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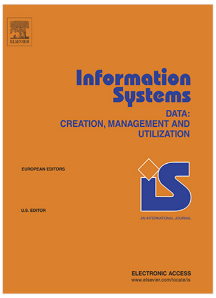

Information system ecology: An application of dataphoric ascendancy

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Information System Ecology: An Application of Dataphoric Ascendancy

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Abstract

Information systems, like biological systems, are susceptible to external perturbations. Similar to flora and fauna in a biome, species of data can be classified within a dataphora [26]. While entropic properties and data geometries can be used to describe local species of data within a dataphora, they are not designed to describe the global properties of an information system or evaluate its stability [30][31]. Ecologists have used Information Theories to describe macro-level properties of biological ecosystems [17] and statistical tools to evaluate biological systems [9]. This research leverages an ecological perspective to model information systems as a living system [14]. Our findings support the theory of dataphoric ascendancy with Wikipedia having a Diversity Index value of 0.68, within the range of 0.65 and 0.80 that indicates a balanced state. We further support our findings with additional evaluations of other ecosystems including the predicted collapse of the information service known as the Digital Universe. This research allows for an information system's stability to be a) characterized and b) predicted using ecological measures specific to the diversity of data within the ecosystem.

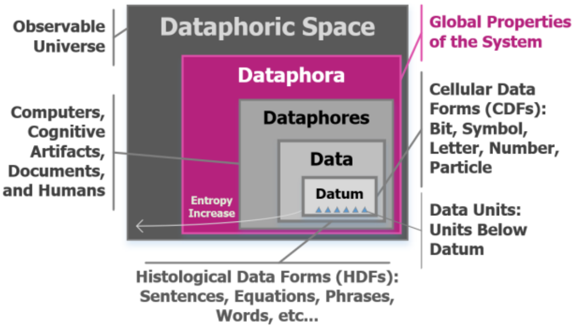
1. Introduction

The theory of dataphoric space describes an information system as a biologically-styled biome in which "species of information" reside [26]. Dataphoric space can structure the components of a data-driven ecosystem at a local level (e.g., dataphores, histological data forms and cellular data forms). While these are locally driven phenomenon within an information system, they do not quantitatively describe the global properties of an information system (See Figure 1. Position of a Dataphora). Understanding global properties of information systems are critical to measuring the evolution of an information system over time. This framework advances information system research by providing an instrument for longitudinal, comparative and point-in-time analyses.

In the 1950s there was cross-disciplinary interest in merging the concepts of information theory [27] and ecology [17]. Ecologists for many years have used theories of information to describe the fauna of a biome in terms of a "diversity index". While informaticists have adopted some ecological concepts and indices, the field has not fully embraced the ecological framework of a living system as a function of an information system. To what extent can information scientists leverage global measures of biological systems for information systems research? [11] Using a quantitative design science approach, we have developed instrumentation towards this goal. In viewing information systems research from this perspective, additional lines of inquiry have unfolded:

1. To what extent can ecological measures be globally applied to information systems?
2. How does this ecological instrumentation provide value for information systems research?
3. Could a researcher simply use a more traditional statistical method?

Addressing the third question, most ecological systems have a tremendous amount of variation. For example, an earthworm has an average soil population size of 35 organisms per cubic meter of soil [4]. Within that same soil is another organism, the Springtail isopod insect with over 6,000 known species across the globe at times having over 100,000 organisms per cubic meter of soil [6]. The n-sample deviation



(Figure 1. Position of a Dataphora [26]) between these two species can be statistically challenging to shape. Therefore, fauna size, diversity and variation within an ecosystem makes some quantitative research methods less attractive for ecological studies [1]. Similarly, diverse units of data such as letters, numbers and symbols make up sentences, equations, and other data forms that ultimately compose documents and other informational artifacts. Modeling information systems from a biological perspective requires a new way of thinking. Our research allows for an information system's stability to be a) characterized and b) predicted using ecological measures specific to the diversity of data within the ecosystem. Herein we introduce a new method for measuring dataphoric ascendancy via the taxonomic structures of a dataphora.

2. Theoretical Framework

Wheeler's "it from bit" inspired us to create this theoretical framework [36]. It is the concept that the entire universe is a computable medium; we are all computationally bound bits of information. A dataphore is a portmanteau of "data" and "phore"; phore is of Greek origin and in English it means, "…to bear or produce". Therefore a "dataphore" is a "bearer of data". In our ontology, a dataphore is a data bearing entity - a knowledge object within an information system that metabolizes data. In our research ontology, a "dataphore" is a noun; "dataphoric" is the adjective that embodies trophic activities of a dataphore within an information system. The dataphora is equivalent to a biological biome; the dataphore is equivalent to the plants and animals within that biome. The dataphora is the information system and the dataphores are the informationally-bound entities within the dataphora. Furthermore, Dataphores are represented by their taxonomy. The dataphora is ontologically bound to this framework. (See Figure 1. Position of a Dataphora).

Dataphores are complex knowledge objects within an organization. Dataphores are composed of histological data forms which are in turn composed of cellular data forms. Cellular data forms are known as datum: symbols, codes, words and phrases. Overtime, a comingling of datum occurs. This leads to the creation of histological data forms known simply as data. Data collectives that are successfully adopted within the organizational dataphora are further refined and used to create complex dataphores (i.e., videos, diagrams, presentations, books). We assert that for a dataphora to survive external perturbations, it must reach certain system thresholds to maintain stability. Ecologically speaking, ecosystems can exist in an unstable state and can survive for many generations [12]. When ecologists refer to the instability of an ecosystem, they are not referring to its demise. Rather this terminology reflects its vulnerability to external impacts [7]. In other words, when a system is unstable, it is more vulnerable to external forces that an otherwise more stable ecosystem can withstand. We hypothesize that a dataphora's success correlates to an increase in species diversity and a decrease in species dominance, and success in this context is a function of a system's stability. This can be modeled via stability metrics using multiple ecological measures of diversity, uniformity, and dominance. Our null hypothesis is that diversity measures have no correlation to system stability. Much like the diversity of fauna within a biological biome, an information system's stability is dependent on the diversity of its species (i.e., dataphores) increasing over time.

2.1. A Description Using Hypothetical Extremes

Data at lower levels of the dataphora are leveraged by data at higher levels of the dataphora (e.g., words in a paragraph: words at a low level, the paragraph at a higher level). This can be visualized in a business sense as well. Using a hypothetical use case, analytical content can consume massive amounts of information [21].

For example, the analytical content of a board report would leverage data from multiple lower level department reports within a business organization. The lower level department reports would in turn use raw transactional data (i.e., creating a product sales metric from raw sales data). In this scenario, the raw transactional data can represent the number of transactional records available for reporting purposes. In this example there are three levels: the board report, the department reports, and the raw transactional data underlying the departmental reports. Using this hypothetical example between the analytical data system and transactional data systems we can conceptualize the role that data dominance, diversity and uniformity play regarding the stability of the information system (Table 1. Hypothetical Example: Analytically Driven Data System).

In this hypothetical example, we will be using a simple four-point scale to convey conceptually how the ecosystem is characterized according to diversity, dominance, and uniformity. This conceptual scale is: Very Low, Low, High, and Very High. The actual ecosystem metrics are numerical (their detail is documented in section 2.2).

