuelwood	TV	−1.014***	1.876	1.322
Social	Honey	No. of livelihood group membership	28.695***	12.250	1.116
	Crabs	No. of co-op membership	−126.818***	42.457	1.161
		No of close member	−7.054***	3.016	1.696
	Shrimp	No. of co-op membership	−80.117***	28.905	1.067
		Neighbours mostly trusted	30.030***	14.976	1.131
	Shrimp fry	Togetherness	−282.420***	54.403	2.124
	Mixed fish	Neighbours are trusted	−21.464	19.498	1.110
	Fuelwood	No. of livelihood group membership	1.508***	0.701	1.199
		No. of close member	−0.056	0.052	1.324
		Villagers mostly help each other	−1.317***	0.486	1.172
		Togetherness	1.192***	0.585	1.197

Note: EL = education level. HH = household head; VIF = variance inflation factor; *** represents significant values at the 99% level; Honey: ($n = 104$, $R^2 = 0.491$, $R^2_{adj} = 0.367$, $F = 3.958$, $p = 0.001$); Crabs: ($n = 104$, $R^2 = 0.575$, $R^2_{adj} = 0.466$, $F = 5.270$, $p = 0.001$); Shrimp: ($n = 104$, $R^2 = 0.215$, $R^2_{adj} = 0.148$, $F = 3.202$, $p = 0.005$); Shrimp fry: ($n = 104$, $R^2 = 0.328$, $R^2_{adj} = 0.239$, $F = 3.666$, $p = 0.005$); Mixed fish: ($n = 104$, $R^2 = 0.161$, $R^2_{adj} = 0.111$, $F = 3.234$, $p = 0.010$); Fuelwood: ($n = 104$, $R^2 = 0.432$, $R^2_{adj} = 0.328$, $F = 4.141$, $p = 0.001$).

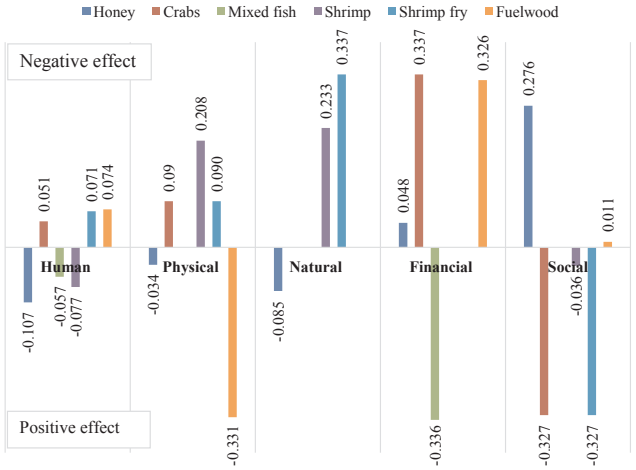

Fig. 3. Composite effects (i.e., average value of standardized effect size) of livelihood capitals on the access to PS in the SMF.

negative effect on most of the PS collection except crabs (0.051) and fuelwood (0.074). The highest negative effect was found in honey collection (−0.107) followed by shrimp (−0.077), mixed fish (−0.057) and shrimp fry (−0.057) (Fig. 3). Education and skills minimize the dependency of the local people on the PS collection and engage in more remunerative activities (Babulo et al., 2008). In Peru, it was found that PS collectors was increasingly engaged in more scientific agricultural activities with the improvement of their education status (Escobal and Aldana, 2003)

3.3.2. Financial capital

Compared to other livelihood capitals, we found that financial capital played significant roles in all PS extraction. Households with higher financial capital were able to invest more, which resulted in larger income from PS extraction. This result is supported by Uberhuaga et al. (2012) who also argued that wealthier families were the primary harvester of PS from forests in lowland Bolivia. We found financial capital to have a strong positive impact on crab and fuelwood collection, likely as these are low risk PS that require little capital demand. According to the collectors the most risky and physically intensive PS was mixed fish; thus if villagers only engaged in its collection if other PS could not be accessed. Villagers also travelled to other areas, especially during the PS extraction ban period (November–December), to work as wage labourers to earn 'quick cash' which they eventually used for PS collection. Pirates also had an overall large impact on PS collection. This is illustrated by one villager from Burigoalini village who stated: "*If there was no pirate I could earn surplus without any outside-assistance. But now I am in huge debt after paying ransom two times in this year. I cannot manage proper meals these days and let alone other family expenses. I have no alternative other than going into Jungle (forest) but very much afraid if again get caught by them. My debt is already unbearable.*" Inskip et al. (2013) also reported that PS collectors in Sundarbans are trapped in a complex set of problems of which pirates attacks are one of the most severe.

