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A simple diagnostic tool for measuring river health - example from a tropical snow fed river

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ABSTRACT

Combined evaluation of river water quality and quantity, habitat heterogeneity, ecological conditions by assessing biodiversity as well as livelihood options provided by a river can be used as measuring tool for assessment of river health of a snow fed tropical river. Seasonally changing natural flow regime is the key controller and wealthy status of biodiversity with threatened species is the foremost index of the healthy condition.

Key words: Tropical River, health, criteria and standard.

INTRODUCTION

Rivers possesses a delicate ecology that depends on a regular cycle of disturbance within certain tolerances .The concept of river health originates from river ecosystem health, but it is not confined to river ecosystem health [1]. Because river has both, natural and social attributes. Ecosystem health is important composition of river health because it is formed by the interaction between river biota and their hydro-geochemical environment. Generally, a healthy river is the river that can satisfy the sustaining need of human, under maintaining health of river ecological environment [2].River health is a term used to illustrate the ecological condition of a river. Health is more than just the plants and animals that live in a river or the quality of the water in it. It depends on the diversity of habitats, plant and animal species, the effectiveness of linkages and the maintenance of ecological processes [1].

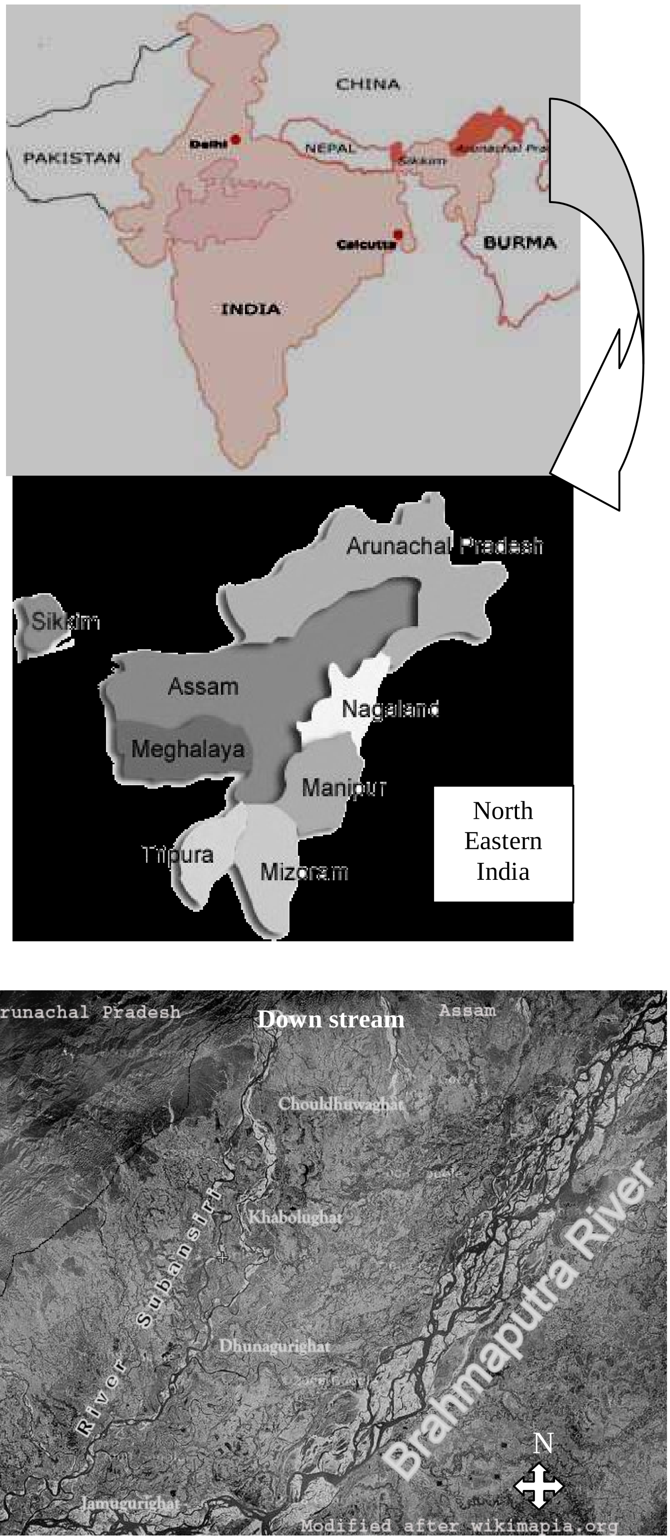


Fig. 1: Location map of the study area

River Subansiri, the largest tributary of the mighty Brahmaputra is also a Himalayan river originates from western part of Mount Pararu (5059m) in Tibetan Himalaya. It is sustained by snowmelt run off, the ablation of glaciers and monsoon rainfall. After flowing for 190 km in Tibet, it enters India, continues it journey through the Himalaya of India for 200 km, and enters the plains of Assam near Gerukamukh of Dhemaji district. Total downstream length (from Gerukamukh to its confluence with mighty Brahmaputra at Jamuguri) is approximately 130 km. Here, we assessed the river health of the Subansiri with certain basic variables and try to find out the different variables responsible for maintaining river health in the plains (considered as down stream) and to identifying a meaningful way for assessing the status of river health with some basic principles.

MATERIALS AND METHODS