This model depicts an analytically driven ecosystem. Each hypothetical example will have 3000 data species (i.e., dataphores). The first example will characterize extreme dominance. The second example will describe extreme diversity - or to be more precise - exact uniformity. The third example will characterize diverse stability. Ten species per example are illustrated:

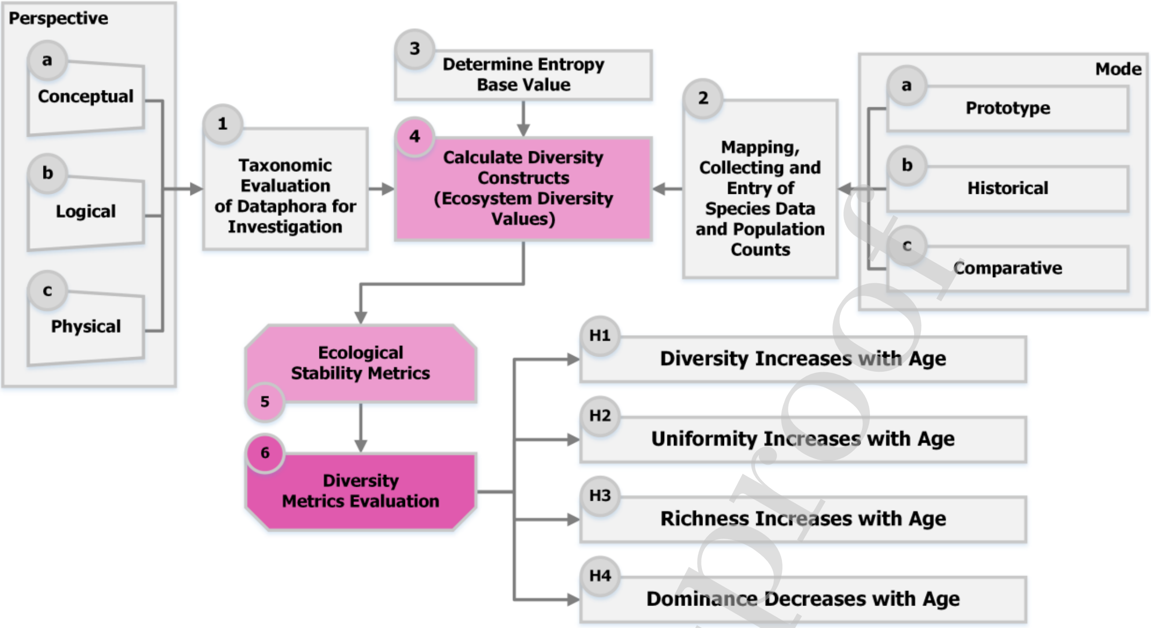
1. Annual Transaction Data
    a. s1: Accounting Transactions
    b. s2: Sales Transactions
    c. s3: Marketing Transactions
    d. s4: Supply Chain Transactions
    e. s5: Technology Transactions
2. Department Reports
    a. s6: Income Statement
    b. s7: Sales Report
    c. s8: Marketing Scorecard
    d. s9: Supply Chain Performance Dashboard
3. Board Report
    a. s10: Board Report

Our first hypothetical model is called “Extreme Dominance”. This model contains one board report (s10). The board report is fed by analytical reporting structures from 4 different departments (s5, s6, s7, s8, s9). The department level reports in turn leverage annual transaction data (s1, s2, s3, and s4). In the “Extreme Dominance” example, we predict that the system will ultimately fail due to transactional data insufficiency. While the accounting level report will be sufficient to maintain s6, the other department reports will be data deficient (e.g., 20 transactional records is most likely not a sufficient amount of information to support the needs of a sales report). Consequently, s7, s8 and s9 will be non-functional as it relates to the board report. For this analytical system to be stable, a larger and more diverse set of lower level transactions is required. This lack of diversity is measurable. In this example, the dominance is very high, the Diversity is very low, and the Uniformity is very low. Conceptually, these ecological measures indicate a system that is vulnerable to eventual collapse, or even immediate collapse.

However, what if we were to take this system to its extreme? Equal numbers across all species? In this extreme diversity scenario, the species are adjusted to be even. This second model is called "Exact Uniformity". In this model we have 300 board reports (s10), 1200 department reports (s5, s6, s7, s8, and s9), and 1500 transactional data records (s1, s2, s3, s4, and s5). The analytical data system now has to contend with 300 board reports. Each board report at this level will be working to displace each other as there should be only one unified board report. In an ideal sense, each “species” of a board report will cross compete for metric relevance. As the number of board reports shrink over time, so will their associated departmental reporting associations. Hypothetically speaking, a technically correct board report could be discarded in favor of a more politically correct board report. This system should eventually settle into a state of stability. High levels of extreme diversity are associated with higher levels of competition [16]. In this second example, the system should survive; however, it will seek to find stability based on the environmental constraints (i.e., most organization

System Character	Dominance	Diversity	Uniformity	Population Size	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10
Extreme Dominance	VERY HIGH	VERY LOW	VERY LOW	3000	2889	20	20	20	20	10	10	5	5	1
Exact Uniformity	VERY LOW	VERY HIGH	VERY HIGH	3000	300	300	300	300	300	300	300	300	300	300
Diverse Stability	LOW	HIGH	HIGH	3000	1000	450	450	410	500	50	50	50	39	1

(Table 1: Hypothetical Example: Analytically Driven Data System)



(Figure 2. Ascendancy Research Method)

usually have a singular board report). In a way, the board report is the "apex predator" [15][29]. In this second model, the dominance score is very low, the Diversity score is very high, and its Uniformity is very high.

In our third and final example, the system reaches "Diverse Stability". This model contains 1 board report (s10), 189 department reports (s5, s6, s7, s8, and s9), and 2810 transactional records (s1, s2, s3, s4, and s5). The system should reach a stable state. Each department report now has access to a complete year of annual transaction data. In turn, the board report has access to consume a more robust set of department level reports. Consequently, the board report should be more functionally complete. This ecosystem of data would be more resistant to external influence. In this final example, the dominance score is low, the Diversity score is high, and its Uniformity is high. This third hypothetical example – conceptually – is a stable ecosystem. Furthermore, this characterization of diverse stability is also exhibited naturally (e.g., biological systems) and artificially (e.g., urban systems) [2][33].

