A Study on Sustainable Financing for the Development and Maintenance of Ecosystem Based Management Tools

Report by the Marine Geospatial Ecology Lab at Duke University for the David and Lucille Packard Foundation

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Introduction

In 2009 the Interagency Ocean Policy Task Force was created to develop a set of guidelines and rules for managing our coasts, oceans and the Great Lakes in a sustainable way, using an ecosystem-based approach, that considers both conservation and economic uses and addresses potential user conflict. (74 FR 242) Coastal and marine resource management is uniquely challenging due to the complex interconnection of ecosystems and the dynamic nature of ocean environments. Many past attempts to manage our ocean resources have failed primarily because they do not fully represent these ecosystem interconnections, limiting our ability to achieve realistic and sustainable management outcomes. With consensus in the call for Ecosystem-Based Management (EBM) of the marine environment (Pew Ocean Commission 2003, U.S. Oceans Commissions 2004, COMPASS 2005, 74 FR 242), the discussion has now turned to how to implement marine ecosystem-based management (MEBM). (Juda 2003, Arkema 2006, Koontz & Bodine 2007, Rucklehaus 2008).

Successful implementation of MEBM practices will involve a diverse toolbox of novel, interoperable tools for marine resource management. For example, there will need to be extensive innovation in the development of new analytical and decision support tools spanning a wide range of disciplines and practitioners. Significantly more detailed analytical capabilities in the areas of dynamic oceanographic analysis, connectivity analysis, multi-dimensional habitat modeling, spatio-temporal representations of food-webs; as well as more advanced analysis of human interactions and responses (e.g. fishing pressure displacement, species by-catch, and links to socio-economic models) will be required.

While the need for tool development to support EBM remains great, many existing MEBM tools remain un-used or under-used due to lack of support, maintenance and marketing. One likely cause of this is that tools are developed in the absence of adequate funding to allow for wide distribution, ongoing technical support and continued product maintenance. We believe that most conservation tool development is funded episodically with short term grants that are designed for conducting research, and that this pulse funding model (sequential short-term grants) is the primary cause of the lack of adequate funding for long-term MEBM tool support.

Here, we sought to investigate and enumerate the factors affecting the financial sustainability of MEBM conservation tools through interviews with twenty-four developers of these tools. Our first hypothesis in this study is that researchers are intentionally pursuing grants as their sole source of funding tool development. Second, we hypothesize that funding mechanisms typically used for commercial software development (venture capital, licensing fees or fee for services) are not viable sources for conservation tools, because in most cases managers and researchers cannot afford to pay the high fees usually associated with these
mechanisms. Our study sought to identify any correlation between organization type or the funding mechanisms used and the ability of the organization to deliver, support and maintain MEBM software tools. Additionally, we examined whether organization type or funding mechanism affects software quality. Lastly, we sought to identify if the amount of funding available to developers affects the normal software development cycle.

In this report, we present:

- Background information on how commercial software is funded and developed and why that financial model might not be available to conservation software developers
- Results of our interviews
- Characteristics of the advantages and disadvantages of several key funding mechanisms
- How the pulse-funding model acutely alters the normal software development process
- The developer’s perspective on financial sustainability
- Recommendations for how both developers and funders can improve the long term sustainability of conservation tools

Commercial vs. Conservation Software Development

Funding Software Development

Commercial software companies are generally started with venture capital (VC) money that is used for research and initial development and release of the product. One or more rounds of money are raised (usually based on the merit of the entrepreneur and a sound business plan) and hopefully carry the operations through to a point where the company is self sustaining through profits, has an initial public offering of stock options to raise more money, or is purchased by a larger entity that has the money to continue the operations needed to maintain and update the product. In the third quarter of 2009, venture capitalists invested an average of $4.9M per deal in new software development companies (based on data taken from http://www.nvca.org on 1/20/2010). In return for their financial outlay, investors are given stock options in the newly formed entity. They are also often given positions with decision making roles (e.g., on the Board of Directors) in the company. Some investors play a more silent role, but given their vested interest in the success of the product, they are frequently involved in product direction and hiring decisions.

Once the venture capital money has “launched” the company, revenue then comes from product sales or services sales and is used to continue operations and continue maintaining the product and releasing new products. Product license fees are set with the goal of maximizing profit, based on the projected size of the intended market. With a large market, the price of software can remain lower to attract a high
number of customers. When the potential market is small, however, the price of the software must be high in order to support the operations of the company.

In contrast to the profit-driven commercial model, the driver of success for individuals in academic fields related to ecosystem-based management is publishing in peer-reviewed literature and, secondarily, the resolution of (or elucidation of) real-world problems. Therefore most academic EBM tools are developed as a by-product of primary research, where the tool is meant as a one-time solution to help answer a specific question. Most research is funded with grants that are easily an order of magnitude less than the $4.9M per deal in the venture capital world. Tools that are developed under these grants, or on a researcher’s own time, are commonly referred to as “skunk works” projects since they have no official source of funding. (See Box 1 for a description of skunk works, and additional funding mechanisms used in academia.) Foundations and granting organizations rarely, if ever, directly fund the maintenance or productization of conservation software tools. Business plans for products developed in academia are not commonly written, due to the lack of financial driver.

