Assessment of the Potential for Conflict between Existing Ocean Space Use and Renewable Energy Development off the Coast of Oregon

by
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Colleen M. Sullivan for the degree of Master of Science in Geography presented on June 5, 2012

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Oregon's ocean waters are a potential source of wind, wave, and tidal energy; of interest to renewable energy entrepreneurs and to the U.S. government as it seeks to bolster energy security. In order to install technology to capture this energy, however, it may be necessary to mitigate conflict with existing ocean space users. The objective of this research was to construct a conflict analysis model in a GIS to answer the following research questions: (1) Within the study area off the coast of Oregon, where are stakeholders currently using ocean space and how many uses overlap? (2) To what extent might existing ocean space use present potential for conflict with renewable energy development? (3) How do various types of uncertainty affect analysis results? (4) What are the implications of these findings for ecosystem based management of the ocean?

All available spatial information on ocean space usage by commercial fishing, commercial non-fishing, recreational, Native American, and scientific communities was gathered. Stakeholder outreach with these communities was used to vet the collected data and allow each to contribute knowledge not previously available through GIS data clearinghouses maintained by government or interest groups. The resulting data were used as inputs to a conflict visualization model written in Python and imported to an ArcGIS tool. Results showed extensive coverage and overlap of existing ocean space uses; specifically that 99.7% of the 1-nm^2 grid cells of the study

area are occupied by at least 6 different categories of ocean space use. The six uses with the greatest coverage were: Fishing – Trolling, Habitat, Military, Fishing - Closure Areas, Protected, and Marine Transportation - Low Intensity. An uncertainty analysis was also completed to illustrate the margin for error and therefore the necessity of appropriate stakeholder outreach during the renewable energy siting process, as opposed to relying only on a GIS.

Ranking of each category by its potential for conflict with renewable energy development demonstrated which areas of the ocean may be particularly contentious. Because rankings are subjective, the tool was created to allow users to input their own rankings. For the purpose of this report, default rankings were assigned to each as justified by the literature. Results under these assumptions showed that space use and potential for conflict were highest between the coast and approximately 30 nm at sea. This is likely because certain space use is limited by depth (e.g., recreational use); there is increased shipping density as vessels approach and depart major ports; and increased fuel costs associated with traveling further from shore.

Two potential applications of model results were demonstrated. First, comparison with existing wave energy permit sites highlighted relative potential for conflict among the sites and the input data detailed the specific uses present. Second, comparison with areas determined most suitable for development by the wave energy industry illustrated that areas of high suitability often also had high rankings for potential for conflict. It appeared that the factors that determined development suitability were often the same factors that drew current ocean space users to those locations.

Current support at the state, regional and federal level under the National Ocean Policy for the use of marine spatial planning as a tool to implement ecosystem based management of the oceans requires that tools such as the one developed in this research are used, to ensure that all components of the marine ecosystem are considered prior to implementation of a management plan. The addition of renewable energy to the current social landscape of the ocean will reduce the resource base for many categories of ocean space use. Model results demonstrated that mitigation of conflict between development and existing space use is not merely a best practice supported by current policy, but a necessity. Results presented a visualization of the social landscape of the ocean that could help managers determine which stakeholders to engage during the initial stage of choosing a site for development.

Master of Science thesis of Colleen M. Sullivan presented on June 5, 2012.

APPROVED:

Major Professor, representing Geography

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Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Colleen M. Sullivan, Author

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And, thank you Jasmine. On to the next adventure!

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1 Introduction

Nationally, the oceans provide a significant contribution to our economy in the form of trillions of dollars each year (Interagency Ocean Policy Task Force 2010). Locally, the Pacific Ocean accounted for 1.8 billion dollars and 26,700 jobs in Oregon in 2009 alone (Backus 2012). In addition to providing local revenue and jobs, the ocean is a highway for shipping, a store of biodiversity that could provide critical pharmaceuticals, a buffer to climate change, and a source of food, recreation and cultural heritage (U.S. Commission on Ocean Policy 2004). As the U.S. struggles with energy independence, harnessing the potential wind, wave and tidal energy sources of the ocean is increasingly important. Momentum is in place with regard to entrepreneurial interest, technological development, and ocean policy. However, responsible implementation is critical in order to preserve ocean ecosystems and maintain ecosystem services important to the public.

In order for the U.S. government to appropriately allocate lease blocks for offshore renewable energy development, it must target sites with existing space uses that are compatible with the project, mitigate potential conflict through stakeholder outreach, and optimize the necessary trade-offs between preserving existing space use and fulfilling the energy needs of the U.S. One tool to consider the ecologic, economic, and social needs already competing for space is marine spatial planning (MSP). MSP is a comprehensive ecosystem-based approach to decision-making concerning human interaction with marine resources (Ehler and Douvere 2007). MSP benefits from spatial analysis in a geographic information system (GIS), which facilitates the combination of multiple datasets to examine the spatial configuration and interaction of various habitats and uses across scales (St. Martin and Hall-Arber 2008). Central to MSP is stakeholder engagement to ensure all space uses are accounted for and to increase legitimacy of decisions (Higgs et al. 2008; Pomeroy and Douvere 2008).

The objective of this research is to help to mitigate conflict in the siting process by using MSP to conduct a conflict analysis between existing and proposed use of the ocean using a GIS. The conflict analysis will help answer the following research questions:

Q1. Within the study area off the coast of Oregon, where are stakeholders currently using ocean space and how many uses overlap?

Q2. To what extent might existing ocean space use present potential for conflict with renewable energy development?

Q3. How do various types of uncertainty affect analysis results?

Q4. What are the implications of these findings for ecosystem based management of the ocean?

Wind, wave, and tidal power have the potential to provide a significant source of energy for the U.S. Offshore energy development is a priority as we struggle to ameliorate anthropogenic climate change and implement a cost-effective energy infrastructure. The ocean, however, is already crowded. The addition of another stakeholder requires careful consideration of existing users to avoid conflict and minimize loss of social, cultural and economic value. In anticipation of increased interest in offshore leases for renewable energy, it is critical for federal decision-makers to prepare appropriately. There is currently no comprehensive decision making framework for siting offshore energy infrastructure, the development of which would be aided by the data compilation and modeling proposed here.

2 Literature Review

2.1 Ecosystem based management and marine spatial planning

Ecosystem based management (EBM) for the oceans is a framework for management that benefits from the use of MSP. EBM requires analysis of connections among components of the marine ecosystem and the social landscape that relies upon its ecosystem services (McLeod and Leslie 2009). Historically, management typically focused on the stock of a single species or the activities of a single stakeholder group. Now, the push is for integrative management that makes use of interdisciplinary analysis and tools such as MSP to inform decision-making and ensure sustainability (McLeod and Leslie 2009). The guidelines of EBM are particularly beneficial for siting offshore renewable energy projects because the process entails understanding of connections within the marine ecosystem, it requires collaboration among participants in the process, and its goal is achievement of multiple objectives.

Because the recently adopted U.S. national ocean policy specifically calls for the use of EBM in ocean management, state and federal governments are making formal attempts at EBM. Rosenberg and Sandifer (2009) outline five management principles for effective EBM that could prove useful for government ocean managers: (1) set appropriate goals; (2) recognize appropriate scales for management; (3) recognize interconnectedness; (4) make trade-offs explicit; and (5) use best available science and adaptive management to deal with uncertainty.

