World Wetland Day: Wetland ecosystems, its benefits and science based conservation management practice

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February 2 is World Wetland Day. It may or may not mean much to people who are either too busy focusing on 'earning money' hence to use money as their standard yardstick of development when it comes to their personal and career growth or simply not interested on this topic. For many years, wetlands are considered as wastelands and still in many developing nations, wetlands are rapidly transforming into agricultural paddy field or cash farm of shrimp aquaculture in the expense of large scale degradation or complete decimation of this biologically most productive ecosystems on earth. So what is wetlands, how do we distinguish wetlands from other water bodies, what are the benefits of conserving wetlands, what are their international conservation status or designation, who is responsible for maintaining the global database of wetlands, how to access these database, what is the biological and or ecological potential of wetlands comparing to other ecosystems like rain forest or shrub land and what species serve as an ecological indicator and how do we go about measuring these species in order to ensure ecological integrity, functions and the processes of the wetlands are maintained so that we human can continue to receive the vested unconditional ecosystem services e.g. fresh water supply either directly or from ground water, nutrients in the form of fish and other aquatic fauna, shoreline stability, retention of silts hence avoiding coastal erosion and so forth.

In this short essay, I am going to provide some brief background information about wetlands of different types, the importance of wetland conservation to human, and the species that wetland ecologist or limnologist may consider measuring and monitoring as part of implementing the wise use and conservation management of wetland ecosystems.

Let me start by finding out what is not a wetland? A fraction of land that is covered with rain water hence formed a small rainwater pool, is not a wetland. It is not a wetland because the water is not a permanent one and the soil may not be the one that is adapted to water based plant species to grow and thrive on it. Water base species of plants means a selective group of botanically important species that can only grow in soil that are either permanently or seasonally wet but wet, nevertheless, throughout the year. These kind of plants are also know
as *Hydrophytes* or *aquatic plants* and the soil they grow on is classed as *hydric soil*. Now that we have some crude idea what is not a wetland, let's just move on finding out what is actually a wetland. Wetland is an ecosystem comprise with hydric soil and hydrophytes. This is possibly the simplest definition to appreciate. Wetlands sometimes are also known as *ecotone* which refers to a transition inter phase between dry soil and wet soil. For example, mangrove ecosystem is essentially an unique ecotone due to the fact that the wetland within the mangroves is in the transition zone between dry or semi-dry land surface that are *regularly* and *periodically* inundated by tidal waves. Dry or semi dry wetland based ecosystems are also known as terrestrial ecosystem although the diversity and the characteristic of *floral* species may set it apart from other terrestrial ecosystems and the botanical species that would inhabit in this particular kind of wet-terrestrial ecosystem would be predominantly hydrophytes. Strictly speaking, there are four major kinds of wetlands—marsh lands, swamp forest, however not all swamp forests are mangroves, but all mangroves are swamp forest, bog lands and fen lands. Although, bogs and fens are often collectively known as *mires*. Below is the list of different types of wetlands that are under various degree of *anthropogenic* threats.


Hence, it is no surprise, that wetlands are one of the most biologically diverse ecosystems on earth. Despite its significant ecological and conservation importance across the globe, wetlands are in peril both in developed and developing nations. This sorry *state of affair* largely stem from lack of ecological education focusing wetlands of various types as listed above and unscrupulous and eco-ignorant development policy implementation that either overlook integrated ecological based development approach or simply failed to adhere the UN *declarations on Sustainable Development* also known as *Rio+ declaration*. Generally speaking, ecosystem benefits of wetlands are punishingly downplayed and the integration of both informal and formal ecological education
on wetlands and its benefits to human is virtually absent in majority of countries. Here the paradox is wetlands have been received UN ratification in the from of United Nations’ Educational, Social, and Cultural Organization (UNESCO) declared World Heritage Sites, The Convention on Wetlands of International Importance informally known as Ramsar Convention and UN Man and Biosphere Reserve Designation. Despite all these international recognition of the values of wetlands, human seem to remain notoriously indifferent to acknowledge the significance of wetlands. The benefits human receive from healthy wetland ecosystems are enormous. Firstly, wetlands are the heart beat of human survival regime considering our life depends on potable water supply and wetlands’ purify, retain and replenish water table. Without wetlands, there would be no freshwater supply for human and even in 21st century, human has not found a economically feasible way to technologically advance the desalination of marine water for their consumption. Secondly, tropical countries are often most prone to cyclones, tsunami and tidal surges (Cyclone is also known as Hurricane in North America and Typhoon in North East Asia) and considering large number of people both in developing and developed nations are regionally migrating to coastal belts, they are putting themselves in high risk of cyclone induced perturbation. Healthy coastal belts depends on wetlands as it retain soils hence invigorate the coastal lands through soil accretions, silt deposition. Maintaining healthy ecotone for example mangrove ecosystem can shelter millions of people from coastal tidal surges- a re-occurring natural calamity in tropical countries like Bangladesh and India. Thirdly, wetlands help reduce flooding that cost life in tropical developing nations. Wetlands posses an immense biodiversity value and healthy biological diversity is an essential pre-requisite for healthy human welfare and their socio-cultural value-wisdom. Human living in or around large wetlands in tropical belt often are artisan fisher folk communities and their traditional livelihood is intricately entwined with wetlands in terms of harnessing the natural resources from the ecotones and its associated ecosystems. These values have significant anthropological, cultural, religious, economical, ethno-botanical, socio-political and research significance which human will loose if efforts are not made to conserve wetlands across the tropical eco-regions. In other words, the economic justification or the monetary significance of converting the wetlands to urban development or large scale irrigation projects carries very minimal values in the long run than to maintaining a ‘self sustaining’ wetlands and its ecological functions viz-a-viz ecosystem services that human continue to receive
from the wetlands and its associated biodiversity.