**Standard Software Development Process Model**
Software creation follows a fairly standard process involving requirements, design, implementation, testing and maintenance. Ideally, the product is created with the intention of meeting the needs (requirements) of a particular set of users (the market). After the initial product is released, feedback from the customer base is used to build a new set of requirements (including fixes to problems and new features or improvements), and the next version of the product is designed, implemented, tested and released. These activities can be carried out in series, with the traditional Waterfall model of development (Figure 1), or in a more parallel and dynamic methodology such as the agile Scrum development model that speeds up the rate of new releases.

Regardless of which process model is used, carrying out each of the steps in the model helps assure the success of the product. Without good requirements, the product may not be useful to a wide audience; without a good design, the implementation will likely be weak and not robust. Good quality assurance during verification helps keeps the quality high and the error rate low, reducing support costs in the long run. Along with these steps, other activities and products that are important to the long term success and widespread use of the product are needed. Documentation, technical support,
expert consultation on graphical user interface design and product training courses all round out a professional, high-quality, usable and maintainable software tool.

To better understand how MEBM tools are financed and subsequently released, marketed, maintained and supported we interviewed 24 researchers whose labs produced MEBM related tools.
Box 1: Sources of funding in academia for EBM software tools

Funding mechanisms commonly used by academics to perform research and develop tools can be grouped into nine categories, including the VC mechanism used by commercial software developers described above. Below, we describe the basic characteristics of these other eight mechanisms.

**Grants** can be from government agencies like NASA or NSF; from Non-Governmental Organizations (NGOs) such as World Wildlife Fund and Pew Charitable Trusts; or from foundations such as The David and Lucille Packard Foundation, The Orton Family Foundation and The Gordon and Betty Moore Foundation. Grant money is episodic, because it is a one-time event with a limited term and no follow-on funds.

**Internal government money** is used by a government agency, such as the National Oceanic and Atmospheric Administration’s (NOAA) Coastal Services Center (CSC). Agencies get annual budgets that are allotted to various projects. There is an internal process for choosing what projects to fund, so a project needs a champion and a good reason (such as a large user base for a tool) to be continued each year. CSC has available infrastructure including equipment and people. CSC used to give out grants and run projects in an “in-kind” manner, where the recipient would lead a research project using the resources (people and equipment) available at CSC.

**Fee for License** models charge a fee for the use of a product. Fees can be based on the number of users, or installations/copies; they can be one-time fees or annually renewable fees.

In a **Fee for Service** or “contract” model, services are sold to generate revenue. Services range from basic training courses and access to technical support to more in-depth software customizations that meet the specific and unique needs of an individual user. Consulting services may be hired to help run an entire project. There may or may not have an associated license fee for the software.

**Donations** are usually associated with NGOs in the form of memberships, but can also be in the form of corporate sponsorship for a specific product. An organization with money that uses a particular tool and wants to see its continued existence might donate to the developer; sometimes this is in exchange for good PR (like getting their name associated with Open Source software). Some tool developers also solicit donations directly from users to support the development effort (this may be referred to as “shareware”).

**Endowments** are funds (or assets) donated to an institution that are invested. Interest earned from the investments can be used to fund research projects. This creates a perpetual source of income for the institution, though the amount of income will vary with the economy and depends on the investments made.

“**Skunk works**” describes the way many tools are started: with funding directed at another project. Whether intentionally subversive or just a positive by-product, skunk works projects are probably the most common starts to MEBM tools. Graduate students are often funded to perform some research task(s), during which time tools are created to aid in the research. At some point the researchers realize the potential benefit others may gain from using the tool, after which any of the other funding sources described here may be used to productize the tool and make it available to others.

Lastly, despite not being an actual source of money, **Open Source** projects are gaining momentum. R, Open Office, and Linux are all popular examples of open source projects. In the MEBM world, OSGeo – the Open Source Geospatial Foundation – is a group of projects developed and made available under an OSI-certified open source license. OSGeo is a not-for-profit foundation created to support (financially, legally and organizationally) the collaborative development of open geospatial technologies and data.
Understanding the MEBM Tool Developer’s Perspective

Potential interviewees were chosen from three sources: the EBM Tools Network Database (http://www.ebmtools.org/), applicants to the MEBM Tool Innovation Fund, and the collective knowledge of the Marine Geospatial Ecology Lab (MGEL), which evaluates and uses many MEBM tools. We sought to include interviewees who produced tools that represented different levels of success, where success of a tool was defined as having a level of long-term financial sustainability that allowed for software updates and improvements, customer support, documentation, and training. Organization type, funding mechanisms, scale of users, and potential scale of impact were factors also used to evaluate tools for inclusion in the study as an attempt to examine a broad spectrum of developer environments.