Study Area: For the study down stream of the River Subansiri is considered from Gerukamukh (longitude N-27^{o}33$^{/}$, latitude E-94^{o}15$^{/}$ and altitude 90 meter), where the river is enters in the plains from upland to its confluence with the Brahmaputra. For a systematic monitoring and study of each selected parameters, the down stream has been divided into four sectors namely Chowaldhowa Ghat, Khabolo Ghat, Dhunaguri Ghat and Jamuguri Ghat (Figures: 1).

Physical Status: Certain physical status such as longitude, latitude and altitude of each sector were recorded with GPS (Global Positioning System: Model no.GPS 12/FC, Serial No-36874080, GARMIN, Made in Taiwan) at the river ports.

In this study, the tools for data analysis are mainly experimental, aimed at defining possible relationships, trends, or interactions among the measured variables of interest were considered to develop a simple way for determination of river health, we consider the following parameters.

Water quantity: Water discharge: Monthly water discharges and sediment influx at Gerukamukh from 2007-2010 were assessed according to the method of [3]

Water quality: Water temperature by using mercury thermometer, while, and conductivity by digital conductivity meter, transparency by Secchi disc, pH by digital pH meter, current flow by [3], TDS, total hardness, calcium hardness, chloride and Dissolved oxygen according to the method of [4]. Free Co_2, carbonate and bicarbonate alkalinity by [5], and Silicate by [6]

Habitat diversity: Through survey and visual observation.

Biodiversity assessment to know ecological condition: the methods of [7, 8 and 9] were used for the assessment of river phyto and zooplanktons diversity. Macro invertebrates were assessed with by adopting the methods of (10, 11, 12, 13).A conventional herbarium technique [14] was employed for assessment of floristic diversity of riparian zones and wetlands and specimens were identified with the help of standard literatures of [15 and, 16]. Orchids were identified with the standard literature (17, 18) .The standard literature 19, 20 for fish and 21 22, 23,24were employed for river dolphin, birds, butterfly and turtle respectively.

People's Livelihood: Information recorded in this study was through the direct observation and discussion with riverine communities, besides using a prepared questionnaire to solicit for data on household socioeconomic characteristics and floodplain use patterns in relation to the influence of river ecology in the selected areas.

RESULTS

Physical data like longitude, latitude, altitude and distance of each selected sectors of the down reaches of Subansiri is given in the Table: 1. Water and sediment discharge in the Gerukamukh are summarized in the Figures: 4 and 5. Water physico-chemical parameters during 2008-2010 are depicted in the Table: 2 and One-Way ANOVA on test values of various parameters among different sampling stations in the Table: 3.

