

## The DRIADE Project: Phased Application Profile Development in Support of Open Science

Sarah Carrier  
School of Information and  
Library Science, University  
of North Carolina at Chapel  
Hill, USA  
scarrier@email.unc.edu

Jed Dube  
School of Information and  
Library Science, University  
of North Carolina at Chapel  
Hill, USA  
jdube@email.unc.edu

Jane Greenberg  
School of Information and  
Library Science, University  
of North Carolina at Chapel  
Hill, USA  
janeg@ils.unc.edu

### Abstract

DRIADE (Digital Repository of Information and Data for Evolution) is a project being developed for the acquisition, preservation, sharing and re-use of heterogeneous data in support of published research in the field of evolutionary biology. Metadata is a fundamental part of DRIADE's information architecture. This paper reports on DRIADE's overarching goals. We describe our phased approach to developing a modularized application profile, which supports three phases of DRIADE's development. We present a multi-method approach to developing the application profile. Our methods included a *requirements assessment*, *content analysis*, and *crosswalk analysis*. The paper concludes by identifying next steps and discussing the applicability of DRIADE's work to other initiatives seeking to tightly couple published research and data.

**Keywords:** application profile, open science, data objects, published data, metadata, data sharing, interoperability

### 1. Introduction

The Internet is dramatically impacting processes and practices for publishing, distributing, and sharing of scientific research. For example, GRID computing efforts, such as TeraGrid for large scale scientific data, are accessible via web interfaced portals that offer centralized data access and services. Equally significant is the growing number of "small science" digital repositories and initiatives, supporting data preservation and sharing. Examples include the Knowledge Network for Biocomplexity (KNB) (<http://knb.ecoinformatics.org/>) for ecological science and the Marine Metadata Interoperability Project (MMI) (<http://marinemetadata.org/>) for marine biology. The field of evolutionary biology is another scientific discipline, in the small science category, that is moving toward an open science model.

Evolutionary biology is an interdisciplinary field drawing from a wide range of scientific disciplines (ecology, genomics, paleontology, population genetics, physiology, systematics, and new biological subdisciplines such as genomics). The current publication process requires evolutionary biologists to deposit certain data in specialized data repositories (e.g., GenBank: <http://www.ncbi.nlm.nih.gov/Genbank/index.html>, and TreeBase: <http://www.treebase.org/treebase/index.html>) and additional supplementary data in journal repositories (e.g., *American Naturalist* (<http://www.journals.uchicago.edu/AN/>) and *Molecular Biology and Evolution* (<http://mbe.oxfordjournals.org/>)). This requirement advances the preservation of data and makes data accessible for reuse, although the discovery of data via these current venues is limited. The field of evolutionary biology could greatly benefit from a central metadata repository that would bring these disparate data pieces together and link data objects to published research.

The National Evolutionary Synthesis Center (NESCent) (<http://www.nescent.org/>) recognizes this need and has launched DRIADE (Digital Repository of Information and Data for Evolution)—a repository for published research and data in the field of evolutionary biology. DRIADE is a partnership between NESCent and the School of Information and Library Science, Metadata Research Center (SILS/MRC) (<http://ils.unc.edu/mrc/>), at the University of North Carolina at Chapel Hill. Metadata is a fundamental part of DRIADE's information architecture. This paper reports on DRIADE's overarching goals. The paper describes the phased approach to developing a modularized application profile supporting three phases of DRIADE's development. The paper concludes by identifying next steps and discussing the applicability of DRIADE's work to other initiatives seeking to tightly couple published research and data.

## 2. Identification of Key Components of an Open Science Publication and Data Repository

Expedient and easy access to information via the Internet, compared to the extreme time delays and costs of traditional publication venues, explain, in part, the growing number of digital repositories primed for sharing research. Among one of the most successful and global efforts for sharing research is the Open Archives Initiative (<http://www.openarchives.org/>), which focuses, primarily, on pre-publication off-prints in addition to electronic dissertations and theses via the Networked Digital Library of Theses and Dissertations (NDLTD) (<http://www.ndltd.org/>). Creating metadata for electronic “documents”, such as prepublications, dissertations, and theses, is fairly straight forward, drawing from bibliographic control practices. This is demonstrated by the wide adoption of the OAI Protocol for Metadata Harvesting (OAI-PMH), based on the Dublin Core metadata standard. The metadata issues become more complicated, however, when a repository wants to include multiple object types, such as publications and data objects, and link them.

Repository developers need to understand the life cycle of all of the items being represented in the repository. Hodge (2000) has identified six stages for digital resources; they are as follows: 1. creation, 2. acquisition, 3. cataloging/identification, 4. storage, 5. preservation, and 6. access. Hodge's stages provide a useful framework for understanding the phases of a digital object's life—whether it is a publication or a data set.