Survey Design, Execution and Analysis

Interviews were conducted via Skype and audio recordings were made. An online survey form was used to capture notes during the interview and during audio recording playback. No incentive or compensation was offered to interviewees. Respondents were given the option of remaining anonymous. Questions were open ended and directed to elicit information about how the respondents sought funding for development of their MEBM tool, how well that funding worked to get the product implemented, if the product is ready for widespread use, and if the product is financially sustainable. We tried to standardize the measure of the quality of a software tool by asking if specific criteria were achieved with the funding available to the researcher:

- Employment of Full Time Developers
- Background Research Performed
- Prototype Developed
- Automated vs. Manual Testing (vs. no testing)
- Marketing
- Business Plan Creation

Alternative Funding Sources

CRADA – Cooperative Research and Development Agreements. CRADAs are agreements between federal government agencies and private sector participants to work together on a mutually beneficial project. Each partner in the CRADA applies whatever resources are agreed to, such as personnel, equipment, or facilities. While participant dollars may be used to fund portions of the government’s effort, the government may not use federal funds to support the private sector participant. For example, see: http://www.usgs.gov/tech-transfer/what-crada.html

SBIR – Small Business Innovation Research grants. “The U.S. Small Business Administration (SBA) Office of Technology administers the Small Business Innovation Research (SBIR) Program and the Small Business Technology Transfer (STTR) Program. Through these two competitive programs, SBA ensures that the nation’s small, high-tech, innovative businesses are a significant part of the federal government’s research and development efforts. Eleven federal departments participate in the SBIR program; five departments participate in the STTR program awarding $2billion to small high-tech businesses.” Get more information at: http://www.sbir.gov/
• Expert Graphical User Interface (GUI) development consultation
• Ability to update product with new features
• Ability to maintain product
• Ability to provide technical support
• Documentation provided

We also probed the interviewees for their ideas and recommendations on how granting agencies could be more helpful to tool developers, and their thoughts on how tool development might be better funded and maintained in the future. Survey responses were entered into the software program NVivo8 (QSR International Pty Ltd., Doncaster, Australia) and coded for recurring patterns that were observed, allowing the codes to evolve from the data. Results of this analysis are presented and discussed below.

Survey Results
Most conservation tools originate from academia, and this is reflected in our sample (Figure 2). Grants and fee for service contracts were the two most commonly reported means of funding MEBM tool development (37% and 24% respectively), followed by internal government money (13%) (Table 1). Five of the 24 respondents charged a license fee for their product at one time (four still do) (Table 1). In 75% of the interviews, more than one funding mechanism was reported, with the majority receiving funding from two sources (Table 2).

![Figure 2. Distribution of organization type of survey responders, illustrating that most MEBM tools are developed in academia.](image)

Twenty of the tools in our survey had gone through more than one development cycle at the time of our survey selection process. Of these 20 tools, 45% met our criteria for having been financially sustained over that time as well as widely adopted (Table 3). All but two (78%) of these sustained tools had multiple sources of funding, and all mechanisms of funding except venture capital and endowment were represented.
### Funding Mechanism

<table>
<thead>
<tr>
<th>Funding Mechanism</th>
<th>Respondents</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grants</td>
<td>20</td>
<td>37%</td>
</tr>
<tr>
<td>Fee for Service</td>
<td>13</td>
<td>24%</td>
</tr>
<tr>
<td>Internal Government</td>
<td>7</td>
<td>13%</td>
</tr>
<tr>
<td>Fee for License</td>
<td>5</td>
<td>9%</td>
</tr>
<tr>
<td>Donations</td>
<td>4</td>
<td>7%</td>
</tr>
<tr>
<td>Open Source</td>
<td>3</td>
<td>6%</td>
</tr>
<tr>
<td>VC</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Endowment</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>54</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Table 1. Number and percentage of respondents that received funding from each mechanism. Grants are the leading mechanism for EBM tool development among interview subjects.

### Number of Funding Mechanisms

<table>
<thead>
<tr>
<th>Number of Funding Mechanisms</th>
<th>Respondents</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>25%</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>38%</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>29%</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>4%</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>24</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Table 2. Number and percentage of respondents by number of funding mechanisms used to support MEBM tool development. The majority of the respondents (75%) used at two or more funding mechanisms.

Most of the interview discussions focused on grants and the two fee-based models. Internal government funds were described by interviewees as being very similar to grants, in the sense that government agencies are given budgets (either annually or for short periods of around 3 years), and a product must have a champion that repeatedly submits proposals to go after funding to keep the project going. As 83% of the funding mechanisms discussed during the interviews were one of these four types, our next section focuses mainly on the advantages and challenges associated with the grant, fee for license and fee for service mechanisms.
<table>
<thead>
<tr>
<th>Interview ID</th>
<th>Organization Type</th>
<th>Funding Mechanisms</th>
<th>We Believe Financially Sustained</th>
<th>They Believe Financially Sustained</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>Consortium</td>
<td>Grants</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>11</td>
<td>University</td>
<td>Internal Government</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>25</td>
<td>Government</td>
<td>Internal Government, Grants</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>24</td>
<td>University</td>
<td>Grants, Fee for Service</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>University</td>
<td>Grants, Fee for Service</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>For profit</td>
<td>Grants, Fee for License, Fee for Service</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>20</td>
<td>Not for profit</td>
<td>Donations, Fee for Service, Open Source</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>University</td>
<td>Grants, Fee for Service, Internal Government</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>10</td>
<td>Government</td>
<td>Fee for Service, Grants, Internal Government, Open Source</td>
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<td>Yes</td>
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<tr>
<td>8</td>
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<td>Internal Government</td>
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<td>No</td>
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<td>22</td>
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<td>Grants</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>13</td>
<td>University</td>
<td>Grants</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>18</td>
<td>University</td>
<td>Grants</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Government</td>
<td>Internal Government, Grants</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>17</td>
<td>Government</td>
<td>Internal Government, Grants</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>15</td>
<td>Individual Proprietor(^1)</td>
<td>Grants, Fee for service</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>University</td>
<td>Grants, Donations</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>14</td>
<td>For profit</td>
<td>Grants, Fee for License, Fee for Service</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>12</td>
<td>For profit</td>
<td>VC, Fee for License, Fee for Service</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Not for profit</td>
<td>Endowment, Fee for License*, Fee for Service, Grants, Donations</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>21</td>
<td>Not for profit</td>
<td>Grants, Fee for Service</td>
<td>Too New</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>University</td>
<td>Grants, Fee for Service</td>
<td>Too New</td>
<td>No</td>
</tr>
<tr>
<td>16</td>
<td>Not for profit</td>
<td>Donations, Grants, Fee for License</td>
<td>Too New</td>
<td>No</td>
</tr>
<tr>
<td>23</td>
<td>Not for profit</td>
<td>Grants, Open Source, Fee for Service</td>
<td>Too New</td>
<td>Yes</td>
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</tbody>
</table>