Table: Physical status of the studied locations

Total length (km)	Total length Length in Tibet (km)	Length in India (km)	Length in Arunachal Pradesh (km)	Length in Assam (km)	Total number of feeder stream
530	200	330	200	130	10
Location	Gerukamukh (A)	Chowaldhowa (B)	Khabolo (C)	Dhunaguri (D)	Jamuguri (E)
Longitude	N-27^{o}33$^{/}$	N-27^{0} 26$^{/}$	N-27^{0} 03$^{/}$	N-27^{0} 00$^{/}$	N-26^{0} 50$^{/}$
Latitude	E-94^{o}15$^{/}$	E-94^{0} 15$^{/}$	E-94^{0} 07$^{/}$	E-94^{0} 01$^{/}$	E-93^{0}48$^{/}$
Altitude	99(m)	76(m)	65(m)	64(m)	59(m)
Slope of the river bed (m/km) between	(Initial spot)	2.3	0.2	0.03	0.12

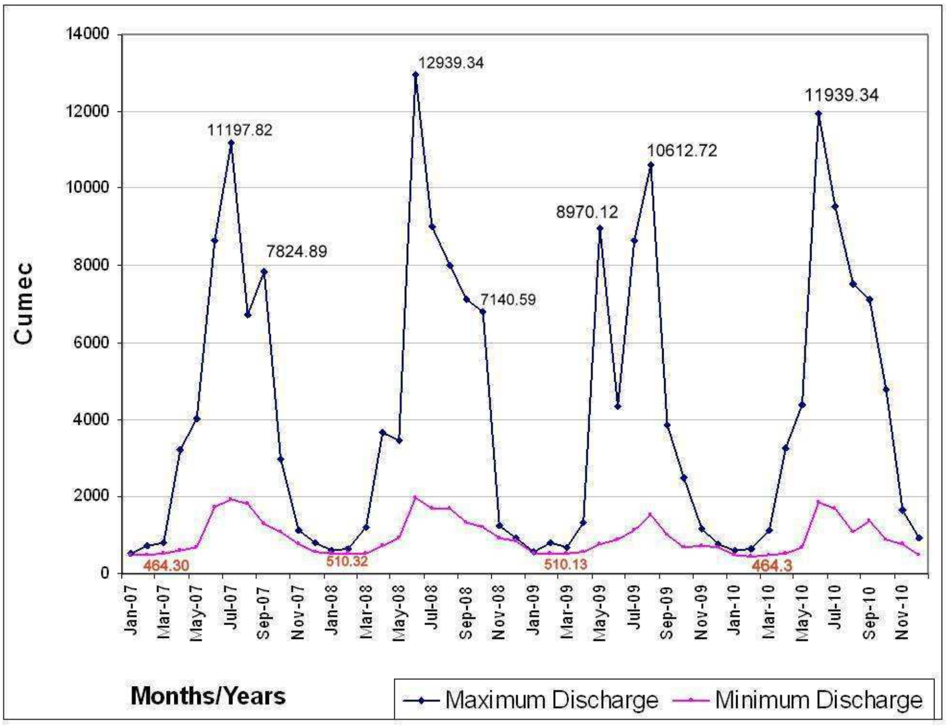


Fig.2: Natural flow regime to the down stream (Gerukamukh)

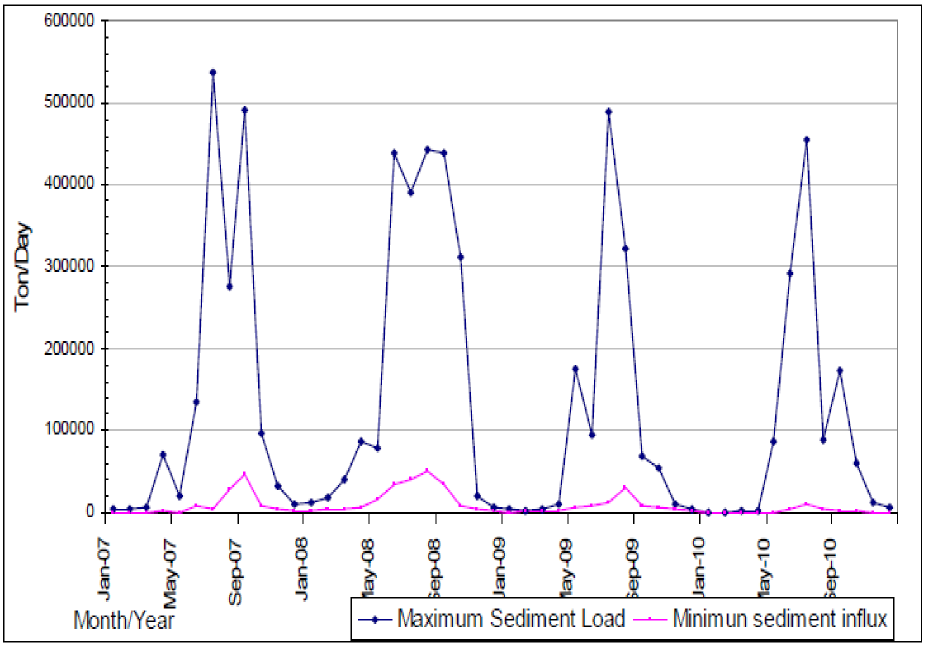


Fig. 3: Natural sediment influx to the down stream (Gerukamukh)