2.2. Ascendancy Research Method

This research method is the first of its kind. The Ascendancy Research Method was developed as part of this research due to the research questions posed. The ascendancy research method (ARM) is grouped into six stages:

1. Evaluation of Dataphora Perspective
2. Taxonomic Species Mapping & Data Collection
3. Base Entropy Evaluation
4. Calculation of Diversity Constructs
5. Construction of Ecological Stability Metrics
6. Ascendancy Evaluation

In the first phase, a dataphora's taxonomic perspective needs to be evaluated (Figure 2. Ascendancy Research Method). In biological cladistics, there are 8 levels of taxonomic classification [20]. Our dataphoric system of classification leverages biological levels in a similar way. The physical taxonomy of Wikipedia – as depicted in Table 1 - represents a containerization of species at a higher level much like *Homo sapien sapiens* is taxonomically containerized in the kingdom of Animalia [28]. In this way, this taxonomic perspective of Wikipedia is measuring the diversity of Wikipedia at kingdom level. Higher levels of species analysis are valid when considering the broader context of diversity across an ecosystem [8]. However, our second study will evaluate a lower – categorically focused – genus level view of Wikipedia taxonomy [5]. To the extent that taxonomic information structures within an information system are evident, these ecological measures can be applied to quantitatively describe the taxonomic diversity of the information system under observation. The taxonomic mapping can be approached from three perspectives: conceptual, logical, or physical. Conceptual mapping is the least quantitatively oriented perspective as this method of mapping is more qualitative in nature. The conceptual usage of a taxonomic mapping is best used when dataphore estimates can be verified via organizational subject matter experts, or when a taxonomic schema of the information space is somewhat vague and needs to be established by the researcher. Conceptual mapping is best used for the 'prototype' mode of the Ascendancy Research Method (See Figure 2, Ascendancy Research Method). A logical taxonomic approach is a topological approach to structuring dataphoric space. The use of topological structures may present challenges in cases where the metadata of the taxonomy exists and the underlying data itself is missing within the topological taxonomy. For example, an information system's published metadata may illustrate what appears to be a comprehensive topological framework (e.g., digitialuniverse.net); however, many topics within the framework were devoid of content [32]. In these cases, the topological framework under observation must be manually traversed to confirm that a taxonomy is indeed devoid of content. If we were to contrast ecological models between two information systems (e.g., digitaluniverse.net versus wikipedia.org) we would find them to be ecologically similar.

Yet, if we look at the actual data content, we would find that their topological species counts would be dramatically different. Lastly, the structure of the taxonomy itself does not impact the stability of a system. For example, the reclassification of a whole species in the taxonomy would do very little in terms of effecting an ecosystems stability. However, if for example, a new species was found and classified as a new species within the taxonomy, the data indicates that this would have an impact on system stability as this would influence the diversity of the taxonomy within the dataphoric ecosystem. In other words, the renaming of a topic does not change the diversity values within the "flora of data". A reclassification of the taxonomy does not change the underlying diversity metrics so long as the species within the taxonomy are still considered to be similar in nature [14].

In the second phase, the researcher must map the taxonomic species according to the type of study they are going to undertake. There are three types: prototype, historical, or comparative. The prototype approach is a quick analysis; the taxonomic population data is usually gathered from a single point in time. This step is to demonstrate that the taxonomic mappings are appropriate and useful before undertaking a larger data collection effort. It can also be used to quickly compare an information system under investigation against baseline diversity values of known biological systems (included as part of this research). The historical data pull is used to evaluate a single dataphora over time. It allows the researcher to see the evolution of a dataphora from a temporal perspective. This is a more rigorous mapping exercise and requires strong historical data reporting of the taxonomy under observation. Lastly, the comparative method is used when a researcher would like to contrast the diversity between two ecosystems. For example, a researcher could compare how the global properties of an ecosystem predicted the rise of one and the decline of another. For the purposes of this research, we will be performing two studies: a singular historical study using the physical taxonomy of Wikipedia. As mentioned earlier in this section, this is a higher-level taxonomic perspective of Wikipedia's ecosystem (Table 2. First Study, Taxonomic Mapping). In the second study, we will be performing a lower level topological study using the comparative method (Section 5, See Table 6. Second Study, Comparative Ecosystem Evaluation). After an approach has been selected, we then enter species and population counts into the dataphore matrix (e.g., species level data matrix) (See Table 3: First Study, Dataphoric Species Matrix [Wikipedia]).

Information Space Mapping: Wikipedia's Namespace					
s1	**s2**	**s3**	**s4**	**s5**	**s6**
Talk	**User**	**Wikipedia**	**File**	**MediaWiki**	**Template**
s7	**s8**	**s9**	**s10**	**s11**	**s12**
Help	**Category**	**Portal**	**Book**	**Draft**	**Module**
s13	**s14**	**s15**	**s16**	**s17**	
TimedText	**Main**	**Topic**	**Gadget**	**Image**	

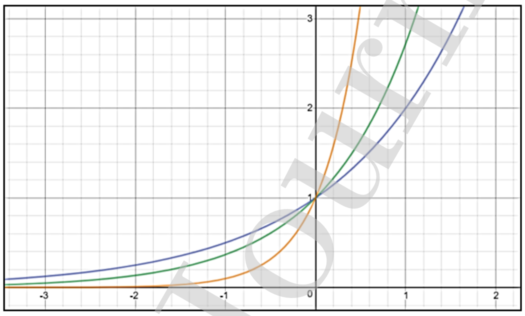
(Table 2. First Study, Taxonomic Mapping)

In the third phase, a base entropy value must be selected (See Figure 3. Log Base Curve Examples).

		Dataphora Species Matrix (Perspective: Physical, Mode: Historical)																
Dataphora Perspective	**Dataphora Name**	**s1**	**s2**	**s3**	**s4**	**s5**	**s6**	**s7**	**s8**	**s9**	**s10**	**s11**	**s12**	**s13**	**s14**	**s15**	**s16**	**s17**
Physical 2008	Wikipedia	2.47×10^6	6.83×10^5	3.93×10^5	0	1.07×10^3	1.93×10^5	4.58×10^2	4.27×10^5	6.55×10^4	0	0	0	0	5.87×10^6	0	0	8.51×10^5
Physical 2009	Wikipedia	3.23×10^6	9.08×10^5	5.08×10^5	9.05×10^5	1.33×10^3	2.55×10^5	6.28×10^2	5.43×10^5	8.07×10^4	0	0	0	0	7.13×10^6	0	0	0
Physical 2010	Wikipedia	3.87×10^6	1.11×10^6	6.04×10^5	8.82×10^5	1.40×10^3	3.21×10^5	8.11×10^2	6.60×10^5	9.49×10^4	2.02×10^3	0	0	0	8.25×10^6	0	0	0
Physical 2011	Wikipedia	4.35×10^6	1.36×10^6	6.91×10^5	8.33×10^5	1.56×10^3	4.06×10^5	9.08×10^2	8.05×10^5	1.07×10^5	2.77×10^3	0	0	0	9.07×10^6	0	0	0
Physical 2012	Wikipedia	4.82×10^6	1.58×10^6	7.50×10^5	8.18×10^5	1.66×10^3	4.67×10^5	1.17×10^3	9.31×10^5	1.15×10^5	3.62×10^3	0	0	3.20×10^1	9.92×10^6	0	0	0
Physical 2013	Wikipedia	5.28×10^6	1.77×10^6	8.01×10^5	8.42×10^5	1.91×10^3	5.32×10^5	1.35×10^3	1.07×10^6	1.22×10^5	4.44×10^3	0	7.35×10^2	1.74×10^2	1.06×10^7	0	0	0
Physical 2014	Wikipedia	5.57×10^6	1.90×10^6	8.42×10^5	8.63×10^5	1.99×10^3	5.75×10^5	1.40×10^3	1.14×10^6	1.28×10^5	4.99×10^3	1.02×10^4	1.51×10^3	2.54×10^2	1.11×10^7	0	0	0
Physical 2015	Wikipedia	6.22×10^6	2.23×10^6	9.48×10^5	9.05×10^5	2.08×10^3	6.44×10^5	1.82×10^3	1.34×10^6	1.39×10^5	6.38×10^3	4.66×10^4	2.76×10^3	4.67×10^2	1.21×10^7	3.10×10^2	1	0
Physical 2016	Wikipedia	6.77×10^6	2.42×10^6	1.01×10^6	8.88×10^5	2.15×10^3	5.79×10^5	1.93×10^3	1.51×10^6	1.44×10^5	7.08×10^3	5.74×10^4	3.79×10^3	5.95×10^2	1.30×10^7	0	1	0
Physical 2017	Wikipedia	7.14×10^6	2.66×10^6	1.07×10^6	8.91×10^5	2.19×10^3	6.07×10^5	2.15×10^3	1.66×10^6	1.48×10^5	7.36×10^3	7.05×10^4	4.83×10^3	7.55×10^2	1.36×10^7	0	1	0
Physical 2018	Wikipedia	7.30×10^6	2.77×10^6	1.10×10^6	9.01×10^5	2.23×10^3	6.12×10^5	2.18×10^3	1.70×10^6	1.49×10^5	7.51×10^3	8.11×10^4	8.39×10^3	8.12×10^2	1.39×10^7	0	1	0