Table 3: Types of funding mechanisms used by respondents, showing the type of organization, our classification of the tool’s financial sustainability, and the respondents’ classification of the tool’s financial sustainability. Entries with differences between the classifications are highlighted. *No longer charging a license fee.

\(^1\) This tool was developed as a side business from the researcher’s primary employment.
Funding Challenges and Advantages
Most of the funding challenge categories reported (67%) were associated with grants (Table 4). Yet grants were also associated with all but one of the funding advantages we tracked (Table 5). (The one advantage not associated with grants was no proposal required.) Primarily, researchers expressed frustration at the lack of granting opportunities available to work on tools, stating that granting agencies prefer giving money for novel research work, not for the development or maintenance of software tools. Second and third most frequently mentioned on the list of challenges with grants is that the funds are for too short of a term (usually less than 3 years) and that funding is erratic and unpredictable. Forty-two percent of respondents indicated that funding in general is erratic, using words like “ad-hoc”, “ephemeral”, “up and down”, “future is uncertain”, and “inconsistent”, and the majority of these comments were referring specifically to grants.

Grant money is usually a one-time event with a limited term and no guaranteed follow-on funding. Thus by intention, grants are episodic. Unlike endowments or revenue streams (see Box 1) they are not designed to be perpetual, long term sources of funding. Continuous financial support of an MEBM tool is therefore extremely difficult to achieve using grants and often results in the researcher being in perpetual fund-raising mode, seeking the next grant opportunity.

“We did a lot of work raising money from people – seeking opportunities, writing proposals, building relationships. We only got a modest amount of money and no repeat donations, which is a costly way to fund something.”

Several of the researchers interviewed recognized that due to the nature of software tools, they need continuous updating. For example, in many cases the tools rely on other software packages that get updated in a way that renders the tool non-functional. In other cases, serious problems are identified with the functionality of the tool that need to be fixed in order for the tool to be continued to be used. Over the long term, technology changes and user needs change, requiring the functionality of the tool to be updated to meet those new demands. This need for continued and long term funding for the maintenance of software tools is highlighted by the following comments from the interviewees:

“One aspect is that software dies within a few years if you don’t have people developing it. Keeping that going calls for enormous commitment from individuals or organizations.”
“Building tools to solve problems takes a significant amount of time and resources. Not something you can “tick off and finish”. The system evolves, legislation evolves, and available technology evolves, environment changes. Have to keep up with what the wide audience is doing.”

“Offering to help endow the software was a great idea. Funders hate the idea of getting nickel and dimed, where people keep coming back asking for more money on a project. But software needs continuous care and feeding. Similar model to endowing land purchases for trust, funders could also include an endowment for continued operation and care of software.”

“Need to think beyond immediate needs presented by specific planning processes we support, and think long term about what is needed over next 5 years. Supporting longer-term projects is key.”

One important positive aspect with grant money is that grants typically have relatively fewer guidelines, with less specific product related deliverables expected from the recipient. Researchers feel a large amount of autonomy by funding their projects with grants. Freedom to explore an unforeseen avenue can lead to interesting and useful discoveries that may have been missed if the researcher had been more restricted and deliverable-focused.

“The benefit is that you can concentrate on doing whatever you think is best at that time. So you don’t get stuck with something you promised and then realize maybe it’s not smartest thing to work on.”

Additionally, and perhaps most importantly to researchers, there is a level of prestige associated with “winning” grant money. It lends credence to the researcher and the lab; similar to the credence and legitimacy received from publishing in peer reviewed literature.
### Challenges by Mechanism Type