MSP is a space-oriented tool to implement EBM and its benefit is the efficient identification of stakeholders and compatible ocean space uses, enabling managers to reduce conflict among users while siting renewable energy projects (Ehler 2008). One possible outcome of MSP, zoning of the ocean, is controversial because historically policy and management have treated the ocean as the “last frontier” in which users are largely free to traverse and extract at will (Norse 2005; Ehler 2012). This era must come to an end, however, because fish populations are declining (and fishermen are simply switching to a different species when another is no longer profitable) and ocean biodiversity and stability are deteriorating (Norse 2005). MSP can designate areas for one or multiple uses in order to balance the demands on ecosystem services and improve resilience. For the purpose of siting offshore renewable energy, MSP helps ensure responsible allocation of lease blocks for development. An added benefit to designated uses of the ocean lies in economic security. Users no longer need to pay for legal counsel or equipment repair resulting from conflict with other user groups, and investors may more easily lend money having been assured of designated use of an area (Norse 2005).

To improve conflict management during MSP it is particularly important to first improve understanding of the human dimension of the marine environment (Bonzon, Fujita, and Black 2005; St. Martin and Hall-Arber 2008; Conway et al. 2010). The increasing utility of a GIS for multi-criteria analyses is an exciting and potentially comprehensive tool to achieve MSP, but only with all the appropriate data (McGrath 2004; St. Martin and Hall-Arber 2008). Specifically, managers need GIS data that represent human reliance on resources at sea, to allow its inclusion with the abundance of spatial data on physical and biological features (St. Martin and Hall-Arber 2008). As a bonus, the process of creating GIS layers to represent the human dimension is highly compatible with another key aspect of MSP – stakeholder research, analysis, and engagement.

There are many benefits to the process of identifying and understanding key stakeholders and subsequently empowering them to engage in MSP (Pomeroy and Douvere 2008; Conway et al. 2009, 2010). Users of ocean space benefit from having their interests accurately represented because early involvement helps to alert planners of major issues, discover compatible uses, and mitigate conflict (Gilliland and Laffoley 2008; Portman 2009). Early and sustained involvement of stakeholders greatly enhances the legitimacy of MSP decisions and therefore the likelihood of cooperation of the affected parties (Higgs et al. 2008; Pomeroy and Douvere 2008). Stakeholders such as fishermen, shippers, and scientists all have critical interests in ocean space use and possess local and traditional knowledge about usage patterns that must be integrated into MSP (Pomeroy and Douvere 2008; Kliskey, Alessa, and Barr 2009). If no attempt is made to gather and utilize this information, then the potential for conflict will increase. The "Not In My Backyard" syndrome is alleviated by stakeholder participation and the development of mutually beneficial solutions to potential conflict (van der Horst 2007). Stakeholder engagement provides key insights as to the complexity and extent of human use in a given area and the potential compatibility (or lack thereof) of their space use with concurrent uses by other stakeholders (Pomeroy and Douvere 2008). This process encourages community involvement in MSP while creating much needed GIS data for use in EBM.

Researchers take different approaches to the process of documenting local knowledge and traditional ecological knowledge. These include asking stakeholders to draw geographic regions of interest in participatory mapping, to input parameters to a computer model, to discuss ranks for preferences related to ocean regulations, or to assign values to aspects of the ocean ecosystem (Lynam et al. 2007). Loosely structured interviews are also used, to discover the uniquely detailed knowledge some stakeholders possess of their resource base, not captured by the more rigid forms of collection (e.g., logbooks) which suffer from lack of detail and participation (Neis et al. 1999; Scholz, Mertens, and Steinback 2005; Wedell et al. 2005).

St. Martin and Hall-Arber (2008) show, however, that logbook data can be a very useful starting point to approximate broad-scale behavior. Their maps of fishing communities in the Gulf of Maine used Vessel Trip Records (VTR), which were analyzed with density maps and contours to highlight spatial clusters of trip destinations and gear-type communities (St. Martin and Hall-Arber 2008). These maps were vetted by local fishermen and found to be useful representations of human dependence on the ocean (St. Martin and Hall-Arber 2008). The combination of existing knowledge (even with its limitations, e.g., VTR data) and participatory mapping as a groundtruthing mechanism is a very valuable tool for documenting the social landscape (NOAA Coastal Services Center 2009).

Ecosystem based management as a guiding framework, and marine spatial planning as a tool to enhance management efficiency are promising approaches to offshore decision-making to not only ensure stewardship of ocean ecosystem services but to incorporate offshore renewable energy, which would bolster the U.S. energy portfolio. The framework is especially useful for recognizing and mitigating potential conflict.

2.2 Environmental conflict management

Sørensen et al. 2003 (Industrial Economics, Inc. 2012) divides ocean space use into two categories to guide discussion of potential for conflict: those with existing regulations that restrict access enough to generally prevent conflict (e.g., shipping routes, military grounds, marine protected areas) and those that have conflicting uses (e.g., fishing grounds, cultural areas). The former makes determination of compatibility with renewable energy development relatively straightforward, while the latter proves more complicated. Strategies for both categories include avoidance, communication and stakeholder engagement, and conflict resolution (Industrial Economics, Inc. 2012). Conflict avoidance entails siting in uncontested areas, at least for specific types of ocean space use (White, Halpern, and Kappel 2012). Stakeholder analysis, using myriad tools and approaches, is used to better understand the social landscape, and encourage community support (Lynam et al. 2007; Pomeroy and Douvere 2008; Gibbs et al. 2012). Conflict resolution (also known as dispute resolution) is used when conflict cannot be avoided or mitigated. Capitini et al. (2004) describe how approaches to conflict resolution should differ depending on whether one of three types of conflict are present: interest or resource-based conflict, identity or values-based conflict, or some combination of the two.

As managers struggle to site offshore renewable energy developments that have the support of commercial fishermen, recreational fishermen, shippers, undersea cable companies, indigenous populations, and scientists, there are existing agreements that exemplify the benefit of cooperation among stakeholders. The Oregon Fishermen's Cable Committee is one such model. Since 1998 participating trawlers have negotiated with undersea fiber optic cable companies to establish procedures for fishing in the vicinity of cables (OFCC 2012). The agreement both protects the cables (by preventing bottom trawling nearby which could cause damage) and protects the fishermen (by indemnifying them against financial loss if they need to cut their gear loose and against potential lawsuits in event of damage) (OFCC 2012). Another example of cooperation is the West Coast Commercial Crab/Towboat Lane agreements, which establish routes from Cape Flattery to San Francisco where towboats will navigate, and where crabbers will not place pots (Washington Sea Grant 2012). Still in place after more than 35 years, this agreement benefits both groups by avoiding the damage to boats and gear following collisions between pots and towboats (Washington Sea Grant 2012).