Table 2: Mean values of stream water physico-chemical properties.

Parameters	Sector I			Sector II			Sector III			Sector IV		
	M	SE	SD	M	SE	SD	M	SE	SD	M	SE	SD
Air temperature (^{0}C)	26.74	4.39	1.27	26.74	4.39	1.35	26.99	4.62	1.34	26.67	4.35	1.26
Water Temperature (^{0}C)	22.23	1.34	4.65	22.87	1.44	4.99	22.05	1.39	4.82	21.25	1.51	5.23
Current flow *(m/s)*	*2.80 (H)*	*1.38 (L)*	*2.09 (AV)*	*2.69 (H)*	*1.10 (L)*	*1.90 (AV)*	*2.75 (H)*	*1.31 (L)*	*1.93 (AV)*	*2.80 (H)*	*1.30 (L)*	*2.05 (AV)*
Transparency (cm)	39.77	5.98	20.73	43.72	5.94	20.51	43.40	5.64	19.53	46.90	6.48	22.45
pH	7.25	0.06	0.21	7.36	0.10	0.34	7.40	0.09	0.32	7.40	0.09	0.32
Dissolve oxygen (Do_2) (mg/L)	8.65	0.24	0.85	10.64	0.39	1.36	10.62	0.34	1.19	9.94	0.55	1.91
Free carbon dioxide (FCo_2) (mg/L)	5.33	0.55	1.91	5.45	0.45	1.57	5.68	0.41	1.44	4.55	0.38	1.33
Total suspended solids (mg/L)	162.33	5.28	18.30	168.41	5.40	18.72	166.16	5.82	18.72	167.25	5.18	17.93
Total dissolved solids (mg/L)	30.75	2.64	9.16	30.41	2.54	8.82	32.50	3.57	12.39	27.83	1.63	5.67
Total solids (mg/L)	193.08	7.78	26.98	200.66	7.32	25.37	202.00	7.35	25.48	195.08	6.06	20.99
Conductivity m/mho	109.40	3.77	13.09	115.81	4.93	17.09	118.08	4.60	15.95	116.96	5.99	20.75
Alkalinity (mg/L)	103.22	3.74	12.97	97.76	4.36	15.12	97.30	4.39	15.22	91.35	4.53	15.70
Total hardness (mg/L)	69.35	2.64	9.15	61.27	2.66	9.22	60.72	2.64	9.16	64.92	2.75	9.53
Calcium hardness (mg/L)	37.35	1.02	3.56	35.65	1.13	3.91	35.72	1.16	4.02	31.26	1.32	4.60
Chloride (mg/L)	7.34	0.56	1.95	6.35	0.45	1.56	6.42	0.44	1.53	5.63	0.39	1.36
Silicate (mg/L)	7.72	0.46	1.62	7.30	0.44	1.54	7.24	0.44	1.55	6.65	0.37	1.28

Key: M=Mean, SE=Standard Error and SD=Standard Deviation

Table 2: One-Way ANOVA on test values of various parameters among different sampling stations.

Parameters	Number of Total Stations	Number of samplings per station	F value	P value
Air Temp. (^{0}C)	4	12	F = 0.01186	p = 0.99821*
Water Temp (^{0}C)	4	12	F = 0.21964	p = 0.88225*
Transparency (cm)	4	12	F = 0.23441	p = 0.87191*
pH	4	12	F = 0.7153	p = 0.54814*
TSS (mg/L)	4	12	F = 0.51173	p = 0.67629*
TDS (mg/L)	4	12	F = 0.2359	p = 0.87086*
Total Solids (mg/L)	4	12	F = 0.36031	p = 0.78194*
Conductivity m/mho	4	12	F = 0.63203	p = 0.59828*
Alkalinity (mg/L)	4	12	F = 1.28999	p = 0.28969*
Total Hardness (mg/L)	4	12	F = 2.2203	p = 0.09913*
Calcium Hardness (mg/L)	4	12	F = 4.988	p = 0.00459*
Chloride (mg/L)	4	12	F = 2.23884	p = 0.09703*
Silicate (mg/L)	4	12	F = 1.0187	p = 0.39352*
Do_2 (mg/L)	4	12	F = 5.44892	p = 0.00283*
FCo_2 (mg/L)	4	12	F = 1.15841	p = 0.33636*