So how we go about making sure we are doing the right thing to conserve and manage wetlands. In other words how do we ensure that our current management practice is as such that we can confidently say that our wetlands are healthy, productive ecological unit. One critically important management practice deeply rooted in to the science of ecology-lending mathematically sophisticated tools and integrating them with further powerful tool of geographical information science. Here we will briefly provide the fundamentals of mathematical estimator that if appropriately employed by wetland ecologist for collecting data can serve as baseline index to measure and monitor the health of wetland ecosystems. Wetlands are dominated by *hydrophytes*. Although there are relatively good number of vascular aquatic plants inhabiting the terrestrial wetlands. However, these woody species need to compete very hard with each other resulting in the local dominance of single or few species through the process of competition. Therefore these species are not necessarily a good *indicator* of understanding or measuring the health of the wetlands considering their low diversity and richness. Therefore, wetland ecologists often relies on rooted submerged aquatic plants known as *macrophytes*. Some of these macrophytes are *halophytes-* a group of submerge aquatic species that grow in high salinity in the water. Macrophytes in general serve as an ecologically valid *indicator species* to statistically appraise the health of the wetland ecosystem. In other words, high diversity (number of different species of macrophytes, their proportional abundance, and evenness of the different species) of macrophytes means grater production of algal species, high biomass and lower loss of phosphorus, all signs of a healthy wetlands. The implication from management perspective is, estimating and monitoring the aquatic macrophytes diversity can atleast provide us the lower bound of the index measure to detect the overall health of the wetlands. Ecologically speaking, management practice that maintain macrophyte diversity and monitor the diversity index both in *spatial* and *temporal* scales, can potentially enhance the ecological functioning and associated services of wetland ecosystems. So how we go about establishing a diversity index focusing *macrophyte* species. Here I have introduced a diversity estimator and mathematically illustrated it through algebraic simplifications.

**Diversity Index** Diversity index is a *mathematically* mathematically valid numeric representation of a value that not only reflects how many different species are there but also simultaneously take into
account the evenness that is how equally or (unequally) the types of different species are distributed across the data sample. Here I start with general estimator and algebraically work my way down to come up with suitable diversity estimator that we can employ in our macrophyte diversity estimation in wetlands. Please note this is a very brief mathematical treatment of figuring out the diversity index hence the estimator. For full treatment, please refer to standard ecological literature that are at your disposal.

\[
q_D = \frac{1}{q^{-1} \sqrt{\sum_{i=1}^{R} p_i^{-q+1}}} 
\]

Here, \(D\) is our Diversity Index, \(q\) is diversity order, in other words, the value of \(q\) can help us to model the estimator in terms of understanding how sensitive our diversity index is that is rare versus abundance species across the species’ proportional abundance in our sample data, \(p_i\) is our proportional abundance of \(i\)th type of species and \(R\) is our total number of species. Notice \(R\) is actually Species Richness that simply reflects how many total number of different types of species we have found. We now simplify the above equation below:

\[
q_D = \left( \frac{1}{q^{-1} \sqrt{\sum_{i=1}^{R} p_i^{-q+1}}} \right)^{-1} 
\]

\[
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\]