As these examples illustrate, the "Tragedy of the Commons," per Garrett Hardin's 1968 thesis, doesn't always take precedence in guiding fisherman behavior (Shackeroff, Hazen, and Crowder 2009). When there is sufficient social capital and communication, fishermen do cooperate and sacrifice personal gain in order to ensure the sustainability of fish stocks; they are a part of the marine ecosystem and thus benefit from its resilience (Norse 2005; Shackeroff, Hazen, and Crowder 2009). Norse explains the bottom line succinctly: "The emphasis on beating competitors to resources (exploitation competition) rather than ensuring resource sustainability often proves economically ruinous because, as resources are depleted, cost per unit of production tends to rise and profitability tends to decline, so users bankrupt themselves as they exceed the capacity of nature to provide what they need" (Norse 2005, 428). Because of this, management can learn from stakeholders as it attempts to implement broader scale integrated plans for offshore energy development.

Multiple objectives are a key component of EBM for conflict management (McLeod and Leslie 2009). The siting of offshore renewable energy projects benefits from informed and content stakeholders which necessitates accomplishment of multiple objectives and explicit decisions as to trade-offs (Conway et al. 2009; McLeod and Leslie 2009; Portman 2009; Conway et al. 2010). By focusing on the full suite of ecosystem services provided by a marine region, compatible uses may be identified and conflict minimized by avoiding particularly sensitive areas with uses that are not compatible with offshore energy development. For example, a potential compatible use exists between offshore renewable energy projects and certain fisheries because the buoys, cables, poles, and concrete bases of the infrastructure may serve as fish aggregation devices and artificial reefs and attract more pelagic and benthic species diversity and abundance than initially present (Boehlert and Gill 2010). This could also lead to increased predation, collision, and injury for the attracted species to renewable energy projects with moving parts underwater, so more research is needed on this subject (Boehlert and Gill 2010).

While best practices and techniques for environmental conflict management vary, in order for an agreement to stick it is ultimately important to ensure the process uncovers the full suite of interests and values at stake (Capitini et al. 2004). Lessons from existing agreements among ocean space users could provide key insights for management as they attempt to design agreements in order to site offshore energy developments.

2.3 Principles of uncertainty

By nature of representing reality in a simplified form at a particular scale, all maps contain some degree of uncertainty (Longley et al. 2011). That is, there is at least some discrepancy between the digital representation of a phenomenon and its ground truth (Arbia, Griffith, and Haining 1998). Consequently, decisions made using data in a GIS are subject to uncertainty as well; it is important for decision-makers to understand the sources and propagation of this uncertainty (Longley et al. 2011). Directly addressing uncertainty improves credibility and may reduce challenges to decisions (Bolstad 2005). The transitions first from reality to conceptualization, then from conceptualization to representation, and finally from representation to analysis each distort reality (Longley et al. 2011). Introduced error may stem from the GIS data model chosen to represent a certain reality and by measurement of that reality (Arbia, Griffith, and Haining 1998). Federal Geographic Data Committee (FGDC) standards address five aspects of quality: positional accuracy, attribute accuracy, logical consistency, completeness, and lineage (Longley et al. 2011).

The process of conceptualization, during which reality is simplified and represented, presents inevitable challenges for accuracy (Plewe 2002). As a starting point, Plewe (2002) differentiates among bona fide entities which are real and have uncertainty only in their extent, fiat entities which owe a fragile existence to legal documents, and motivated entities which are simplifications via aggregation or categorization of much more complex phenomena. In addition to the philosophical limitations encountered during conceptualization, the choice of a data model for representation has direct implications for analysis uncertainty. For example, the use of a raster dataset limits positional accuracy to one half the cell resolution and may overgeneralize in the process of assuming a single value for each cell (Bolstad 2005). Similarly, the use of a vector dataset can overgeneralize in its simplification of reality and may contain increased attribute error near boundaries, as vectors are limited in their ability to show gradual changes in attributes (Bolstad 2005).

Positional accuracy refers to the degree to which coordinates used to represent a point in a GIS differ from their true values. This might be expressed as an error distance or a probability that that the true values fall within a given distance of the representative coordinates (Bolstad 2005). Positional accuracy is introduced during data collection. GPS devices have limited accuracy. Digitization may introduce error first in distortion when converting paper to digital by photographing or scanning and second in human error while tracing the contents of the map (Bolstad 2005).

The only way to quantify this aspect of uncertainty is to test the data against “true” values to provide an indication of the mean and spread of error (Bolstad 2005). True values may come from groundtruthing unambiguous locations in the field with a GPS device, or from a higher accuracy source (Bolstad 2005). In accordance with the FGDC National Standard for Spatial Data Accuracy (NSSDA), this usually means calculating the Pythagorean distance between true and digital coordinates for 20-30 well distributed test points of a dataset to obtain the root mean square error (RMSE) for the dataset (Bolstad 2005). According to statistical theory, provided the error is normally distributed, the RMSE of the distances, multiplied by 1.7308, provides the threshold distance within which 95 percent of points are expected to fall relative to the true coordinates (Bolstad 2005).

For lines and polygons, the procedure is less straight-forward. One comparable procedure for lines involves calculating an epsilon band that encompasses the probable location of the line (Bolstad 2005). However, because lines and polygons are a series of nodes and vertices (points) with connecting segments, the error estimation method for points could be adapted to derive a buffer distance for the feature because unless the connecting segment is significantly curved, the error along the line cannot be greater than at the nodes (Bolstad 2005). One limitation to this approach applies for digitized polygons, which have been shown not to have normally distributed positional error, such that lines with high curvature tend to have more error on the concave side (Gong, Zheng, and Chen 1995). Gong, Zheng, and Chen (1995) also found that increased curvature correlates with increased digitizing error and that the areas of smaller compact polygons are typically underrepresented. Despite these issues, Leung and Yan (1998) advocate for an integrated stochastic error model for points, lines and polygons that uses positional error of points as its foundation.

Attribute accuracy refers to how close categorization of representations in a GIS match true values. Attribute error stems from definition of the attribute categories and measurement and is plagued by issues of vagueness and ambiguity (ESRI Resource Center 2011; Longley et al. 2011). Attribute assignment (e.g., distinguishing kelp habitat from non-kelp habitat) can be vague due to the subjectivity associated with certain units of measurement and ambiguous due to variation in definitions used to categorize reality (Longley et al. 2011). Like positional accuracy, error in continuous attributes can be conveyed as the mean and spread of errors, while for categorical attributes a percentage to indicate how often a value is wrong may be more appropriate (Bolstad 2005). There is no NSSDA standard for attribute accuracy calculation, but common methods involve the use of error tables (also known as a confusion matrix) to summarize accuracy by comparing attributes with ground checked values (Bolstad 2005; Longley et al. 2011).

Logical consistency refers to the presence of conflicting information (Bolstad 2005). An example of poor locational logical consistency could be buoy coordinates that fall on land. An example of poor attribute logical consistency could be classification of fishing grounds as ideal for recreational groundfish trawl (because recreational fishermen do not trawl for groundfish).

Completeness refers to the extent to which a dataset is missing features (Bolstad 2005). Omissions may be intentional for the purpose of generalization or may result from error (Bolstad 2005). Both situations translate to uncertainty in representation.