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Donations</th>
<th>Endowment</th>
<th>Grant</th>
<th>Internal Government</th>
<th>Open Source</th>
<th>Fee for License</th>
<th>Fee for Services</th>
<th>Skunk works</th>
<th>Venture Capital</th>
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<tbody>
<tr>
<td>Commercial competition</td>
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<td>Competitive</td>
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<tr>
<td>Decision makers lack knowledge</td>
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<td>Dependent on economy</td>
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<tr>
<td>Erratic funding</td>
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<tr>
<td>Give up autonomy</td>
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<tr>
<td>Government agencies are limited in grants they can apply for</td>
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<tr>
<td>Grantors prefer novel research work over tool development</td>
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<td>Lack of ability to provide documentation, support and website</td>
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<td>Lot of effort invested to obtain a small amount of funding</td>
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<td>Only open to large organizations</td>
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Table 4. Funding mechanisms and associated challenges as reported by respondents. Grants were reported to have the most (14) disadvantages, followed by Internal Government (8). Resource restriction was the most common challenge across funding mechanisms, associated with 67% of the mechanisms.
<table>
<thead>
<tr>
<th>Advantages by Mechanism Type</th>
<th>Donations</th>
<th>Endowment</th>
<th>Grant</th>
<th>Internal Government</th>
<th>Open Source</th>
<th>Fee for License</th>
<th>Fee for Services</th>
<th>Skunk Works</th>
<th>Venture Capital</th>
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<tr>
<td>Able to keep tool free</td>
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<td>Able to update product</td>
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<td>Collaboration opportunities</td>
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<td>Covers operational expenses</td>
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<td>Funder provided marketing(^2)</td>
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<td>IT Infrastructure(^2)</td>
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<td>Keep up with external technology</td>
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<td>No-cost extensions</td>
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<td>Prestige in grants</td>
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Table 5. Funding mechanisms and advantages as reported by respondents. Grants are associated with all but one advantage (93%). Revenue from services were associated with 50% of the advantages. Endowments were not specifically mentioned by the respondents to have advantages, but that does not imply there are none.

Where grants are generally characterized as expecting relatively fewer explicit products, fee for service contracts generally define more precisely the specific products to be delivered and the expectations of delivery. Although this somewhat limits the direction a researcher can take while developing a tool or methodology, it provides a narrower and more clearly defined scope of what is to be accomplished. Services that a developer may provide include adding a particular feature to a tool; customizing the tool for a specific use or scenario; installing, configuring and assisting in operation of the product. Even language localization can be a provided service. Limitations on what the money can be used for might prohibit a researcher from being able to fully maintain and support a product using service fees alone. Revenue generated from services can only be used for product maintenance and

\(^2\) NOAA’s Coastal Services Center (CSC) had a grant program in the past that was run as a cooperative agreement with a researcher. The researcher conducted the scientific study, while CSC provided infrastructure to support the effort, including development and marketing.
enhancements when those changes are in-line with the customer’s requirements. By contrast, the advantage with the fee for license mechanism is that the revenue stream can be used directly for product support and maintenance, research and development, and operational expenses helping to ensure the long-term sustainability of the tool.

Two disadvantages were identified by the interviewees regarding both fee-based models. First, there is overhead associated with managing and enforcing the license scheme. Researchers in academia, not-for-profits and government agencies expressed a strong lack of desire to deal with the business end and overhead that is required to implement and support any type of fee model. This is not just a personal position, but a reflection on the organization structure and mission of these institutions. Universities do not typically have the capacity to set up and protect licensed software from becoming “pirated” (stolen and released through other non-authorized channels). Government agencies that develop MEBM tools are also similarly not in a position to set up a fee-based business model. Rather, these agencies are more normally in a position to give out grant money to help fund research.

Second, the fee, depending on the amount, can severely limit the potential customer base. If the developer charges too high of a fee, there will be fewer customers and possibly not enough revenue stream to support operations; charging too little also limits the revenue stream and the ability to support operations. Both of the fee models may exclude large numbers of people who could use the tool to solve problems, but have insufficient resources to acquire the tool or services needed. Furthermore, we did not see any evidence in our responses to indicate that the fee-based funding mechanisms alone led to better financial sustainability than grants. One researcher said:

“Selling my product would go wholly against the grain of the science that I do, since the tool would be out of the dollar range of developing countries explicitly. I would rather give it to the people who need it.”

Another argument in-favor of charging license fees is that it adds to the perceived value of the product, thereby increasing the likelihood of getting additional grants. Two interviewees noted that granting organizations are more inclined to give money in support of a tool that people are willing to pay for. Charging a license fee helps to justify grant money.

“It’s easy to get grant money if you can demonstrate that people use it and are willing to pay for it.”

“Because it’s an existing free stand-alone tool, it is hard to get anyone to fund improvements to it.”
Perhaps this tradeoff between giving up some autonomy and prestige afforded through the grant-based pulse funding mechanisms and exploiting more continuous sources of revenue will be beneficial to the conservation world. Three respondents highlighted, in the quotes below, a shift in attitude around funding tool development and support of conservation organizations in general.

“Technology is changing; the way it is deployed is changing. Charging for service makes more sense rather than selling a packaged product. 'Software as service' model. In terms of funding tools, that is a basic question: is the software a service or a package end-product? This changes the business model, approach and funding model.”

“We’re thinking about the business model as not just an opportunity to sell a product. We see ourselves as a team of experts that can provide the necessary technical expertise to further develop and shepherd the application through the whole marine spatial planning process. Planning processes change over the course of lives, so it is important to have our team available so we can change the application in response to user needs. We like to be plugged into the process, giving ideas on how the project can evolve in response to changing needs.”

“The future of software is that development will be free, and the money will be in services. More people will fund support services for a product than they will fund development of a product.”