Specifically, pirate activity in the forest had an impact on honey, mixed fish and crab collection (Table 4). For honey and mixed fish, it had the biggest negative impact as people frequently had to pay a pirate group in advance or during collection, which could not be afforded by the majority of villagers. As honey collection generally takes more than 15 days, villagers are very susceptible to being caught by pirates during this activity. For mixed fish, fishermen were required to enter deep inside the forest for a good catch where they must face the pirates, which occasionally occurred so much that people become reluctant to catch fish. People also mentioned that they sometimes got caught by more than one pirate group and had to provide ransom to each of them. Piracy had the opposite impact on crab collection. Villagers reported that if they had no money to pay the pirates, they would collect crabs because this could be done within 1–2 km of the forest edge where pirate attacks could be avoided. Crab collection was also a less laborious job and required less time with as few as two people being needed to obtain crabs. This typically involved the household head going to the forest with either his wife or his son.

Other financial capitals that had negative impacts on access to PS were income from wage labouring and the number of chickens a household possessed (Table 4). Income from wage labouring both significantly and positively influenced access to honey. During the lean season/period many people worked as hired wage labourers, mostly in other parts of the country to harvest crops. They would invest some of the money afterwards in collecting honey as it requires higher capital investment. Mixed fish were collected during the 'Gon' period at 15 day intervals. The number of domestic chickens was negatively associated with fuelwood collection. This was reported to be because women stay in the house to rear the chickens, which limits their access to PS collection.

The composite effects of financial capital showed the highest positive and significant impact on the collection of crabs (0.337) followed by fuelwood (0.326) and honey (0.048) (Fig. 3). With the increase in financial capital fuelwood collection was likely to increase as these families had higher levels of food consumption that needed cooking. Contrary to this, there was a significantly negative effect of financial capital found on mixed fish collection (−0.336). According to the collectors the most risky and physically intensive PS was mixed fish. Hence, if they could manage money to invest for other resource collection, they would avoid going for mixed fish. Despite honey being profitable, it was less strongly influenced by the change in financial capital than expected. This may be because honey was only collected for 3–4 months in a year, therefore more financial capital was invested in accessing the PS available all year round (Fig. 3).

3.3.3. Natural capital

Our results found that land ownership was the only natural capital to have significant impact on access to PS having a highly positive relationship with PS that are cultivated on farms, such as shrimp. In fact, total land area had a significant and positive relationship with access to shrimp and shrimp fry collection. Cultivating shrimp is very profitable because of the agro-climatic conditions, abundant saline water, cheap labour force and growing demand in the international market (Deb, 1998; Paul and Vogl, 2011), which explains why villagers reported that shrimp farming could easily generate income. However, wild-caught shrimps were higher priced than cultivated ones in the market because naturally grown shrimps were reported to taste better and be free from hormones and antibiotics. This is similar to patterns seen in Madagascar suggesting that market value will always factor into decisions about shrimping (Gruzen et al. (2006). In our study, land ownership allowed households to both build shrimp farms and to spend 3–5 days in every fortnight collecting wild shrimp. Thus, there was a wide level of interest across the villages to collect shrimp for greater market demand even if a household also farmed them. In addition, if villagers had enough land, they would also use it for shrimp fry collection because it was free from pirate attacks. Santiphop et al. (2011) reported that land size, either owned or rented, significantly and consistently influences the livelihood strategy of marginalized people around natural ecosystems. In our study, we found shrimp farm size had a significant and negative influence on access to honey. Individuals with larger properties on which they could farm shrimp, crab or poultry had less need to become involved in risky and difficult activities like honey collection (Table 4). Therefore, composite effects also showed that higher natural capital were likely to lead pressure on the shrimp resources but would reduce pressure on other PS (Fig. 3).

3.3.4. Physical capital

Our results found that depending on the maintenance costs of each PS physical capital could have either a positive or negative effect on access to the respective PS. Possessing a television played a significantly positive role in crab collection, which may be because there is an increased close connection among the households that watch popular shows together. During this time they were likely to share information (e.g., location of crab, market price) with close family members about the high price of crabs. Conversely, mobile phone possession had a significantly negative role in crab collection. Mobile phones allowed people to keep in regular contact with other villagers, which also resulted in greater social cohesion and bigger groups which eventually allowed them to become engaged in other PS collection instead of relying on crabs. We found boat possession had significantly positive effect on the shrimp collection (Table 4). This may be because owning a boat is costly and, hence, those who had fishing boats also used them to catch shrimp regularly – resulting in a positive relationship between the two PS. The effect of physical capital was also found to be highly positive on shrimp collection, but highly negative on fuelwood collection. The lowest negative effect of physical capital was found on honey collection because people could collect this non-perishable item while collecting other PS. Moreover, because they do not need to sell it immediately, it does not interfere with the collection of other PS. The lowest positive impact was noticed on crab collection mainly because crab collection requires a small boat, strings to tie baits, and small storage box (Fig. 3).