Lineage refers to a set of clues as to the quality of a dataset from information on its creation – sources of data, expertise of people involved, methods used, and date of creation (Bolstad 2005). The date of creation can be of interest because positional and attribute accuracy may degrade over time, as natural and anthropogenic disturbance consistently modifies the positions and qualities of the environment (Bolstad 2005). The methods used can be of interest to help detect spatial autocorrelation of errors. Data collected with the same methods over a relatively short time span are more likely to have spatially autocorrelated error, thus reducing the overall range of error (Longley et al. 2011). In the same vein, concatenation of GIS data from different lineages can seem to amplify uncertainty by revealing where the use of different sources causes issues with logical consistency (Longley et al. 2011).

Consideration of these different sources of error is important when evaluating utility of analysis in a GIS because error in the input data will propagate throughout a model, with important implications for interpretation of results. Managers making use of MSP with a GIS for conflict mitigation should be mindful of the influence of uncertainty on model outputs.

3 Methods

3.1 Study area

The study area for the first two stages of this project, data collection and data creation, was the OCS of the U.S. mainland Pacific coast. The OCS extends from the edge of the territorial sea, 12 nautical miles (nm) from baseline, to the greater of 200 nm from the baseline or the edge of the continental margin. The baseline is the mean lower low water line along the coast. While the Bureau of Ocean Energy Management (BOEM) (the agency responsible for lease block allocation for offshore renewable energy development) considers areas beyond 200 nm as part of its planning extent on the OCS, technically its jurisdiction extends only to 200 nm because the U.S. has not signed the United Nations Law of the Sea (U.S. Commission on Ocean Policy 2004). This study area, in conjunction with the work of Industrial Economics, Inc. to collect and create data for the U.S. mainland Atlantic coast OCS, provided BOEM with a comprehensive ESRI file geodatabase for U.S. ocean space use. BOEM chose not to include the OCS of the Gulf of Mexico, Alaska, Hawaii, or U.S. territories due to limited resources.

The study area for the potential for conflict analysis, the focus of this thesis, was narrowed to the ocean off of Oregon, 0-200 nm from shore, a combination of the territorial sea and EEZ of Oregon (Figure 1). The study area was extended to the coast (as opposed to 12 nm from baseline) because this analysis is relevant to state waters as well as federal waters. The study area was limited to 200 nm from the coast (as opposed to the edge of the continental margin) to reflect current jurisdiction and because some downloaded data were already clipped to this boundary. The study area was limited to waters off the coast of Oregon (as opposed to the entire Pacific Coast) in order to increase analysis efficiency and facilitate comparison with other studies.

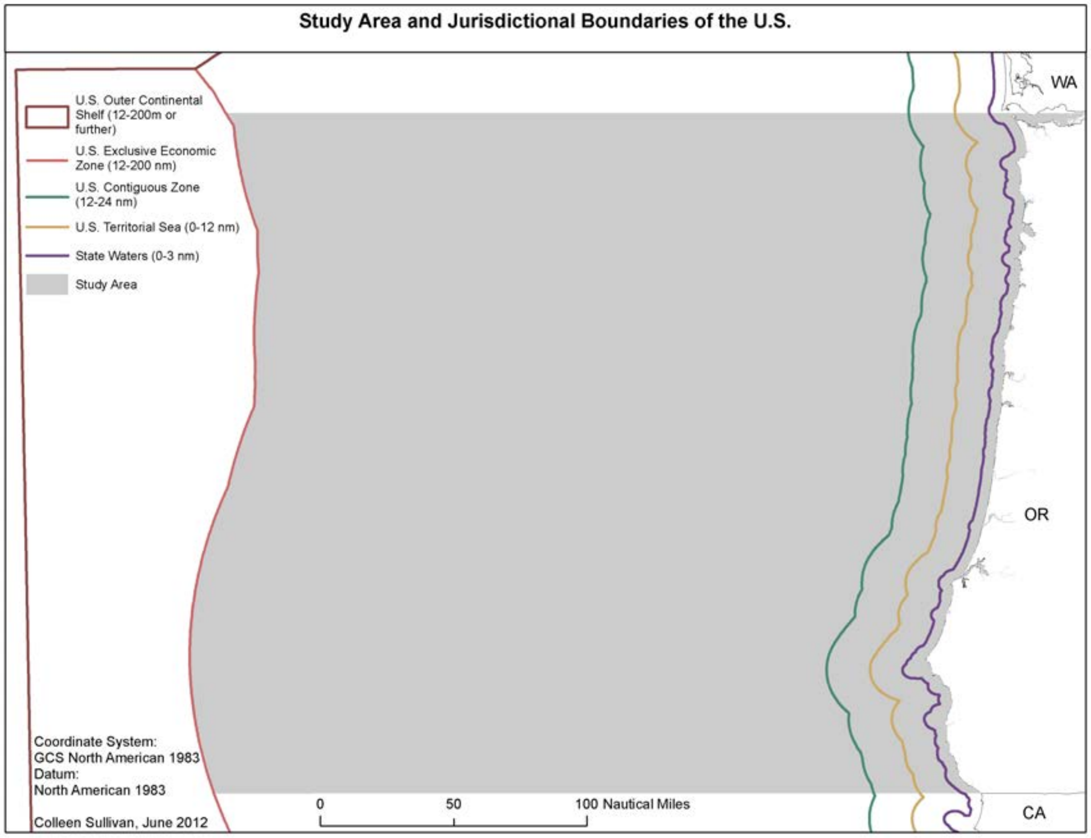

Figure 1. Study area and jurisdictional boundaries of the U.S.

3.2 Data collection

Federal, State, and nongovernmental GIS data clearinghouses were searched, and ocean related data, particularly those relevant for marine spatial planners, were downloaded. If any downloaded data did not have FGDC metadata, then the necessary information was gathered from internet searches and correspondence with data managers and documented using ArcCatalog's metadata editor. Information was also added to some downloaded data and metadata to make them more useful for BOEM (e.g., NOAA's ENCDirect, California Ocean Uses Atlas). When tabular or qualitative spatial information was obtained (e.g., coordinates of dive sites, shipwrecks, etc.), it was used to prepare new shapefiles. Complete metadata were written for these created shapefiles. Correspondence concerning data and metadata requests was recorded in a Microsoft Excel spreadsheet contact log to track inquires. Email conversations with 60 individuals or groups of colleagues were used to obtain data and metadata not available for direct download. The shapefiles were tracked using an Access database and characteristics of each were recorded (e.g., coverage, category, source, description).

3.3 Ethnographic research

Dr. Flaxen Conway (Oregon Sea Grant) and Dr. Carrie Pomeroy (California Sea Grant) conducted ethnographic research on members of three broad ocean user communities: commercial fishing (harvesting, processing, Native American, aquaculture), commercial non-fishing (shipping, tug, service and safety), and non-commercial (recreational fishing and boating, scientific) communities of Washington, Oregon, and Northern California in order to produce data on ocean space use. Conway and Pomeroy used their network of contacts to seek key informants and ultimately research subjects from the three ocean space use communities.