** Not significant*

DISCUSSION

In the winter months (lean months), the Subansiri River use to carry between 450 to 550 cumecs and 11000-12000 cumecs during the peak months (rainy season) regulates the downstream ecological balance by nourishing the Subansiri River and its associated freshwater ecosystem (wetlands) and terrestrial (riparian zone) ecosystems as per the seasonal requirements. Natural flow discharge and cyclic flooding influenced in its floodplain in three dimensions: **1. Longitudinal** – where water, sediments, nutrients, chemicals and biota are moved from the higher areas within the catchments downstream to the confluence. **2. Lateral** – where the river links with the riparian and floodplain land maintaining recharge and discharge of water, nutrients and biota **3.Vertical** – where a river links vertically with groundwater systems for ground water recharge as suggested by [25].Heavy downpour resulting in maximum sediment influx to the down stream in the rainy wet period. Seasonal flooding pattern (Pulse and magnitude) of Subansiri is a predictable event and its influences on the river health is significantly fragile because flora and fauna in the river has spent millions of years adapting to the conditions around them, and floods have become simply an integral part of a larger cycle of river ecology for them. Riparian flora, fauna, crops, fishes depend almost exclusively upon their streams' flooding cycles for their way of life because floods are natural events of river, but their influence on river ecology is not only delicate but also essential for many ecosystems for restoration of ecological integrity. Flooding always provides a reward in economical new food sources for stream denizens [26]. Floods flush insects, bugs, and worms that used to be on land into the stream, which become food for fishes. Floods cause the predictable advance and retreat of water onto the floodplain and organisms as well as ecosystems have evolved in response to them and adapted [27]. The floodplain is regularly wetted and dried, which in term mobilizes and mineralizes nutrients, increase biological productivity and maintains diversity. Among all, fish assemblages are adapted to a great deal of year-to-year variability in the flood regimes in any particular river reach [28].

Statistical observations of all the parameters under investigation exhibit a narrow variation in all the studied parameters in the different sectors. The values obtained in the water physical-chemical properties indicate that the Subansiri is biologically productive. In maintaining river health, the water quality and quantity is the master variable, which includes flow regimes, physico - chemical properties, sediment transport and drainage basin runoff. Flow regime is of central importance in sustaining the ecological integrity of flowing water systems. The five components of the flow regime–magnitude, frequency, duration, timing, and rate of change–influence integrity both directly and indirectly, through their effects on other primary regulators [29].

Rich biodiversity within river catchments (in the river and its associated ecosystems) of the Subansiri is a clear indicator of healthy status of the river system. High biodiversity is a realistic marker of biologically controlled ecosystem [30]. Thus, the biologically controlled ecosystem is a meaningful indicator of superior ecological condition. Rich biodiversity always indicates healthier ecological conditions. The river Subansiri has not only supporting the variety and variability of species, but also harbor a good number of threatened species. Healthy riverine ; riparian zones and the floodplain wet lands of the Subansiri providing a great variety of services such as agriculture, fishing, quarrying operation, animal husbandry, building materials and the life-giving medicines those contribute to peoples' well-being and poverty alleviation. Healthy river system certainly provides a wide range of commodities and services that are important in supporting the livelihoods of many rural communities [31].