Another important requirement in developing a publication/data repository is to define the “types of information objects” and “data types” that are going to be represented or possibly contained in the repository. It is also imperative to identify where linking among objects and data types is desired. In the context of the Dublin Core, linking could be supported by the “relation” element. A preliminary analysis by Carrier, et al (2007), presented in Tables 1 and 2, provides a framework for helping to build a repository linking published resources and their data.

**Table 1: Object Types**

Publication (e.g., journal article, conference paper)
Published piece of data in the publication (e.g. a table)
Dataset behind the published data (e.g. supplemental data)
Initial data source (e.g., American Ornithologists' Union checklist)
Newly created data (e.g., data derived from any of above)

**Table 2: Data Types**

Structured labeled data (e.g., tabular data with column and row headings)
Structured unlabeled data (e.g., tabular data <i>without</i> column and row headings, or with undecipherable headings)
Unstructured textual data (e.g., readable text)
Unstructured non-textual data (e.g., maps, graphs, images)

An initial step in developing the DRIADE project was to identify these components. This work, combined with DRIADE's goals (discussed in section three), helped us to realize our metadata scheme would need to be modular to support access to: 1. published research (journal articles and potential conference papers) and 2. data objects supporting the published research. It also became clear that metadata would be crucial for linking these two modules. The next section of this paper introduces the DRIADE project.

### 3. The DRIADE Project

DRIADE is a collaboration between NESCent (National Evolutionary Synthesis Center) and the SILS Metadata Research Center (MRC) at the University of North Carolina at Chapel Hill. DRIADE is being developed to support data acquisition, ensure long-term preservation of data objects supporting published research in the field of evolutionary biology. Overarching goals include promoting resource discovery, data sharing, and data reuse of heterogeneous digital datasets. We have developed a set of functional requirements based on an analysis of existing data repositories (Dube, et al, 2007). A synopsis of these requirements include support for the following:

- Computer-aided metadata generation and augmentation.
- Specialized modules linking data submission and manuscript review.
- Data and metadata quality control by integrating human and automatic techniques.
- Support for identity, authority and data security.
- Support for basic metadata repository functions, such as resource discovery, sharing, and interoperability.

### 4. The Application Profile Approach for DRIADE

A number of namespaces have been developed to serve the data preservation and sharing needs of biologists, including Darwin Core (<http://wiki.tdwg.org/DarwinCore>) and Ecological Metadata Language (EML) (<http://knb.ecoinformatics.org/software/eml/>). Despite the existence of these relevant and well documented schemes, the DRIADE metadata team realized, early on the metadata planning, that a modularized application profile was the most logical approach. Specific factors impacting our approach included DRIADE's goal to couple of published research and supporting data, and the plan to support data preservation, discovery, and reuse. Following is a more detailed discussion of three key reasons why the application profile approach was selected:

*First*, there are a number of metadata schemes applicable to DRIADE, and can support at least some of the desired functionalities (e.g. data preservation, discovery, use/reuse). For example, the Dublin Core supports resource discovery of published resources (or articles, in DRIADE's case) and selected Dublin Core elements support resource discovery of data objects. It does not make sense to reinvent the wheel, and it has been practical and productive to evaluate and draw from existing schemes.

*Second*, although there are already schemes developed that support aspects of DRIADE, we have not found a single scheme that satisfies all of the desired functionalities. As indicated above, selected Dublin Core elements support resource discovery of data objects, although it does not support other desired functionalities, such as preservation and data integrity that are also important for DRIADE. Examples of elements from other schemes important to DRIADE include “fixity” from PREMIS and “depositor” from the DDI.

*Third*, evolutionary biology is an interdisciplinary field, and a goal of our project has been to create an interoperable environment, one where DRIADE can “shake-hands” with other repositories (e.g., Genbank and TreeBase) used by evolutionary biologists. Zhang explains, “Establishing metadata interoperability has long-term benefits for resource discovery and retrieval, especially in increasingly interdisciplinary science research” (2006).

## 5. Methodology and Procedures

The DRIADE team used a multi-method approach to develop the modularized, multi-leveled application profile. Our methods included a *requirements assessment*, *content analysis*, and *crosswalk analysis*. We conducted this work following best practices defined by Hillmann (2006), Heery and Patel (2000) and Dekkers (2001).

The *requirements assessment* involved identifying DRIADE stakeholders. Stakeholders include evolutionary biologists, journal publishers in the field of evolutionary biology, professional societies in evolutionary biology, and NESCent—a research center for synthetic research addressing fundamental questions in evolutionary biology. The needs and goals of these individuals and groups were identified in a stakeholder’s workshop held in December 2006 at NESCent in Durham, North Carolina. Among initial questions addressed at the workshop were: What is the minimum number of metadata elements required? What functions will the DRIADE scheme support? Answers to these questions have informed the development of DRIADE’s functional requirements and the metadata framework.