Maps were created for use in the interviews, in order to vet the data compiled, created, and organized in the first two phases of the project and to encourage data sharing about the space use of stakeholders. Specifically, the goal was to understand characteristics and use of space and place, compatible and conflicting use, economic and social impacts, communication preferences, and perspectives on mitigation. The shapefiles collected through the beginning of November 2010 that included coverage off of Washington, Oregon, and Northern California were organized into 13 categories: recreational, shipping, closures, designations, obstructions, platforms, cultural, commercial non-fishing, and commercial fishing effort organized into troll, trawl, trap/hook and line, crab pot, all else. The data in each category were merged to create a single point, line, and polygon shapefile for each, which were given the same symbology and set to 50% transparency to show overlap. Nautical charts were used as a background to help orient the research participants in a familiar medium (Wedell et al. 2005).

For the purpose of interviews in which discussion would center on the space use of an individual, it was determined that extending 40-60 nm from shore would be more appropriate than showing the entire OCS. Thus, a grid (and associated bookmarks in ArcMap) was prepared to divide the region from Washington to Northern California into 11 sections, each at a scale of 1:180,000 (Figure 2). Each section was printed 3’x4’ (ARCH E) and included the index number and inset map of the grid to assist organization (Figure 3). Conway and Pomeroy each received the set of 11 maps to use in their interviews. During ethnographic research, interviewees used sharpie pens to mark mylar sheets placed over the printed maps (or blank nautical charts) to record their understanding of ocean space use, drawing from their background and personal experience.

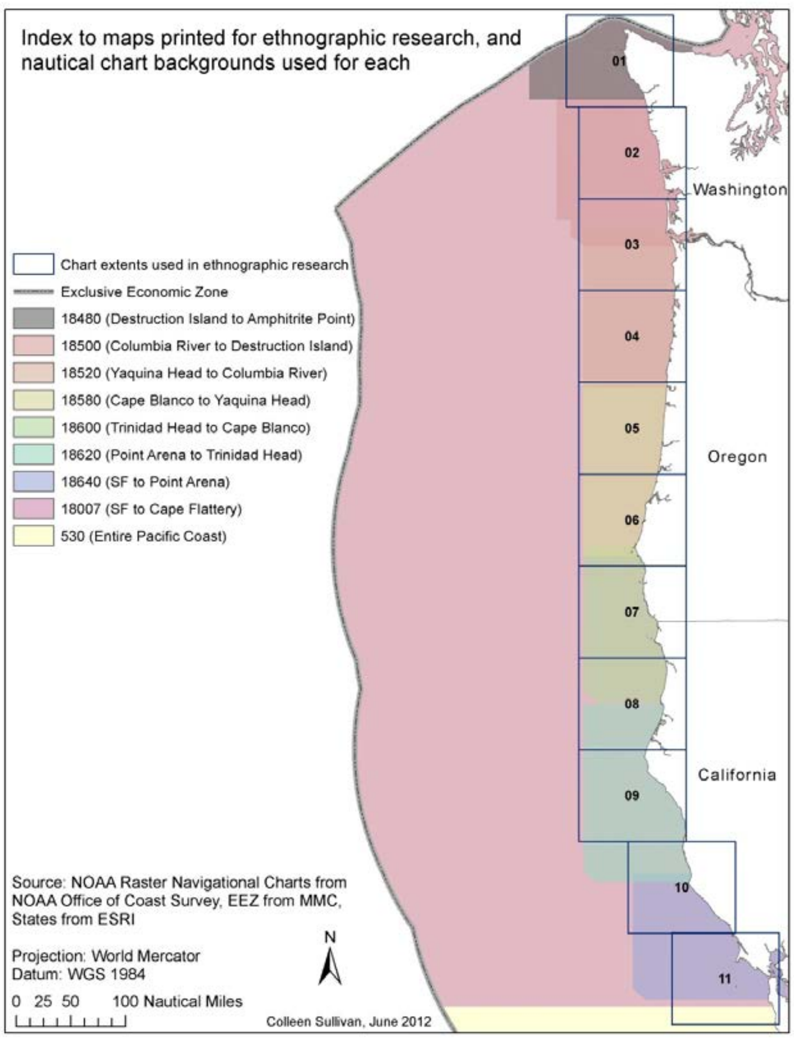

Figure 2. Index to nautical charts and maps produced for ethnographic research.

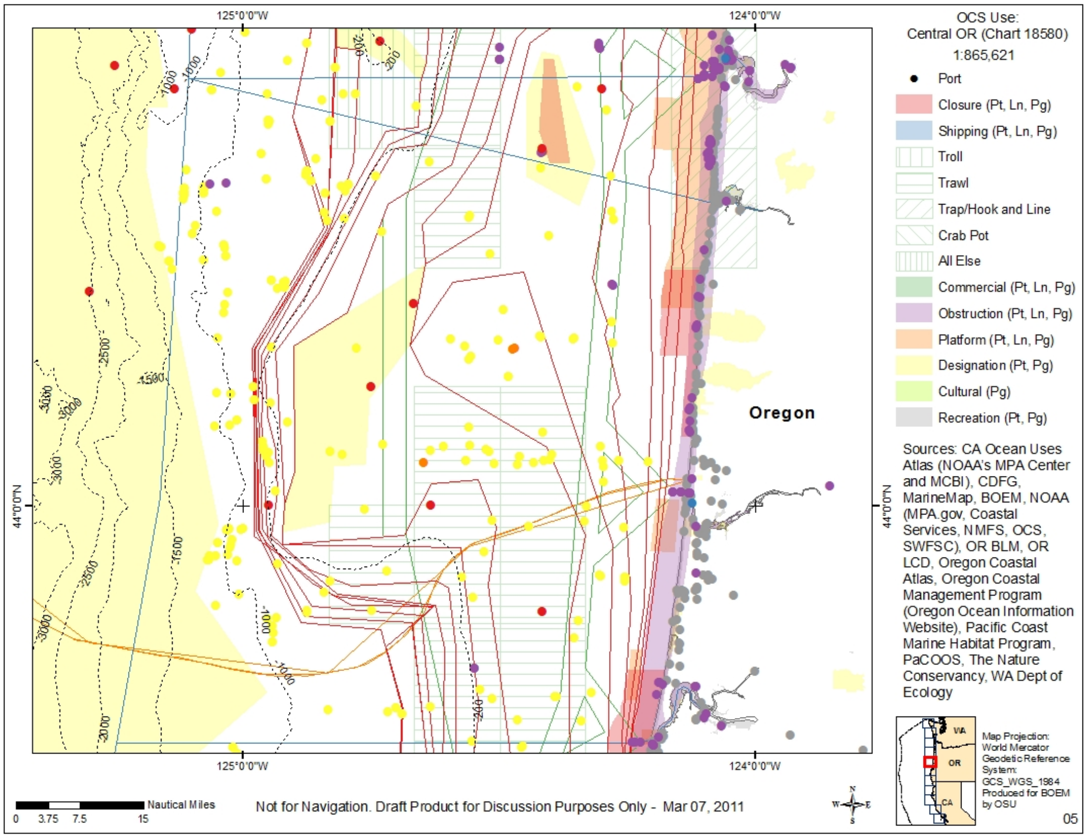

Figure 3. Example map printed for use in ethnographic research (resized from its 3'x4' layout for the purpose of legibility).