It is obvious that first circumstance, water quality and quantity (physico-chemical properties, natural flow and sediment discharge , cyclic floods and drainage basin runoff) regulates the other two circumstance , habitat heterogeneity and their ecological conditions along with the sources of livelihood options. All these attributes are interrelated and regulated by water quality and quantity (Figure: 4). If these attributes able to providing biologically controlled habitat heterogeneity with rich biodiversity as well as manifold livelihood options for people who have gained their economic benefits as observed in the present investigation, any river can be termed as healthy. Healthy river is a river whose social and natural functions can be balanced or compromised in terms of the socio-economic, ecological and environmental values associated with the river. The environmental values of river systems should be judged according to the following criteria: the signal of a healthy river should be associated with favorable riverbed, acceptable water quality, sustainable river ecosystem and compatible runoff [32].

Obviously, there is a correlation between diagnostic tools for measuring human health and river health (Figure: 5). Rivers are often portrayed as the 'ecological arteries' of our landscape (strictly speaking, they are more like veins in terms of direction of flow but this does not quite convey the same image of vigour and vitality). Symbolically, it is worth noting that the distinctive dendritic branching pattern of rivers is similar to that of blood vessels which carries essential nutrients for maintaining human health, therefore there are clear direct links between human health and the health of rivers [33,34,35and 36] . From this point of view, an analogy can be drawn between methods of diagnosing river health and methods commonly applied to human health assessment [37]. According to him, a doctor wishing to assess the health of a patient may checks several indicators, such as pulse, breathing, temperature, the patient's reactions and the blood differential count. The doctor will use a specific measure of each indication, such pulse rate per minute, or the oxygen levels, sugar levels and Red Blood Cell count of a blood sample, and compare the measurements against the expected normal or healthy values (benchmark). One may also expect the doctor to diagnose the source of the problem, when certain indicators are not normal, and prescribe a course of treatment to improve the patient's health. Therefore, a proper review to check on not just one but number of these diagnostic tools.