Impact on Standard Development Process Model
We heard from many of the respondents that the pulse funding model normally used to finance tool development greatly affects the standard development process in two ways. First, without stable financing, research labs are unable to attract and maintain experienced software developers to work on their teams. It results in a high turnover-rate of developers who work on the project, with gaps of time where little or no development is done when funding is absent. Frequent changes in resources leads to repetition of work as new developers must become acquainted with the research, the existing code, and the infrastructure available. In some worst case scenarios, new developers re-write entire tools based on their language or platform preferences.

Experienced, professional developers are deterred from working in such an insecure, rapid-turnover environment. Students or less experienced developers are often recruited to do the work, potentially leading to poor quality code. Salaries for quality developers with experience are typically on the high-end, a requirement to attract and maintain “talent”. Based on our data, universities and non-profits paid developers significantly smaller salaries than for-profit commercial organizations. Inadequate funding fails to lure professional software developers into academia.
“We are severely limited in salaries that we are able to offer to developers. Has been a significant problem. At universities, salaries are typically lower than outside. Another non-profit had a talented developer quit due to being underpaid; trouble recruiting due to low salary offers.”

“Can’t compete with big money, like from mining companies: graduates in GIS are being sucked into this. We try to attract people who are looking for a vocation.”

Second, the lack of long term financial support for EBM tools negatively affects the normal software development process, truncating or interrupting it. Funding events, when they occur, are inevitably focused on implementation and further development. Once that funding runs out, the project returns to a skunk works project, where maintenance and support work is performed by people who are funded under other grants, scholarships or by the primary researcher in his or her own time.

“Level of technical support offered was not great, haphazard. I didn’t have the capacity to answer the phone, and I still get 100 [email] messages a week for support. It went beyond my capacity to offer support.”

Documentation, training materials, and professional user interface design are often skipped or skimped on when a tool is funded erratically.

“There is no long term, permanent or semi-permanent solution for development of software, including documentation, support, website etc. Resources are not very high: to do things fast and well need more people hired. Long term maintenance and other stuff are things that cannot be guaranteed at present time. It would be possible to do nicer software products if planning, testing, and implementation were done as standard software development project with dedicated people ... then you would have a higher quality user interface, documentation, testing etc. But then that would come with the cost of needing to hire multiple people and we haven’t had those kinds of resources available.”

Mission Belief
Researchers in conservation are not profit driven, whether in academia, government agencies, or not-for-profit organizations. Instead, their focus and interest lie in researching and solving environmental problems. A strong “mission” belief was expressed by several of the interviewees, with a desire to help solve a real world environmental problem. Getting their product used by the people who need it supports that mission. Looked at by organization type, 80% of government respondents, 60% of not-for-profit respondents, and 22% of academic respondents specifically stated the desire for their product to be freely available to everyone as
part of "the mission" (38% of all respondents). One possible reason that academia had the lowest percentage of respondents mention the mission belief is that academics are more likely to have this belief be so pervasive that they felt it was too obvious to state. In comparison, people in government agencies or other organizations are more exposed to commercial thinking and beliefs, so the idea of keeping their products free stands out more. Below are some quotes reflecting this theme:

“People using it were scientists trying to get something done, who were hard pressed to find their own salaries and would have had a hard time finding funds to purchase expensive software.” [Government agency]

“The license fee was hurting our 'mission success': we built the tool to help conservation and if not many people are using it how much of a dent are we making?” [Not for profit organization; About transitioning from a fee for license model to a fee for service model.]

“Right now the collegial environment for EBM tools tends to be in it for the mission rather than for a profit. We have to charge for software. This probably prevents some people from using it because they can’t afford to, or choose not to as a matter of principle, or because they are suspicious of anything commercial. I sometimes wish that we didn't have to charge for it.” [For profit organization]

“Charging a license fee is not our philosophy. Especially being a non-profit doing conservation work.” [Not for profit organization]

“Intellectual property is theft.” [Academia]

Considering much of the world’s coastline is in under-developed nations that can’t afford expensive software, free software ensures there are options for managers working in those parts of the world.

**Perspectives on Financial Sustainability**

A priority in this study was to identify if there is a link between funding mechanism or organization type and the success of a tool. Does a particular mechanism or organization type give an advantage to the developer in ensuring long-term financial sustainability of the product? Surprisingly, we saw no clear pattern between sustainability and funding mechanism or organization type (Table 3). Rather, from our interviews it appears that the more successful tools had more successful champions – a person who intentionally devoted continued (sometimes over decades) time and resources to finding additional sources of funding; finding graduate students to continue work on the tool; pushing it forward and supporting it on their own time and money when unable to raise funds.
“If I hadn’t worked with it continuously all these years it would have died long ago. Needs someone to carry the flag.”

Related to this concept of a “product champion”, our initial belief that researchers are restricting their search for funding to only grants was not supported in the interview results. When asked about the process used to select their funding mechanism(s), several researchers answered that it was “opportunistic” – they were aware of an opportunity for money, and were in the right place at the right time. Others benefited in the long run from the reputation of the product: For one academic lab, all of the external funding they have received over the years has come from people recognizing the utility and quality of the product and asking to contribute funds to help keep it going.