Following the interviews that resulted in spatial data, the 36 mylar sheets were returned. These were placed on the floor on top of a blank poster, and photographed with a digital camera while standing on a chair, with the camera centered over the map, to try to minimize distortion (Figure 4). In some cases the mylar sheets were photographed by Pomeroy, on top of the relevant printed chart, and only the images were returned to save on shipping costs. The .jpg images were then georeferenced using corner marks traced by Conway and Pomeroy, along with other known reference points. Effort was made to choose high quality control points and obtain a low RMSE during georeferencing. The reference point data were saved to a text file for each photograph.

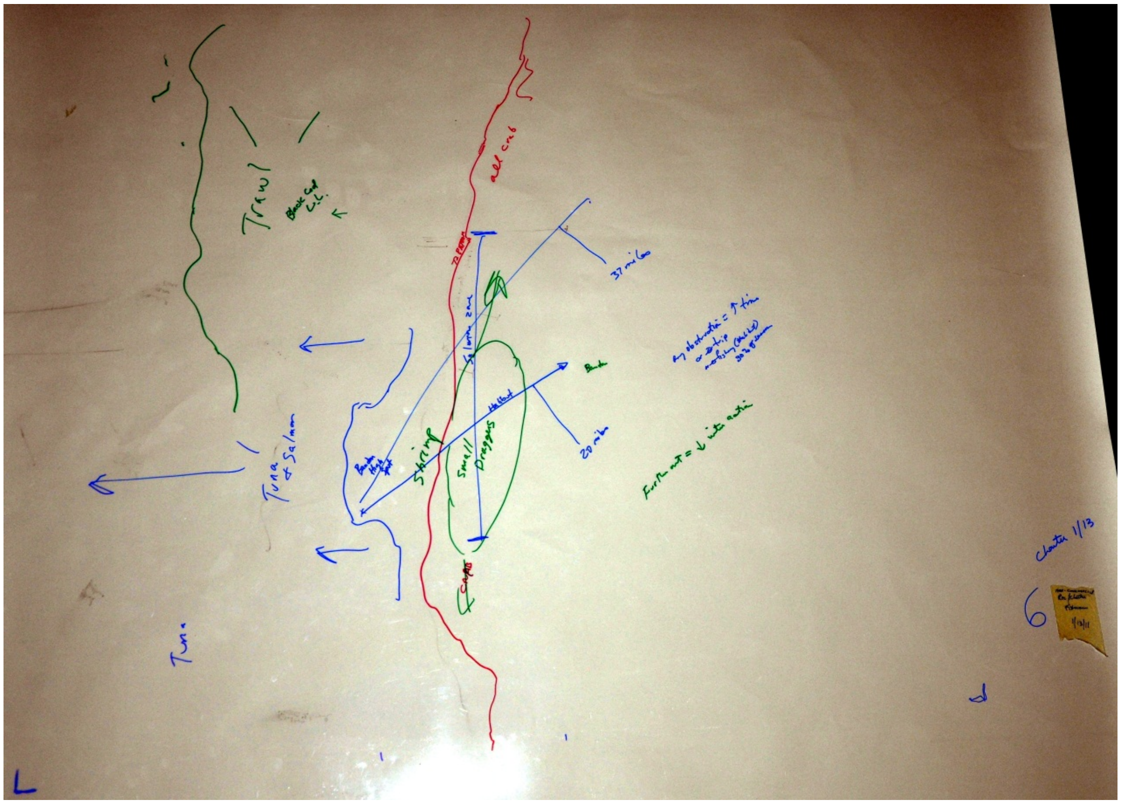

Figure 4. Example photograph of mylar sheet with comments drawn during an interview.

Marks made by the interviewees were digitized to record interview results in a GIS. A new shapefile with a unique ID was created for each feature or comment written on the mylar and the area was traced using the Editor tool in ArcGIS 9.3. Any assumptions or judgment calls necessary were recorded for future reference. When the comment referred to a distance range from shore (e.g., recreational boating between 3 and 20 nm from shore), then the shape was created by buffering the shoreline by the appropriate distances and using the buffers to clip a shapefile of the study area. When the comment referred to a depth range in fathoms (e.g., recreational fishing for crab between 0 and 20 fathoms), a soundings point shapefile from NOAA's ENCDirect was used as a starting point. A field for fathoms was added and calculated using the existing depth attribute in meters. For each fathom range comment, “Select by Attributes” for the appropriate range was used, and the selection was exported to a new shapefile. Then, the method for data area delineation from light detection and ranging (LiDAR) points was adapted to derive a boundary of the points. This method was described by Crawford (2009) in a series of ArcGIS Blog posts on LiDAR solutions and involves 5 steps to transform a point dataset to a polygon outline of that dataset. The point shapefile was used as an input to a ModelBuilder model to automate the 5 steps outlined by Crawford (2009) as follows: (1) rasterize the points, (2) ensure the raster has a uniform value, (3) use the expand tool to fill in small NoData gaps and prevent holes in the output, (4) use the shrink tool to effectively undo the previous step only along the edges, and (5) convert the raster to a polygon (Figure 5, exported script in Appendix A). All georeferencing and shapefile creation was done in the same projection as the printed maps, and then projected to GCS_North_American_1983, per BOEM's request.

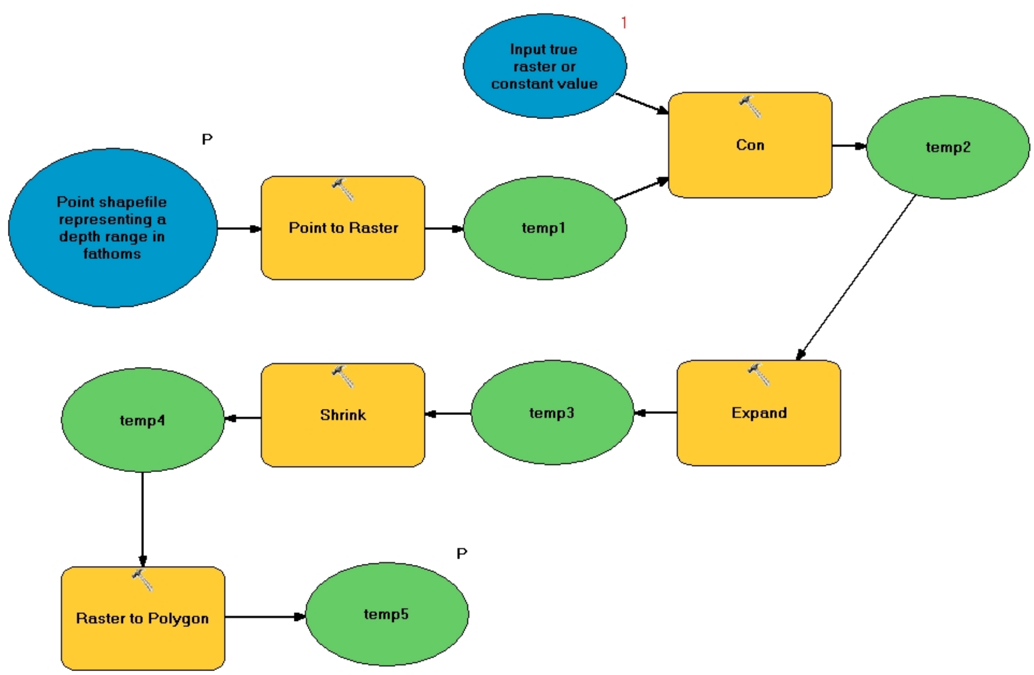

Figure 5. Screenshot of ModelBuilder model made to assist digitizing of social science research results that involved a depth range in fathoms.