(Table 3. First Study, Dataphoric Species Matrix [Wikipedia])

The base value of the log can be 2, *e*, or 10 (Euler's number - *e* - is approximately 2.71828). Why is *e* important in this context? Euler's Number is important when discussing the limit of growth. Euler's Number is to the scaling of growth (or decay) of natural systems like pi (π) is to the scaling of a circle. A higher base value is used in cases where the ecosystem growth is observed to be faster than *e*. A lower base value is used in cases where the ecosystem growth is slower than a natural process (See Figure 3. Log Base Curve Examples). Setting the log base to *e* is a good start as it approximates rather well the limit of growth found within natural processes [19]. Lastly, the base value in our tool only influences the Margalef Index (for richness) and Entropy (for uniformity).



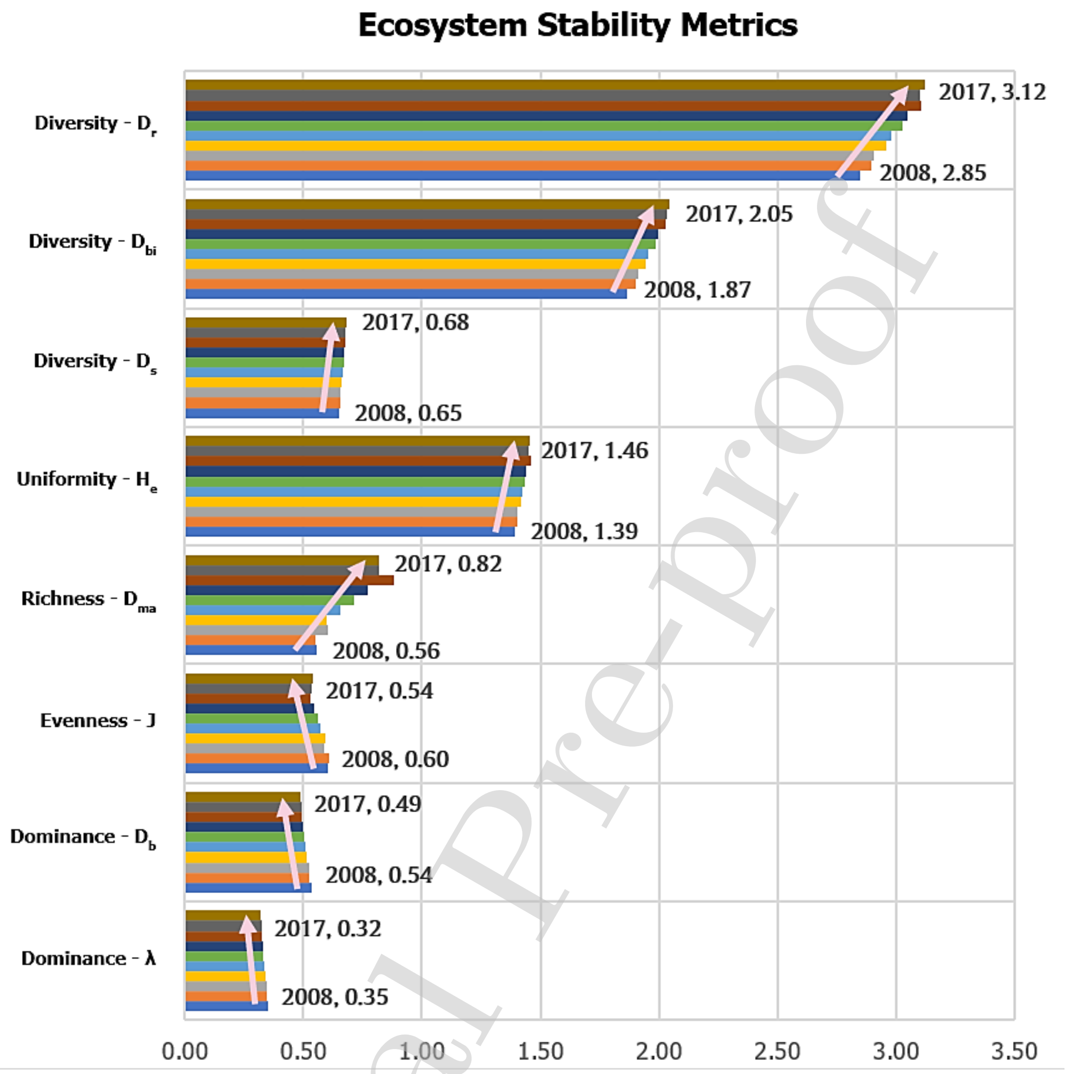
$x = log_e y$ (green), $x = log_2 y$ (blue), $x = log_{10} y$ (orange)

(Figure 3. Log Base Curve Examples)

In phase four, we calculate the diversity values according to eight common ecological measures:

1. Berger-Parker Index, Inverted (D_{bi}) – Measure of Diversity: higher equals more diversity
2. Berger-Parker Index (D_b) – Measure of Dominance: higher means more dominance
3. Margalef Richness Index (D_{ma}) – Measure of Richness: higher equals more species
4. Simpson index (λ) – Classical Dominance: higher means more dominance
5. Simpson Index (D_s) – Classical Diversity: higher equals more species
6. Simpson Index (D_r) – Reciprocal Simpson Index: higher equals more species
7. Shannon Index (H_e) – Measure of Homogeny: higher means uniform ecosystem [27]
8. Pielou Index (J) – Measure of Evenness: higher means a more equal distribution of species [23]

While many of the metrics above were found via historical scholarly references, combined references of the above ecosystem metrics do exist [22][25]. We constructed a spreadsheet tool to calculate the above values automatically. This tool has been made available for others to use on ResearchGate [25]. After the ecological values have been calculated, our tool outputs an ecological stability metrics (See Figure 4. First Study, Ecological Stability Metrics). In the final



(Figure 4. First Study, Ecological Stability Metrics)

phase, we compare the source ecological measures for dominance, diversity, richness, evenness, equitability and size against the target dataphora under investigation (or a historical average).