Six people mentioned in different ways that personal connections, or the reputation of a research group is a big part of getting funding. One researcher who developed a systematic conservation-planning tool stated the level of success and sustainability of that tool is the result of both cultivated relationships and a high volume of peer-reviewed publications citing the use of the tool. More publications open doors to new research funding. Others highlighted that existing relationships between the person or organization developing the tool and a Program Officer at a foundation can be an asset when seeking funding. Conversely, a lack of personal contacts hinders researchers with good ideas.

None of the four tools that were charging a license fee at the time of the interviews were sustainable based solely on that stream of revenue – they all had additional grants, donations, endowments or venture capital money. Further, 75% of those charging license fees did not believe their tool was financially sustainable (Table 3).

Only 37.5% of interviewees felt their product was financially sustainable. Several of the respondents who felt their product was financially sustainable felt so for very different reasons than our a-priori definition of sustainable. There are many ways to define sustainable, including more traditional corporate definitions that involve net income, gross revenue, annual burn-rate (expenses), etc. For this study, we took a more immediate and pragmatic viewpoint, and we defined a product as being sustained if:

- It has gone through more than one development cycle and release
- Technical support is available via email or telephone
- Complete user documentation is available
- There is an expected source of revenue for the foreseeable future

Respondents who felt their product was financially sustained over time, on the other hand, used phrases like:

“Been able to limp along.”
“Can do minor things on my own time.”

“Yes because it will probably continue to be a low cost operation. Small and focused will be sustainable.”

“Sustainable in the sense we’ve continued to work on it for 2 years and continue to work on it even without direct funding.”

“95% is just spare time, self motivated and self funded.”

This difference in attitude towards sustainability is paramount. If a researcher believes that “limping along” or updating and supporting a tool on his or her own time is sustainable, then it is unlikely that alternative solutions will be sought. It’s noble, but not truly sustainable at the scale of use that we expect MEBM tools will start experiencing as more projects are begun in response to the federal mandate for managing our marine environment in an ecosystem-based way. Without truly sustained funding sources, the product “limps along” until the researcher no longer has the time or resources to support it and it ceases to be updated. Users eventually move on to other products (or develop their own independent solutions in-house).

Open Source Development Model

A growing awareness, availability of and adoption of open source based software could be part of the solution to finding long term sustainability of MEBM tools. Open source development is a collaborative model that distributes the development effort across many individuals in various organizations, and even in different industries. People who contribute to open source code are often employees of companies that use the software (or a module that the conservation software tool is built upon), which means their salary and time are paid for by someone other than the primary researcher.

“That’s part of the decision of going open source: to get tools out to share creates better ideas and work through collaboration.”

Many products, both commercial and otherwise, are currently available as open source projects. Allowing product users to contribute to the development and maintenance of the tool expands the working base, sharing the cost of maintaining the product. Several of the organizations interviewed here are already proficient in working with open source development combined with fee for service contracts, and many others brought up the idea of moving towards open source development.

Specific benefits that accrue through open source development include:

- Provides an insurance policy. When original developers can’t continue working on the tool, others can pick up and continue development.
- Ability to accrue users who are also developers, providing a community based development environment.
• Self-supporting customer base that is able to fix bugs they have encountered, and answer their own questions by examining source code.
• Others can build on the functionality, if permitted by the licensing terms.

Conclusions
With the current imperative from the federal government for Marine Spatial Planning through activities like Ecosystem-Based Management, there is an even greater need than in the past for a comprehensive array of tools to help researchers, conservationists, government agencies, and environmental managers get the job done. During the course of our interviews, we elicited many thoughts and ideas from the people who develop these tools on the reasons why today, so few conservation software tools are widely available and financially sustained over a long time period.

Because the potential audience for conservation products is small, commercially available products end up with license fees that some researchers and conservation managers are unable to afford (for example, Myriax’s Eonfusion or Placeways’ CommunityViz, neither of which are fully sustained through license fees yet). This lack of viable financial market has resulted in the conservation industry being built and run on software tools that were developed by researchers in academia, rather than commercial products. Almost all highly successful academic EBM tools (e.g. Ecopath with Ecosim and Marxan) are free, and the conservation industry remains dependent on academia to maintain and add to this collection of tools and to keep them affordable. Venture capital money is not a viable option for funding MEBM tools because there is no likely return on the investor’s money.

Without the long term financial success of the product as a driver, no business plan is created. As a consequence, the majority of these EBM tools are not financially sustained over the long term. A few of these tools do mature to high enough quality for public consumption and have gained widespread use, but because of the lack of planning, the majority of tools created in academia (a) are not made publicly available to other researchers or conservation organizations and (b) are unusable in their current form due to lack of a robust user interface, documentation, reliability, and ongoing support.

Our results support our hypothesis that most conservation tool development is conducted using a pulse-funding model, with short term non-renewable grants. Many tools start off as “skunk works” projects under grants, which are really designed for performing research work rather than for the long term financial support of a software product. Responses from our interviewees supported our idea that this pulse-funding model directly contributes to the lack of adequate funding for long term support of tools.

Grants have many advantages associated with them, including freedom to pursue innovation, prestige, autonomy, and the opportunity to collaborate with others. While other funding options are open to researchers, the default mechanism is
grants. Many respondents were explicitly not interested in pursuing alternative funding models, such as any form of remuneration from users, supporting our assumption that researchers intentionally try to fund tool development only via episodic grants.