Interview transcripts were used along with text actually written on the mylar to record a "comment" associated with each unique ID in Microsoft Excel. The spreadsheet was provided to Conway and Pomeroy for review. Once the comments were approved for inclusion with the geodatabase, a series of ArcGIS ModelBuilder models were used to batch process the digitized shapefiles to first dissolve on the ID field (preserving multi-part features) to prevent duplication of comments in the resulting shapefiles, add a text field (length 254) called “Comment,” and calculate the field with the approved textual comment from the spreadsheet (Figures 6-8, exported scripts in Appendix A).

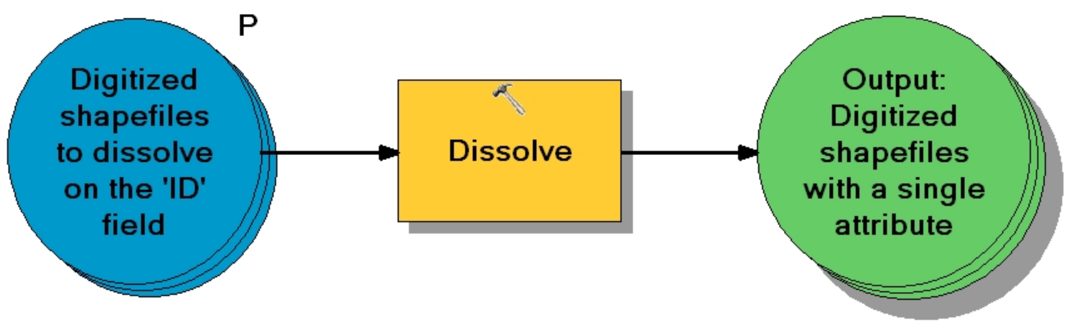

Figure 6. Screenshot of ModelBuilder model - In this first step each digitized shapefile is dissolved on the ID field (preserving multi-part features) to prevent duplication of comments added in following steps.

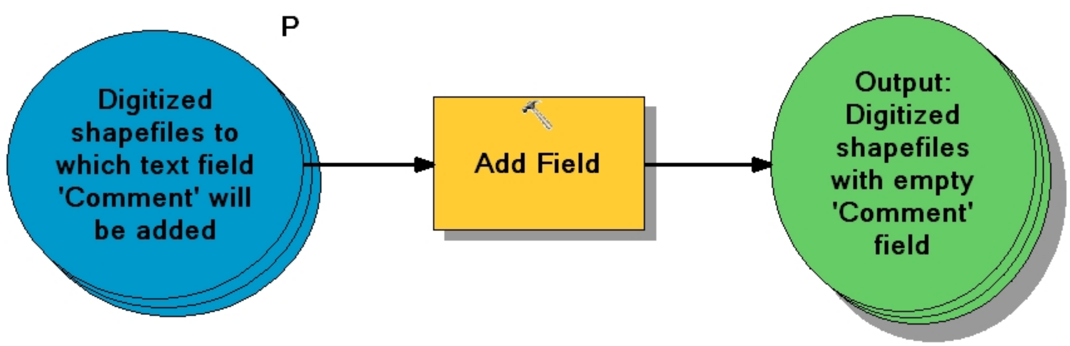

Figure 7. Screenshot of ModelBuilder model - In this second step a text field (length 254) called ‘Comment’ is added to each digitized shapefile.

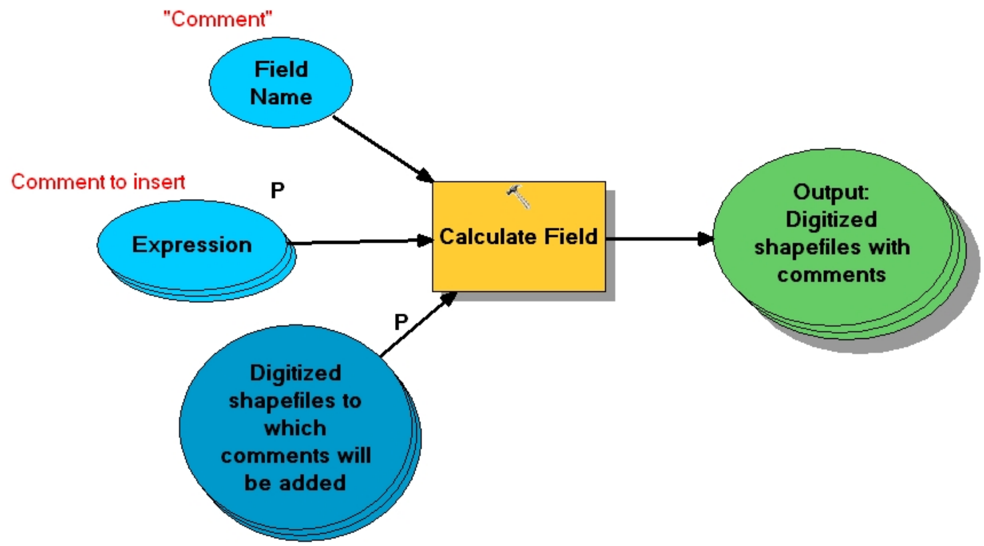

Figure 8. Screenshot of ModelBuilder model - In this third step the 'Comment' field is calculated using approved text appropriate to each digitized shapefile.

The resulting 222 shapefiles (with comments in the attribute table) were then merged to consolidate into 24 subcategories within 4 broader categories (Table 1). Some comments were placed into more than 1 subcategory if applicable. Separate shapefiles were created for point, line, and polygon comments as needed for each of the 24 subcategories, resulting in 37 shapefiles as opposed to 24. Metadata were written and imported to each of the final shapefiles, which were then copied into the final geodatabase for BOEM. This proved to be an affordable and effective method of incorporating ethnographic research results in a GIS. If repeated, it is recommended to consistently photograph the mylar on top of the chart, as opposed to relying on traced reference marks for use in georeferencing.

Table 1. Categories and subcategories used to organize the ethnographic research results.