Having more physical capital generally puts fishermen in a more secured position in the midst of already vulnerable livelihoods of the coastal communities (Iwasaki et al., 2009). Natural calamities often damage their boats and nets which are the most essential inputs for the fishermen's livelihood (Islam et al., 2014). Hence, maintaining these possessions requires a fair amount of financial capital. Thus, the poor become reliant on the wealthy merchants who could afford the physical items (Barua et al., 2012). Moreover some physical capital can have effects on the access to more than one PS. Possessing higher physical capital (such as a television) had an influence on fuelwood collection, may be watching popular programs reduced the available time but had positive effect on the access to crabs possibly because of sharing information especially among women regarding crab availability and price trend which they shared with their men later on.

3.3.5. Social capital

We found that the number of group memberships a collector had a significantly positive impact on access to honey and fuelwood. This is because honey collecting requires a group of 10–13 people thus having an increased livelihood group membership allows villagers to engage more in honey collection while that PS is available (March–June) each year. More engagement in groups also led the collectors to gathering more fuelwood while collecting other PS. Contrary to this, the number of co-op memberships a person had led to a significantly negative role in access to crabs and shrimp. Membership in cooperatives may accelerate group formation and increase their ability to work in a team which eventually reduced access to crab significantly. Trust between the neighbours had positive and significant influence in access to shrimp. Shrimping is a specialized activity and collectors generally stay in this activity, hence trust between them in the society was a major criterion to form a long standing group for shrimping (Table 4).

Fuelwood collection was negatively impacted by the helping attitudes of villagers possibly because they helped each other to be engaged in the groups of PS collection. Togetherness in the society was found significantly reduce access to shrimp fry but increase access to fuelwood. Togetherness within the society enhances social networks increases so do the opportunities to be part of larger groups who would be more proficient at profitable resource extraction, and thereby reducing extraction of less profitable activities like shrimp fry collection. On the other hand, this social relation also allowed them to collect the fuelwood while collecting other PS collection as fuelwood collection is only for household consumption. Some families had to borrow a boat from another family to get fuelwood, hence togetherness across the society tends to increase the level of access to fuelwood. Moreover, it was mentioned that people often collect PS other than they are permitted (both type and amount) and fuelwood was used to hide those productions from confiscation (Table 4).

The composite effects of social capital were found significantly positive in access to honey (0.276) but negative in shrimp fry (−0.327) and crabs (−0.327) (Fig. 3). Higher level of social capital opens up various employment opportunities to the villagers such as wage labour and migration in the urban areas (Rozelle et al., 1999). As a result villagers with higher social capital were engaged in only a particular profitable PS. Moreover, the social capitals has been effective in improving rural people's understanding of ecosystem and helping to develop new social rules, norms, and institutions for accessing to ecosystem services (Mastrangelo et al., 2014). This process of social learning and sharing spread rapidly where there is high social capital, and thereby can greatly influence access into the PS within a socio-ecological context (Pretty and Smith, 2004).

4. Conclusion

'Access' to PS or the 'ability to benefit' from PS is essential for the wellbeing of ecosystem dependent communities. Components of each livelihood capital may have different levels of influence on household's access to specific PS. With the increase in human capital people were likely to use the forest merely for the resources which had no better alternatives. Due to improved physical capital collectors intensified their activities into the profitable PS. Natural capital had positively directed only to the resources that can be cultivated in household premises. But financial capital increased the extraction of PS except those which were not required higher investment of other capitals. Social capital had positive influence in deciding the resources where were collected larger groups and collection process was less capital intensive. Therefore, our study suggests that improving the human capital and social capital would be vital in changing the access to the PS and thereby ensure better conservation. For instance, the education level of the eldest son influenced access to honey and shrimp fry significantly and negatively. Therefore, access to PS is not granted; instead, it is achieved by using the range of livelihood capitals. In order to ensure proper access to the forest, the interactions of the livelihood capitals are required to be addressed. To protect a certain PS, the influence of the interactions leading to collect that particular PS should be controlled. Wider understanding of the access-livelihood capital nexus is extremely important for protecting any ecosystem from over exploitation and ensuring sustainable local wellbeing. To implement conservation projects these results would provide valuable guidelines. However, the research should be extensively replicated in order to determine the activities of the other villages around the SMF.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecoser.2018.05.003.

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