The *content analysis* involved the application of a social science technique designed for the systematic examination of content (Krippendorf 2004). We examined various metadata schemes and employed the content analysis methodology to identify relevant elements. For each schema we asked the following questions in the following sequence:

1. Which schema is being analyzed and what elements are included?
2. How is the schema defined?
3. In what context was the schema designed, and how is it currently applied?
4. How does the context relate to DRIADE? Where would it fit into the application profile, and at what level? What function(s) does the element support? How useful is it for us, useful for the users?

Finally, we conducted a *crosswalk analysis*, which involved the mapping of selected elements from various namespaces (NISO 2004). Metadata standards selected for the crosswalk included the Dublin Core (<http://dublincore.org/documents/dces>), PREMIS (<http://www.oclc.org/research/projects/pmwg/>), EML, DDI (<http://www.icpsr.org/DDI/>) and Darwin Core. The crosswalk was constructed using established methods (Dekkers 2001). Intersections in meaning and utilization were noted. During the normalization process, redundancy amongst the chosen elements was eliminated, extraneous elements were discarded, and where possible, Dublin Core elements were chosen. We prioritized the Dublin Core standard because it allows for maximum interoperability and flexible mapping possibilities. The following steps summarize our Application Profile development process. We:

1. Reviewed NESCent Stakeholders' workshop outcomes and DRIADE overall goals.
2. Assessed the information life-cycle for data objects.
3. Researched the use of standards, recommended best practices, case studies, and development processes of several scientific repositories.
4. Identified potential metadata schemes/elements: Dublin Core, Data Documentation Initiative (DDI), Darwin Core, PREMIS and Ecological Metadata Language (EML).
5. Developed a list of metadata required for support of DRIADE's functional requirements
6. Mapped the required metadata to elements (crosswalk).
7. Chose the metadata elements (Dublin Core where possible--mandatory and required elements from each scheme were considered a priority).

## **6. Stages of the DRIADE Application Profile**

The DRIADE application profile is being developed in three stages to support three levels of DRIADE's development. An immediate stated goal, coming from the Stakeholders workshop in December 2006, is to preserve as much data as expediently as possible, due to threats of data loss. To address these immediate needs, we have developed the first level of the application profile to serve basic acquisition and preservation functions. We have also been developing level two and three of the applications profile--each with a more granular and sophisticated approach to preserving data and serving the sharing needs of users. The second level of DRIADE's application profile will extend level one functionalities by capturing the complex relationships that exist among data objects. Finally, the third level of the application profile will support "next generation"/Web 2.0 functionalities in the DRIADE repository, including semantic web functionalities. The next section of this paper review the application profile levels in more detail.

### **6.1 Level One Application Profile**

The level one application profile is intended for initial repository implementation. At this level, metadata supports preservation, access, and basic usage of data. In order to record and trace the relationships between data sets and published articles, two modules were created within the application profile: the bibliographic citation module and the data object module. Bibliographic information for the published article is linked to the associated data sets via the Dublin Core "relation" and "identifier" elements. Tracking reuse of data sets for further research and publication is accommodated with these two modules, with multiple article Digital Object Identifiers linked to individual data sets across time. Such a structure is also intended to facilitate resource discovery. Throughout level one, automatic metadata generation techniques are employed where possible. Automatic methods are desired because they are more expedient and efficient and less costly than manual approaches, although we are aware of the shortcoming as well (Greenberg, et al, 2006). Level one will employ controlled vocabularies for selected elements. Several metadata elements will not be displayed to the public, such as fixity (PREMIS), simply because it is for administrative use. Those elements that are manual have been by and large also designated as optional. This decision is driven by stakeholder concern regarding buy-in and participation. The level one application profile is seen in Table 3.