We continue further algebraic simplification
\[ q_D = \left( \sum_{i=1}^{R} p_i p_i^{q-1} \right)^{\frac{1}{1-q}} \]

If we take radical of \((1 - q)\) in both side of the equation, things will start to make more sense:

\[ 1 - \sqrt[q]{qD} = \left( \sum_{i=1}^{R} p_i p_i^{q-1} \right)^{\frac{1}{1-q}} \]

\[ 1 - \sqrt[q]{qD} = \sum_{i=1}^{R} p_i p_i^{q-1} \]

Now this is simply a raw version of **Shannon-Weaver Index**, also commonly known as Shannon entropy. Let me trim the equation to make more sense out of it.

\[ [qD]^{\frac{1}{(q-1)}} = \sum_{i=1}^{R} p_i p_i^{q-1} \]

\[ [qD]^{\frac{1}{(q-1)}} = \sum_{i=1}^{R} p_i p_i^{q-1} \]

\[ (q^{-\sqrt[q]{qD}})^{-1} = \left( \sum_{i=1}^{R} p_i p_i^{q-1} \right) \]

We are going to take natural logarithm \(\ln\) in both side of our equation in order to bring down our exponents.
\[ \ln\left( q^{-\frac{1}{\sqrt{qD}}} \right)^{-1} = \ln \left( \sum_{i=1}^{R} p_i q^{-1} \right) \]

\[ -\ln q^{-\frac{1}{\sqrt{qD}}} = \sum_{i=1}^{R} p_i (q - 1) \ln p_i \]

We multiply both sides of our equation with negative (-) resulting simply a Shannon entropy.

\[ \ln q^{-\frac{1}{\sqrt{qD}}} = -\sum_{i=1}^{R} (q - 1) p_i \ln p_i \]

The left hand side of our equation is simply a value of Shannon Diversity Index and can be written as \( H' \), however, the value of \( q \) as mentioned earlier can take up any magnitude although, considering to the fact that \( p_i \) is our proportional number of species and we are interested to find out the weighted distribution and the richness \( R \) in order to enumerate the value of species diversity index that takes both the distribution and evenness into account, therefore, a general rule of thumb in this case would be to consider the value of \( q = 1 \) that would give us a weighted geometric mean across our proportional number of individual type of species in our sample data set. Hence plugging in the value of \( q = 1 \) in our equation results a Shannon Diversity Index Estimator:

\[ H' = -\sum_{i=1}^{R} p_i \ln p_i \]

Please note the above equation. Shannon index is grounded to the weighted geometric mean of the proportional abundances of the types of species viz-a-viz the species richness \( R \), and it equals the logarithm of true diversity as calculated with \( q = 1 \). We can carry out further simplification of our \( H \) as shown below:
\[ H' = - \sum_{i=1}^{R} \ln p_i^{p_i} \]

This can also be written as

\[ H' = -(\ln p_1^{p_1} + \ln p_2^{p_2} + \ln p_3^{p_3} + \ln p_4^{p_4} + \cdots + \ln p_R^{p_R}) \]

Which equals

\[ H' = -\ln p_1^{p_1} \ln p_2^{p_2} \ln p_3^{p_3} \ln p_4^{p_4} \cdots \ln p_R^{p_R} \]

\[ H' = \ln \left( \frac{1}{p_1^{p_1} p_2^{p_2} p_3^{p_3} p_4^{p_4} \cdots p_R^{p_R}} \right) \]

The final algebraic simplification of the above equation can be written in a succinct form as shown below:

\[ H' = \ln \left( \frac{1}{\prod_{i=1}^{R} p_i^{p_i}} \right) \]

Algebraic simplifications of our original general estimator lead us to workable succinct Shannon-Weaver Diversity Index which if utilized in a conceptually unified and statistically valid sampling framework can produce ecologically correct diversity index of macrophyte species in wetland ecosystems. Therefore conservation management plan, particularly in the developing nations where tropical wetlands are facing grim future, must focus on integrating scientifically valid statistical sampling design- lending necessary mathematical estimator to better appraise the species diversity index. With adequate baseline data on macrophytes both in spatial and temporal scales, conservation managers will be armed with accurate limnological knowledge to detect any changes in the overall functionality of the wetland health hence to adopt sound management prescription that can help maintain macrophyte diversity viz-a-viz enhancing the functioning and associated ecological services of the wetland ecosystems both in tropical and semi tropical belt.