Not a lot of business planning for the long-term financial support of products that are freely available takes place. A pervasive lack of desire to deal with the “business” side of tool development and support exists within the academic, government and non-profit organizations with whom we spoke. To some degree, the structure of the organization itself tends to make certain avenues of long term financial support, such as revenue from license fees, difficult. However, we believe that this institutional limitation can be overcome, and more perpetual revenue streams can be made available to tool developers. We also believe that tools can be kept available at little or no cost to users who cannot afford to pay typical commercial product fees, such as the government of a developing country.

The lack of a clear pattern between financial sustainability and funding mechanism or organization type surprised us. We saw no magic bullet of funding mechanism, or even combination of mechanisms. Rather, successful tools had a champion who devoted continued energy to keeping the product alive. Moving forward, we believe combinations of funding mechanisms and more widespread adoption of open source methodologies will provide the best foundation for success of tool sustainability. In the current economic environment, we recognize that no single source of funding will support the long term financial needs of software tools. Funders should understand the strain this puts on the developer: To be in constant funding raising mode and to be managing multiple streams and sources of funding. Funders should consider longer-term, more consistent funding for tool development to reduce the huge inefficiencies in the current system.

We believe that finding the balance between the mission-oriented belief and desire to keep products affordable, with the need for a more reliable and continuous stream of funding for product development, maintenance and support is achievable. We suggest the following recommendations for developers and funders, to promote the creation of more sustainable and more widely adopted MEBM tools.

**Recommendations for Developers**

- Seek multiple revenue streams to ensure financial sustainability.
  - Consider a scaled fee for license or services model to maximize adoption without sacrificing revenue.
  - Don’t under-value the expert knowledge and the services that you can provide; where applicable, charge for services that make your tool more valuable to users.
- Plan for and allocate funds and personnel for development of documentation and training, and for marketing the tool, supporting users, and maintaining the code (fixing bugs) after the product has been released.
- Educate funders about the benefits of funding these long term activities.
- Retain professional software engineers and other skilled specialists.
- Use engineering practices that promote sustainability.
  - Educate yourself about different software development methodologies (e.g. Agile Unified Process, Extreme Programming, etc.) and choose one that best fits your organization.
  - When transitioning from an internal tool developed by non-professional developers (e.g. graduate students) to a publicly available tool, consider having professionals rewrite the code from scratch. This will likely be more cost effective in the long run than trying to build upon the existing code.
  - Consider a modular product plan that promotes interoperability by packaging key functionality in compact modules that can be easily reused in other projects.
- Explore open source licensing models as a means for creating a community development environment that will contribute to the long term sustainability and support of the tool.
- Commit yourself to funding, maintaining, supporting, and championing your tool over its foreseeable lifetime, which is usually at least several years.

**Recommendations for Funders**
- Break the episodic funding cycle.
  - Consider endowing established tools, or open-source development communities.
  - Consider longer-term funding.
- Perform more due diligence and market research before funding a project to avoid funding duplicate efforts, unless you see a specific benefit to duplication (e.g. competition).
- Explicitly fund the development of tools, not just the research that makes them possible.
- Explicitly fund the additional activities needed to deliver quality tools to the users who need them, including the development of documentation and training, marketing the tool, supporting users, and maintaining the code (fixing bugs).
- Favor proposals that describe how the tool will be sustained in the long term, and address how the activities listed above will be funded, staffed, and completed.
• Favor proposals that identify specific customers or users and describe how this audience will be incorporated into the requirements gathering and product validation phases.
• Favor proposals that plan to employ sufficiently talented software engineers and other required personnel.
  o Be prepared and willing to pay competitive compensation to attract those people away from commercial development opportunities to conservation development.
  o Be wary of proposals that plan to use non-professional developers, such as students and post-doctoral researchers who lack university or professional training in software development.
  o Be wary of under-budgeted proposals.
• Favor proposals that promote developing generic and interoperable core-functionality modules that can be re-packaged in different applications.
• Encourage partnerships between academic, government or NGO developers and the commercial development community.
• Favor proposals with a demonstrated product champion.
• Favor proposals that plan to use proven software development methodologies.
• Encourage academic, NGO and government institutions to make it easier for their employees to use fee-for-service or fee-for-license funding mechanisms.

Despite all the challenges associated with long term funding for the development of MEBM tools, it can be done. There are many successful tools available. Continuing the support and maintenance of these tools is the primary challenge of the developer. If resources are not found to update the tool, provide support for users and fix bugs then often these tools eventually fall by the wayside, wasting the original money invested and robbing conservationists and environmental managers of the benefits the tool could provide. Together, changes adopted by both developers and funders will increase the rate of success and sustainability of conservation software tools, contributing to better understanding and management of our coastal and marine resources.

Disclaimer
The opinions, findings and conclusions expressed in this report are solely and exclusively those of the Marine Geospatial Ecology Lab and not those of Duke University or the David and Lucile Packard Foundation.
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Lance Garrison
Tim Haverland
Philip Hooge
Kevin Kohler
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Robert McGuinn
Tyler Mitchell
Atte Moilanen
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Keith Reynolds
Francesca Riolo
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Ken Snyder
Charles Steinback
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References