**Table 3. The level one application profile**

<b>Namespace:Name /Label</b>	<b>Obligation</b>	<b>Generation Method</b>	<b>Occurrences R=Repeatable NR=Non- repeatable</b>
<b>Module 1: Bibliographic Citation</b>			
dcterms:bibliographic Citation/Citation Information	Required	Automatic	R
dc:identifier/Digital Object Identifier	Required	Automatic	NR
<b>Module 2: Data Object</b>			
dc:creator/Name	Required	Semi-Automatic	R
dc:title/Data Set Title	Optional	Manual	NR
dc:identifier/Data Set Identifier	Required	Automatic	NR
PREMIS:fixity/(hidden)	Required	Automatic	NR
dc:relation/DOI of Published Article	Optional	Semi-Automatic or Automatic	R
DDI:<deposit>/Depositor	Required	Manual, then Automatic after profile creation	NR
DDI:<contact>/Contact Information	Required	Manual, then Automatic	R
dc:rights/Rights Statement	Required	Semi-automatic or Automatic	NR
dc:description/ Description of the Data Set	Optional	Manual	NR
dc:subject/Keywords Describing the Data Set	Required	Manual and Automatic	NR
dc:coverage / Locality	Required	Semi-automatic	R
dc:coverage/Date Range	Required	Semi-automatic	R
EML:software/Software	Optional	Semi-automatic	R
dc:format/File Format	Required	Automatic	NR
dc:format/File Size	Required	Automatic	NR
dc:date/(Hidden)	Required	Automatic	NR
dc:date/Date Modified	Required	Automatic	NR
Darwin Core: species/ Species, or Scientific Name	Optional	Semi-automatic	R

## **6.2 Level Two Application Profile**

Level two of the application profile is in the planning stages and will satisfy full repository implementation. Building upon the functionalities of level one, this stage of the project will support expanded usage, interoperability, preservation and administration. Most importantly, level two will expand upon the concept of known linkages, namely between data object and publications, as well as capture sophisticated, subtle relationships between the data objects themselves. These relationship instances, called instantiations, are essential for the future functionality of the DRIADE project. Instantiations stem from the information life cycle described above, and are captured by the Dublin Core relation element. At this stage of the development, feedback and assessment strategies will be implemented to determine metadata quality. Furthermore, automations in the process of deposition will streamline user workflow. The establishment of user profiles accommodates this process and will also prepare DRIADE for the third stage implementation.

## **6.3 Level Three Application Profile**

Level three of the application profile will support next-generation semantic web functionalities for the DRIADE system, such as:

- Personalization: in which multiple (optional) levels of personalization and recommendation are made possible for users. System functions such as query results, workflow “macros”, and user interface could be optimized for individual users.
- User community “virtual societies” utilizing “social tagging” (Web 2.0) functionalities: in which the system user-members contribute new value to the repository holdings by sharing classifications, evaluations, usages, and other communications.
- Knowledge organization systems: the integration and extension of existing ontologies (or taxonomies) will be explored.
- Harvesting metadata (pull) / Exposing metadata (push): DRIADE fully supports interoperability, and will be continually involved in a multi-pronged effort to facilitate and increase metadata sharing, particularly in this phase of development.
- Syntactic interoperability for data: in which interrelationships between datasets and data elements are exposed to the user. This can be effected via extensive hypertext linking, “standardization” of data labels and formats, and implementation of emerging standards such as Minimal Information About a Phylogenetic Analysis (MIAPA) (Leebens-Mack, Vision, et al 2006).
- Data and collection visualizations: topic clustering and data relationship maps will be developed, and utilized for access, discovery, and system administration.
- User feedback: Extensive collection and analysis of feedback from users will be employed for evaluation purposes, followed by design and development of revisions.

We are in the early phases of developing level three functionalities. A second DRIADE workshop planned later this year will help us further define our level three goals.

## **7. Conclusions and Future Work**

This paper presents our phased approach to developing a modularized application profile supporting three phases of DRIADE's development. We reviewed our multi-method approach, which included a requirements assessment, content analysis, and crosswalk analysis, and we presented our level one application profile. DRIADE is being developed for the field of evolutionary biology. Although this interdisciplinary field can be viewed as a specific domain, the techniques and methods are applicable to other application profile initiatives, particularly small science initiatives wanting to

link published research and supporting data. We also believe our work has implications for other disciplines beyond the scientific domain having similar goals.

One of the biggest challenges of our work has been linking the application profile development with the stages of DRIADE's implementation. DRIADE's metadata needs cannot be fully defined without defining each phase of DRIADE's development. And, yet, in some cases, it has been useful to project desired metadata functionalities first, and then take a step back to determine in which phase an activity fits best. For example, the DRIADE team spent a considerable amount of time discussing the metadata element "description" and its place as a level one or two requirement. While this is considered a simple Dublin Core element by basic abstracting and indexing practices, the DRIADE team determined that asking scientists to write an abstract or description was too labor intensive for level one, where our goal is, partially, to incite cultural change and generate interest. The "description" element will be integrated into either phase two or three of the application profile.

Our next steps include a DRIADE workshop to review phase two of DRIADE's development and further define phase three goals, an experiment testing the application profile, and a survey/use case study. The application profile experiment will require evolutionary biologists to create metadata for their data objects with our application profile. The survey/use case study will allow us to gather data from evolutionary biologists about their experience with and support of data sharing, data repositories, and the DRIADE initiative. The workshop and research activities will further inform the development of DRIADE's functional requirements and, in turn, impact the development and the modularized application profile.

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