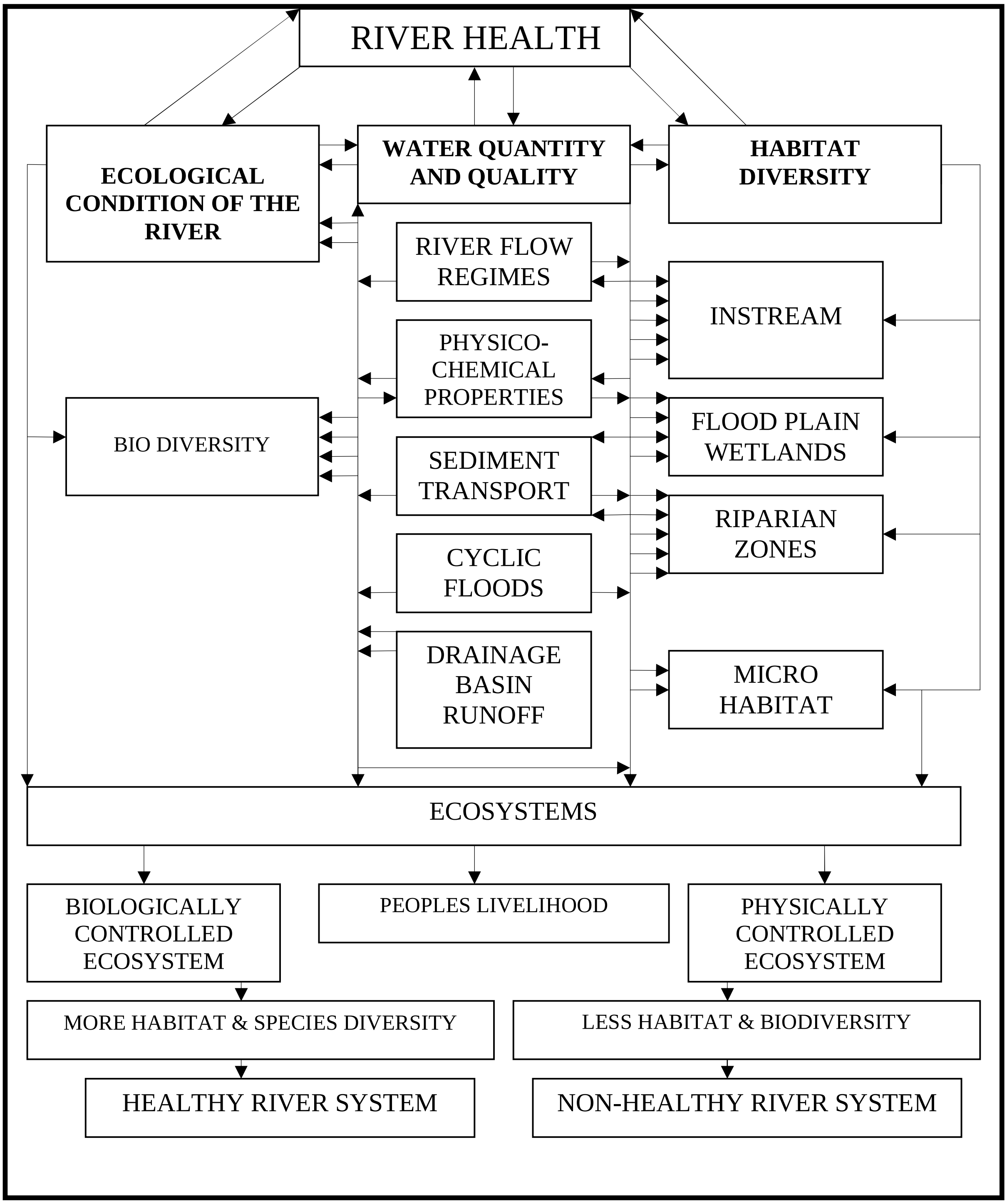
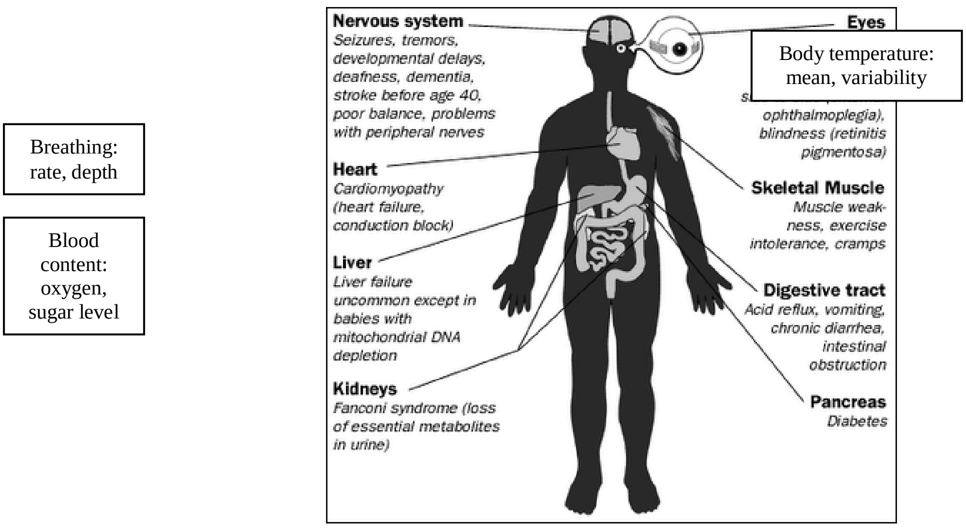


Fig. 4: River Health Assessment Standard

The same is true for assessing river health. The indication includes the ecological status, water quality, hydrology, geomorphology and availability of physical habitats and its biological diversity. To check these indicators of river health, specific measures must be addressed within each such as biotic diversity, flow regime or evidence of channel instability [37]. A multitude of factors determine the health of a river ecosystem like its geomorphologic characteristics, hydrological and hydraulic regimes, chemical and physical water quality, and the nature of in-stream and riparian habitats [38].

The standards for a healthy river should be determined according to the requirements for maintaining river's normal natural functions and the extent whether the social and natural functions could perform in a balanced way, and the standards adopted should be adjusted according to the change of the given conditions [32]. River Subansiri with its strong natural flow regime has able to provide ecologically sound ample habitats between aquatic and terrestrial ecosystem in its down stream, with high biological diversity as well as multiple livelihood options to the riverine people. The hydro-ecological characteristics of the Subansiri influences household use of river and its associated ecosystem's resources either seasonally or throughout the year and thus provided a safety net for the poor people. In the Subansiri river system, dynamic physico-chemical properties of water and natural behaviour (natural flow regime) maintaining its own ecological condition, providing ecological security to its dependent ecosystems and organism therein besides offering many economical benefits to the living communities including human beings. Therefore, combined assessment of multiple factors of river and their dependent ecosystem as well as sustainable economic benefits of a river system is too essential for assessment of river health. In tropical snow-fed River, combined evaluation of river water quality and quantity, habitat heterogeneity, ecological conditions by assessing sum of biodiversity as well as livelihood options provided by a river can be used as measuring tools for assessment of river health condition.