3. Data Collection & Taxonomic Mappings

We collected 39 point-in-time samples of Wikipedia's Namespace covering a time span of eleven years [38]. The taxonomic structure of Wikipedia is a measurable framework [10][35]. Wikipedia is considered a successful knowledge management system [39]. We collected the number of pages per taxonomic species by the point-in-time page counts via multiple samples per year as labeled via a specific Namespace. Unlike a topological taxonomy, Wikipedia's namespace is more physically oriented. For example, Wikipedia's namespace documents the number of physical items, such as books, images and files.

After having established the taxonomic mappings, we entered the taxonomic data into the dataphoric species matrix (See Table 3. First Study, Dataphoric Species Matrix [Wikipedia]). This correlates the taxonomic species information according to the dataphora under observation. Our first study comprises a physical taxonomic structure using the historical mode of the Ascendancy Research Method. Since we collected annual Wikipedia Namespace counts, our dataphoric species matrix requires that each line of the taxonomic page data be correlated to its appropriate time period. After finalizing the dataphoric species matrix we are now able to focus our efforts on the evaluation of the ecosystem.

4. Baseline & Ecosystem Evaluation

Included in the research is a broad spectrum of ecological measures. This increases our ability to measure the global properties of a dataphora as accurately as possible. The eight ecological measures are used to ensure internal validity, external validity and construct validity. For example, we have multiple measures of diversity and dominance. We also know that there should be an inverse relation between diversity and dominance. Therefore, if we see multiple measures of dominance rise, we should also see multiple levels of diversity decrease.

We mentioned earlier that traditional statistical methods are less than ideal in ecological studies. While they work fine for lower levels of analysis (i.e., local phenomenon within the dataphora), they begin to breakdown at a global level. To illustrate this point we included the variance and standard deviation of each population species sample; as one can see the variations and deviations are quite large (See Table 4. First Study, Descriptive Statistics).

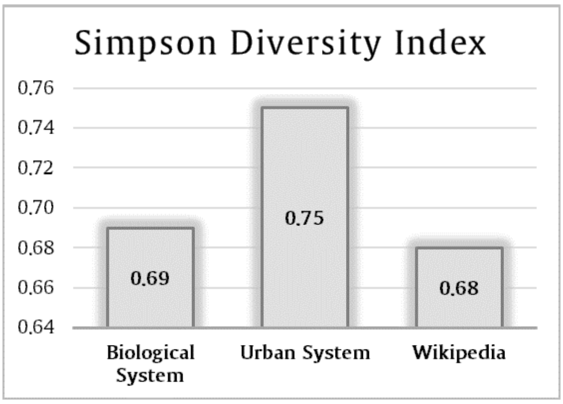
For comparative purposes, a measurable baseline of the Simpson Diversity Index (D_s) of other systems was captured. Biologically, an ecosystem reaches a balanced state when the Simpson Diversity Index is approximately between 0.65 ~ 0.80 [24][33]. In urban systems analysis, a stable urban system has a Simpson Diversity Index (SDI = D_s) that approximates 0.75 [2]. In this first study, when computing the SDI for Wikipedia we arrive at a D_s value of 0.68 as measured in 2018. This compares favorably to other systems. (See Figure 5. First Study, SDI Compared).

Given the aforementioned diversity value of Wikipedia, we can ecologically describe Wikipedia as a diverse, and stable, information system. However, we must be careful when making a case for this characterization based on a singular metric. A higher degree of diversity can be confirmed via the other measures of dominance and evenness.

If there is a higher degree of diversity there should be a corresponding decrease in dominance. Indeed, in this first study, measures of dominance descend (D_b and λ) as measures of diversity rise (D_r, D_{bi} and D_s). In addition, the value of evenness (J) being equal to 0.54 also indicates that the system is not dominated by a single taxonomic species.

Dataphora Perspective	Dataphora Name	Descriptive Statistics		
Physical 2008	Wikipedia	6.44×10^5	2.18×10^{12}	1.47×10^6
Physical 2009	Wikipedia	7.97×10^5	3.29×10^{12}	1.81×10^6
Physical 2010	Wikipedia	9.29×10^5	4.45×10^{12}	2.11×10^6
Physical 2011	Wikipedia	1.03×10^6	5.42×10^{12}	2.32×10^6
Physical 2012	Wikipedia	1.14×10^6	6.52×10^{12}	2.55×10^6
Physical 2013	Wikipedia	1.23×10^6	7.48×10^{12}	2.73×10^6
Physical 2014	Wikipedia	1.30×10^6	8.21×10^{12}	2.86×10^6
Physical 2015	Wikipedia	1.44×10^6	9.96×10^{12}	3.15×10^6
Physical 2016	Wikipedia	1.55×10^6	1.14×10^{13}	3.38×10^6
Physical 2017	Wikipedia	1.64×10^6	1.27×10^{13}	3.56×10^6
Physical 2018	Wikipedia	1.68×10^6	1.32×10^{13}	3.64×10^6
Descriptive Space Data		Statistical Mean	Statistical Variance	Statistical Standard Deviation
N Total Organisms	28577778			
Population x̄	1681046			

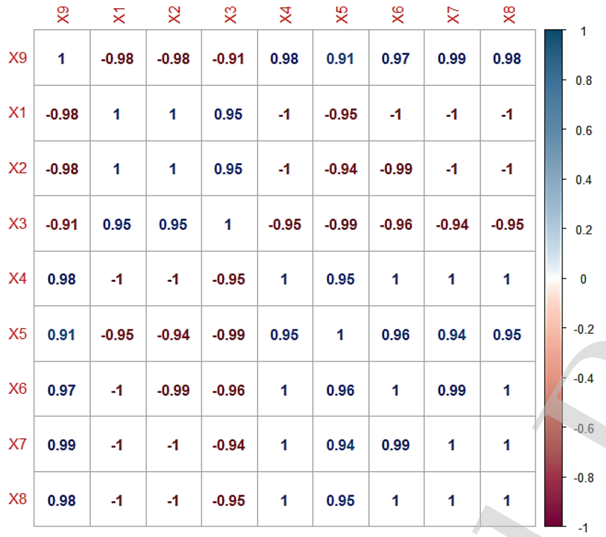
(Table 4. First Study, Descriptive Statistics)



(Figure 5. Fist Study, SDI Compared)

Using R-Studio for statistical regression analysis, we created 8 dependent variables (associated with each ecological measure) and 1 independent variable (associated with the system's ecological time period).

1. DV, First Group = Wikipedia Ecological Measures
    a. X1 = Dominance: Simpson (λ)
    b. X2 = Dominance: BPI (D_b)
    c. X3 = Evenness: Pielou (J)
    d. X4 = Diversity: Simpson (D_s)
    e. X5 = Richness: Margalef (D_{ma})
    f. X6 = Uniformity: Shannon (H_e)
    g. X7 = Diversity: I.BPI (D_{bi})
    h. X8 = Diversity: Simpson (D_r)
2. IV, Second Group = Ecological Time Period of Wikipedia
    a. X9 = Year/Age



	X9	X1	X2	X3	X4	X5	X6	X7	X8
X9	1	-0.98	-0.98	-0.91	0.98	0.91	0.97	0.99	0.98
X1	-0.98	1	1	0.95	-1	-0.95	-1	-1	-1
X2	-0.98	1	1	0.95	-1	-0.94	-0.99	-1	-1
X3	-0.91	0.95	0.95	1	-0.95	-0.99	-0.96	-0.94	-0.95
X4	0.98	-1	-1	-0.95	1	0.95	1	1	1
X5	0.91	-0.95	-0.94	-0.99	0.95	1	0.96	0.94	0.95
X6	0.97	-1	-0.99	-0.96	1	0.96	1	0.99	1
X7	0.99	-1	-1	-0.94	1	0.94	0.99	1	1
X8	0.98	-1	-1	-0.95	1	0.95	1	1	1

(Figure 6. First Study, Variable Correlation Matrix)

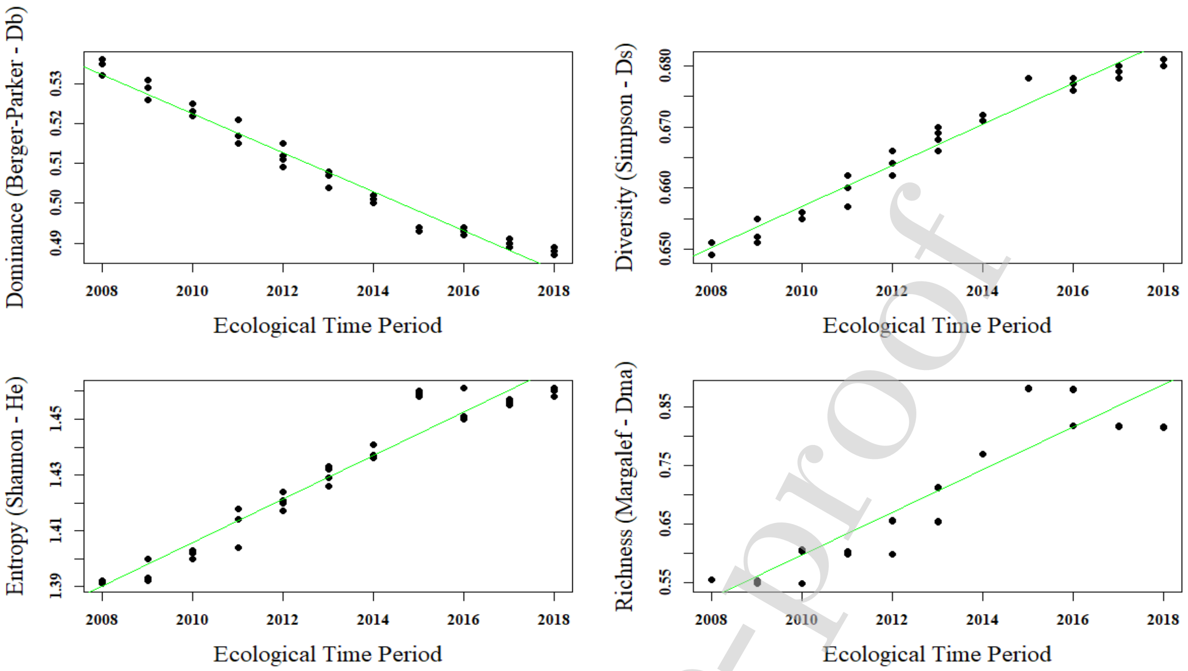
Using "Year (X9)" as the independent variable, we compare its correlation to the dependent variables (X1 though X8). Ecological time periods (X9) strongly correlates to X4 through X8 and negatively with X1 through X3. While all correlations are strong between X4 and X8, the highest correlation is X7 (the Inverted Berger-Parker Index [I.BPI]). The highest negative correlations are X1 (Simpson, Dominance) and X2 (Berger-Parker Index, Dominance). To ensure construct validity we leverage multiple measures of dominance and diversity to ensure that if we see dominance in one ecological indicator we can be sure that dominance is occurring if multiple indicators of dominance are increasing (i.e. versus relying solely on inversion measures such as I.BPI).

The regression analysis of diversity, dominance, richness and entropy all have strong correlations with the independent variable (Figure 6. First Study, Variable Correlation Matrix; See Figure 7. First Study, Regression Plots). Considering all dependent variables, here are the following statistical metrics. The residual standard error is 0.3832 across 31 degrees of freedom. The multiple R^2 value equals to 0.9873 with an adjusted R^2 of 0.9845. The F-statistic is 344.18 on 7 and 31 degrees of freedom. The *p* value is measured at 2.2 x 10^{-16}. Using the adjusted R^2 of 0. 9845 we can say that the 98.45% of the total variation of X9 is explained by the 8 dependent variables (X1 – X8). We reject the null hypothesis given the overall correlations found in the model and the statistical significance as measured by the *p* value. This finding allows us to corroborate many of our hypotheses. However, to increase our confidence, we expanded our dataset to include taxonomic data across 3 additional ecosystems (See Figure 5. Comparative Ecosystem Evaluation).

5. Evaluating Other Ecosystems

We have determined that in an established information system such as Wikipedia, as the diversity of a system increases with age, so does its overall stability. What does our method say for other ecosystems? In this regard, we evaluated 3 additional ecosystems: Citizendium (Physical), digitaluniverse.net (Conceptual) and YouTube (Logical) (See Table 5. Second Study, Comparative Ecosystems Analysis). In addition, we will be comparing these three ecosystems to that of the categorically focused perspective of Wikipedia's taxonomy (i.e., genus level perspective).

Citizendium and digitaluniverse.net are recognized as systems in decline [13][[22]. In the case of digitaluniverse.net, much of the content is nonexistent (per our research); many of the features do not appear to function (we requested an account and never received a login for the service). Therefore, the taxonomic species counts for digitaluniverse.net were modeled based on evaluations from our observations (i.e., manually traversing the taxonomic directory) as well as information from other documented parties [37]. In contrast to digitialuniverse.net, Citizendium is a more complete encyclopedic framework. In contrast to Wikipedia, Citizendium is small. Wikipedia's ecosystem is approximately 604 times larger than Citizendium's ecosystem (Wikipedia Data Species Count: 28,577,778; Citizendium Data Species Count: 47,265). Since January of 2019, our historical data of Citizendium shows that the data species count of



(Figure 7. First Study, Regression Plots)

Citizendium has remain unchanged. The ecosystem diversity values of Citizendium were calculated based on Citizendium's reported categorical counts [3].

The historical research mode is a singular ecosystem evaluation. The comparative research mode of the framework allows us to compare multiple ecosystems side by side (See Table 6. Second Study, Comparative Ecosystem Evaluation and Figure 8. Second Study: Diversity, Uniformity and Dominance). In our follow up analysis, we observed that lower levels of richness lead to an increase in system vulnerability (Citizendium: D_{ma} = 0.465). We also determined that entropy and diversity are useful indicators of system stability (YouTube: H_e = 2.059 and D_r = 6.021). However, system stability can be predicted when higher levels of entropy were found with higher levels of diversity and evenness (YouTube: J = 0.829, D_r = 6.021 and H_e = 2.059). In addition, vulnerability as it relates to higher levels of dominance within an information system is corroborated in our follow up study (digitaluniverse.net: D_b = 0.878). A lack of diversity can also lead to vulnerability (Citizendium: D_r = 2.670; digitaluniverse.net: D_r = 1.293). Overall, the general trends showcase that increasing diversity and uniformity of information within an information system leads to more stability (See Figure 8. Second Study, Diversity, Uniformity and Dominance).