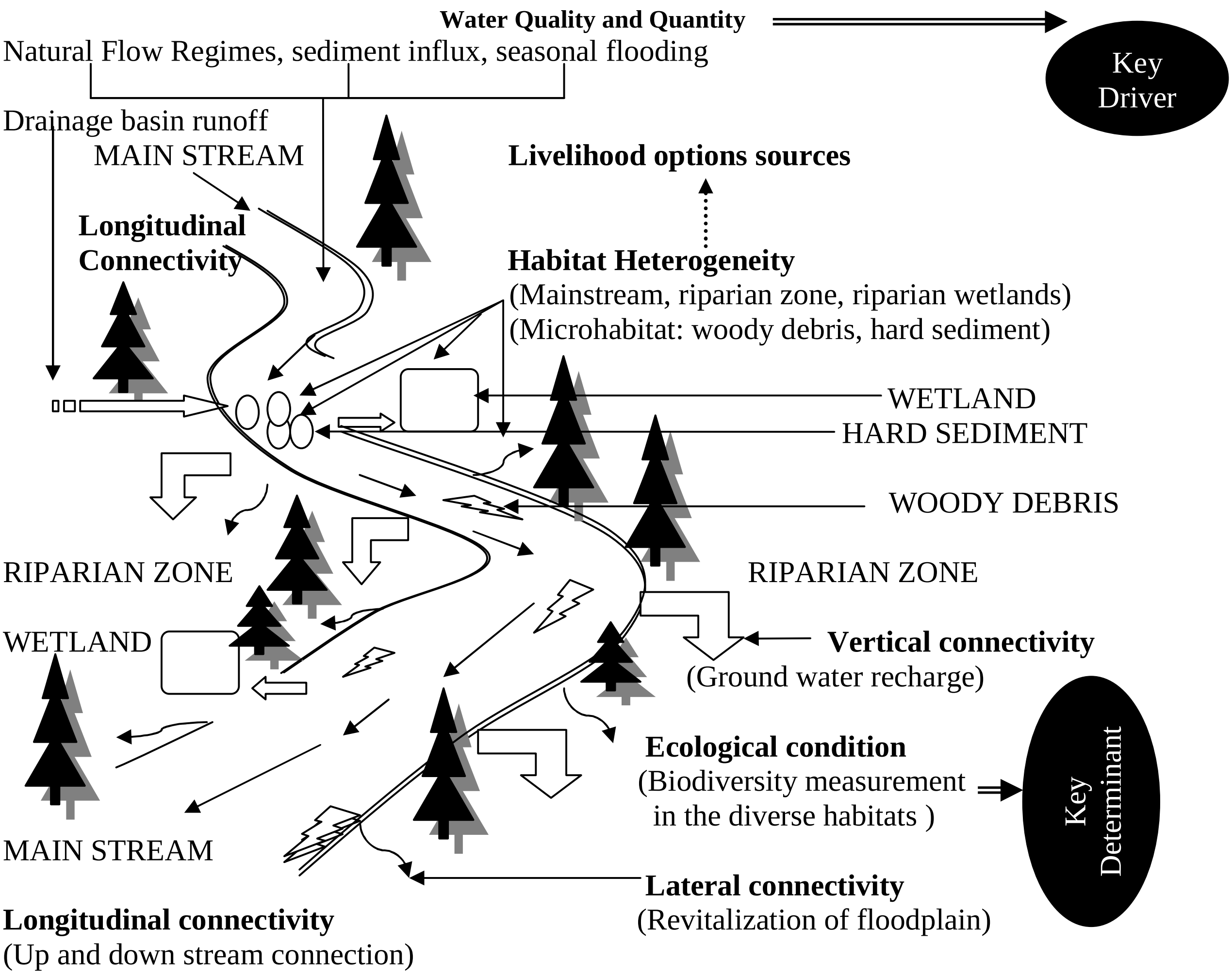


Fig 5: Correlation between diagnostic tools for measuring human health and river health.

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