6. Implications

Our research correctly predicted the collapse of digitaluniverse.net (i.e., the information service known as Digital Universe). In January of 2019 digitaluniverse.net was serving web pages. At that time, we determined that the ecosystem was not diverse based on our theory of dataphoric ascendancy and we therefore categorized the system as lacking diversity and we predicted that this would lead to instability. While the digitaluniverse.net ecosystem was available for use between 2006 and 2009, it's lowered taxonomic diversity, higher taxonomic dominance and lowered uniformity all predicted that the system would not reach dataphoric ascendancy. In the latter half of 2019, digitaluniverse.net was found to be nonfunctional. The demise of digitaluniverse.net lends additional support to our research framework.

Our model indicates that increasing levels of uniformity and diversity have ecosystem benefits. Conversely, increasing levels of dominance can also have benefits if the desired outcome is to effect system dissolution. For example, an organization may want to rid itself of a legacy system. Using methods contained within this research, the system's vulnerability can be influenced via the introduction of an extreme dominance protocol.

Information Space Mapping: Wikipedia Topology (Logical)				
s1	s2	s3	s4	s5
Reference	Culture	Geography	Health	History
s6	s7	s8	s9	s10
Human Activities	People	Philosophy	Religion	Society
s12	s13	s14	s16	s17
Religion	Society	Technology		

Information Space Mapping: YouTube Topology (Logical)				
s1	s2	s3	s4	s5
Entertainment	Music	Comedy	People & Blogs	Film & Animations
s7	s8	s9	s10	s11
Sports	News & Politics	Autos & Vehicles	Howto & Style	Pets & Animals
s7	s8	s9	s10	s11
Travel & Events	Education			

Information Space Mapping: digitaluniverse.net Topology (Conceptual)				
s1	s2	s3	s4	s5
Arts & Entertainment	Earth, Nature & Environment	Education & Learning	Home, Family & Health	Places & Geography
s6	s7	s8	s9	s10
Professional & Career	Science & Technology	Society & Government	Sports & Recreation	The Universe

Information Space Mapping: Citizendium Topology (Physical)				
s1	s2	s3	s4	s5
Definitions	Articles	Bibliographies	External Links	Galleries
s6	s7	s8	s9	s10
Videos				

(Table 5. Second Study, Comparative Ecosystems Analysis)

In this regard, there are three system characterizations of interest. First, systems that exhibit dominance tend towards instability. These systems are resistant to change and they are also vulnerable to collapse. Second, systems found to have higher levels of uniformity are unstable. However, these systems are not resistant to change. These systems are described as stability seeking (i.e., they are stable yet porous to external influences). Lastly, systems that are of diverse stability are stable and are resistant to change.

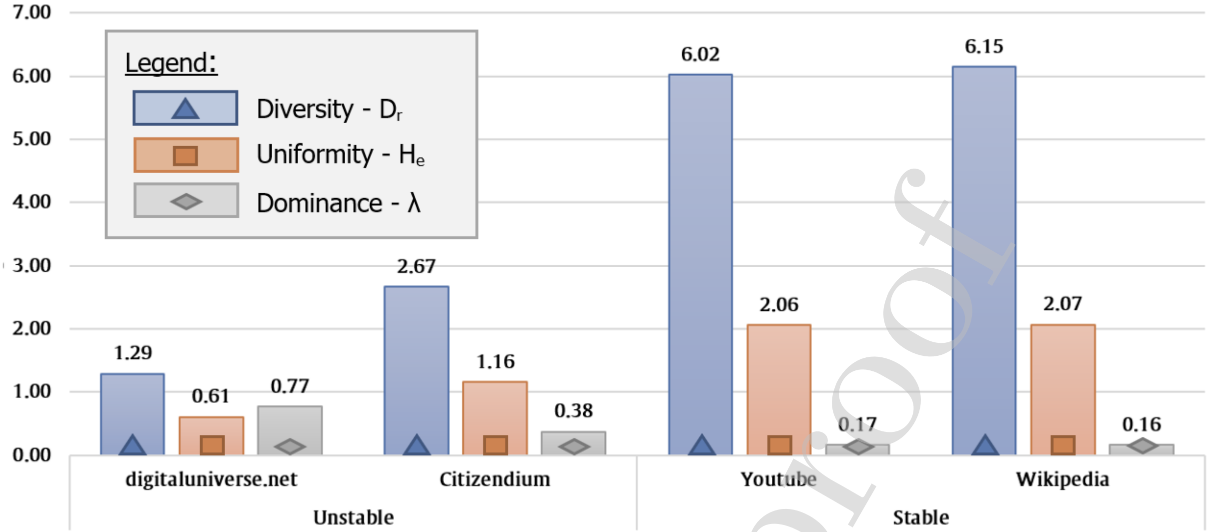
Strategically, these implications are profound. This research can be used to influence a system's stability (e.g., stability or instability) or pliability (e.g., pliability or inflexibility). For example, is a system's resistance to change ideal? Adjusting the uniformity of a system would influence the pliability of a system, such that a system becomes more susceptible to suggestion through the introduction of an "exact uniformity" protocol. In addition, this research provides a means to measure a systems proximity to exact uniformity or its movement towards either extreme dominance or diverse stability. Conversely, when system pliability is not warranted, this research illustrates how a researcher could influence a system "hardening" process and measure a systems progress towards a state resistant to change (e.g., a critical production system). Using factors related to the population of technology devices (or information taxonomies), we can apply this instrumentation to urban systems analysis, derelict information systems on the web, and expansion-decay of information within social media platforms.

7. Limitations & Conclusions

We have evaluated multiple ecosystems in various states of diversity. First, we were able to measure the diversity of an ecosystem overtime. Second, we were able to define, and contrast, the success factors of two ecosystems (Wikipedia and YouTube) to that of two ecosystems in decline (Citizendium and digitaluniverse.net). Third, we determined that an increasing species uniformity combined with increasing

		2.718	<= Log Base Options: 2, 10 or *e* (Euler's Number)						
Dataphora Perspective	Dataphora Type	Ecosystem Diversity Values							
Physical	Citizendium	1.962	0.51	0.465	0.375	0.625	2.67	1.159	0.647
Logical	Wikipedia	3.695	0.271	0.753	0.163	0.837	6.146	2.066	0.806
Logical	YouTube	3.842	0.26	0.713	0.166	0.834	6.021	2.059	0.829
Conceptual	digitaluniverse.net	1.139	0.878	1.049	0.773	0.227	1.293	0.606	0.276
		D_{bi}	D_b	D_{ma}	λ	D_s	D_r	H_e	J
Average Diversity (All Dataphoras)	0.631	Inv. Berger-Parker Index	Berger-Parker Index	Margalef index	Simpson index(λ)	Simpson index(D)	Simpson index(Dr)	Shannon index(He)	Pielou index(J)
Average Dominance (All Dataphoras)	0.369	Diversity	Dominance	Richness	Dominance	Diversity	Diversity	Homogeny	Evenness

(Table 6. Second Study, Comparative Ecosystem Evaluation)



(Figure 8. Second Study: Diversity, Uniformity and Dominance)

species diversity led to higher levels of system stability. Fourth, we learned that that taxonomic diversity alone is not always a good indicator of system stability (e.g., Citizendium). Lastly, in our follow-up study, we did not see as strong a correlation for richness as a contributing factor towards system stability. However, additional ecosystem studies should determine more accurately the effectiveness of the richness metric.

To some extent our addition of Citizendium showcases a non-stable system that is diverse. Citizendium had a lower than expected dominance value (0.38) which would be considered stable via this metric alone. However, when combined with taxonomic uniformity (entropy values approaching 1.00) we have characterized Citizendium as a vulnerable ecosystem. In the case of a non-diverse information system, we found that digitaluniverse.net fit this mold – and we correctly predicted its demise. At its inception in 2006, it was not diverse by any measure we could find.

Statistically speaking, the degrees of freedom are low. However, to put this into perspective, the sample size, while low, was quite high when the whole ecosystem is considered. There were thousands of Wikipedia data samples available to us; yet, the variation in the data species between quarters was very gradual, such that the diversity indices were sometimes equivalent, even over many months. Much like in statistical sampling, a higher number of distinct species is more explanatory. In this case, a researcher should aim to have at least eight - preferably above 12 - taxonomically distinct dataphores within a dataphora. Other quantitative studies such as structured equation modeling or logistic regression (stable or not stable) could be applied to ecological studies in dataphoric space [18].

Like dataphoric diversity, we believe that the establishment of a taxonomic structure is just as important to establishing eventual stability of a dataphora. A taxonomy of the dataphora does not confer ecological stability; however, it is essential to dataphoric theory. The taxonomy itself does not impact ecosystem stability. However, in ecosystems analysis such as this, the taxonomy itself is the measurement model. The taxonomy does not impart stability, it merely allows us to measure it. In addition to the taxonomy, the uniformity of the ecosystem creates an interesting dynamic. Lower levels of uniformity within an ecosystem are susceptible to eradication by more well-established ecosystems. For example, a small pond containing a variety of fish, frogs and snails could have a high diversity index but could easily be eradicated by a short drought in rainfall. Yet, we hypothesize that extremely high levels of uniformity (i.e., exact uniformity) may create system instability.

The principles of dataphoric ascendancy in theory could apply not only to data within an organization, but should in theory extend to its people as well. The concept of dataphoric space treats any computational-based node (e.g., a human brain) within the system as "informationally bound" and would therefore be also bound to the same dataphoric principles of any other data object within the dataphora.

We have developed a method and theory that can influence and globally evaluate the evolution of an information system. The instrumentation introduced as part of this research creates, as an output, many useful ecosystem metrics. Our findings provide support for a) the Ascendancy Research Method and its associated ecological stability metrics b) our theory of dataphoric ascendancy using measures of uniformity, diversity and dominance and c) a stable dataphoric pattern of a dataphora that is measurable and predictive.

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Information System Ecology: An Application of Dataphoric Ascendancy
(Highlights)

1. Introduction

- The theory of dataphoric space describes an information system as a biologically-styled biome in which "species of information" reside [13].
- To what extent can ecological measures be globally applied to information systems?
- How does this ecological instrumentation provide value for information systems research?
- Could a researcher simply use a more traditional statistical methods?

2. Theoretical Framework

- A dataphore is a portmanteau of "data" and "phore"; phore is of Greek origin and in English it means, "…to bear or produce". Therefore a "dataphore" is a "bearer of data".
- Dataphores are complex knowledge objects within an organization which become more complex as organizations grow.
- We hypothesize that a dataphora's success correlates to an increase in species diversity and a decrease in species dominance, and success is a function of age of the information system.
- This can be modeled via a stability curve using multiple ecological measures of maturity, dominance, diversity, richness and evenness.

2.1. A Description Using Hypothetical Extremes

- Data at lower levels of the dataphora are leveraged by data at higher levels of the dataphora (e.g., words in a paragraph: words at a low level, the paragraph at a higher level).
- Using a hypothetical use case, analytical content can consume massive amounts of information [21].
- Using this hypothetical example between the analytical data system and transactional data systems we can conceptualize the role that data dominance, diversity and uniformity play regarding the stability of the information system

2.2. Ascendancy Research Method

- This research method is the first of its kind.
- The Ascendancy Research Method was developed as part of this research due to the research questions posed.
- In biological cladistics, there are 8 levels of taxonomic classification [20].
- Our dataphoric system of classification leverages biological levels in a similar
- In the first phase, a dataphora needs to be evaluated for suitability.
- In the second phase, the researcher has to map the taxonomic species according to the type of study they are going to undertake.
- In the third phase, we need to pick a base entropy value.
- In phase four, we calculate the diversity values according to eight common ecological measure.

3. Data Collection & Taxonomic Mappings

- We collected 39 point-in-time samples of Wikipedia's Namespace covering a time span of eleven years [22].
- The taxonomic structure of Wikipedia is a measurable framework [7][19]. In addition, Wikipedia is considered a successful knowledge management system [23].
- We collected the number of pages per taxonomic species by the point-in-time

page counts via multiple samples per year as labeled via a specific Namespace.

4. Baseline & Ecosystem Evaluation

- A higher degree of diversity can be confirmed via the other measures of dominance and evenness.
- The regression analysis of diversity, dominance, richness and entropy all have strong correlations with the independent variable.
- Taking into account all dependent variables we come up with the following statistical metrics.
- The residual standard error is 0.3832 across 31 degrees of freedom. The multiple R^2 value equals to 0.9873 with an adjusted R^2 of 0.9845.
- The F-statistic is 344.18 on 7 and 31 degrees of freedom. The p-value is less than "2.2e-16".
- Using the adjusted R^2 of 0. 9845 we can say that the 98.45% of the total variation of X9 is explained by the 8 dependent variables (X1 – X8).
- We reject the null hypothesis given the overall correlations found in the model.

5. Evaluating Other Ecosystems

- Citizendium and digitaluniverse.net are recognized as systems in decline.
- In the case of digitaluniverse.net, much of the content is nonexistent (per our research); many of the features do not appear to function (we requested an account and never received a login for the service).
- We also determined that entropy and diversity are useful indicators of system stability (Youtube: $H_e = 2.059$ and $D_r = 6.021$).
- Overall, the general trends showcase that increasing diversity and uniformity of information within an information system leads to more stability.

6. Implications

- Our research correctly predicted the collapse of digitaluniverse.net (i.e., the information service known as Digital Universe).
- We have developed a method that allows for the global evaluation of an information system.
- There are three system characterizations of interest.
- First, systems that exhibit dominance tend towards instability. These systems are resistant to change and they are also vulnerable to collapse.
- Second, systems found to have higher levels of uniformity are unstable. However, these systems are not resistant to change. These systems are described as stability seeking (i.e., they are stable yet porous to external influences).
- Lastly, systems that are of diverse stability are stable and are resistant to change.

7. Limitations & Conclusions

- We have evaluated multiple ecosystems in various states of diversity.
- Like dataphoric diversity, establishment of a taxonomic structure is just as important to establishing eventual stability of a dataphora.
- Our findings provide support for a) the Ascendancy Research Method and its associated ecological stability metrics b) our theory of dataphoric ascendancy using measures of uniformity, diversity and dominance and c) a stable dataphoric pattern of a dataphora that is measurable and predictive.