Category	*Subcategory - shapefiles created for each geometry as needed*
Commercial Fishing	Crab, Groundfish, Hagfish, Halibut, Sablefish, Salmon, Shrimp, Spot Prawn, Tuna and Tribal
Commercial Non-fishing	Cables, Shipping, Towlane
Noncommercial	Crab, Groundfish, Halibut, Sablefish, Salmon, Tuna, Boating, Research
Other	Marine Reserves, Physical features, Placemarks

The maps used for interviews were updated with the additional data collected and created between November 2010 and June 2011. The updated maps showed the categories of: historical fishing and fishing areas, archeological, area of special concern, marine transportation/shipping lanes/ferry routes, military use area, oil and gas deposits and infrastructure/cables, recreation activities, renewable energy, research areas, sand and gravel source and disposal. A different approach to symbolization was used to help show exactly what use overlapped in each area - each category was given a unique color and gradient that allows all overlapping use to be seen. An example export of all data in central Oregon is shown in Figure 9. Despite these changes, maps showing all data were prohibitively complex and confusing, so more specific maps were exported showing subsets of the data. The number of sections between Washington and Northern California was reduced from 11 to 8 (2 in WA, 3 in OR, 3 in CA). For each state and each section of each state, maps were exported showing:

- A blank nautical chart
- All commercial nonfishing
- All noncommercial
    - Fishing and boating only
    - Science and military only
- Each of the following was exported once for Oregon and California and twice for Washington, the second set including Tribal fishing use:
- All commercial fishing (by species)
    - Spot Prawn, Sablefish, Halibut only
    - Groundfish only
- All commercial fishing (by species), without closures
    - Spot Prawn, Sablefish, Halibut only, without closures
    - Groundfish only, without closures
    - Tuna and Salmon
    - Crab
    - Shrimp

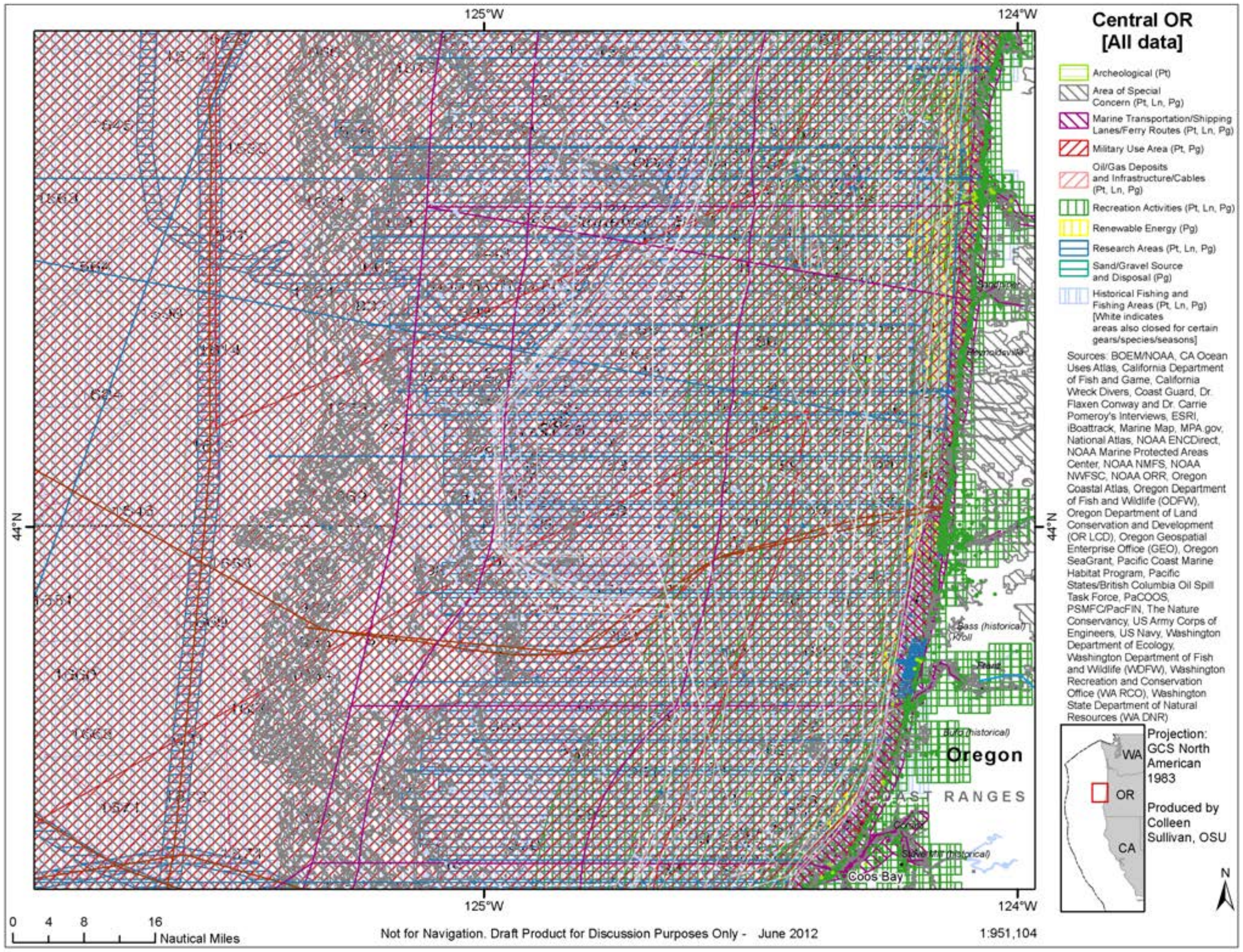

Figure 9. Example final map for follow up meetings with stakeholders, showing all data collected, created, and digitized in central Oregon.

This resulted in a set of 53 images for Washington, 54 images for Oregon, and 53 images for Northern California. Electronic versions of these maps were provided to Conway and Pomeroy for use in larger group meetings in PowerPoint presentations, to communicate our findings and provide opportunity for stakeholders to voice concerns with the outputs. I attended one such meeting with the Southern Oregon Ocean Resource Coalition (SOORC) in Charleston, Oregon on June 14, 2011 to gain exposure to the stakeholder research vetting process. The feedback received at this and other vetting meetings was incorporated before delivering the final ESRI file geodatabase to BOEM on July 15, 2011.

3.4 Ranking potential for conflict

Multicriteria decision analysis (MCDA) models are commonly used with a GIS to manage conflicts in environmental planning (Joerin, Thériault, and Musy 2001; Kiker et al. 2005; Ramsey 2009). Rather than mimic existing model designs, the tool created in this research is a ranking model that produces a visualization with an ordinal scale to demonstrate relative potential for conflict between existing use and renewable energy development. Each input category of space use is given a rank based on the user's perception of its compatibility or lack thereof with development. The rank values and explanations are presented in Table 2.

Table 2. Conflict rank values and meanings, a key to the parameters accepted by the conflict analysis tool.

Rank	*Activity is present and…*
0	Poses no potential for conflict with renewable energy development
1	Poses little potential for conflict, possibly even compatible with renewable energy development
2	Poses some potential for conflict that could probably be mediated with reasonable effort
3	Poses likely potential for conflict requiring in-depth negotiation that could be successful depending on location targeted
4	Poses nearly insurmountable potential for conflict, wherein one party might need to forfeit use and adapt accordingly

For the purpose of demonstrating the model and discussing its results, default rankings are assigned to each category based on a literature review. Table 3 and the paragraphs that follow include an explanation of each default conflict ranking assignment for the 26 categories of data used in this analysis. The methods used to arrive at the list of categories are explained in the next section.

Table 3. Default rankings assigned to each category of data used in this analysis.

	Data category	*Weight*
1	Wrecks	4
2	Habitat	1
3	Protected	4
4	Native American	3
5	Research - Sampling location	4
6	Military	4
7	Disposal/Dump	4
8	Dredge	2
9	Cable	4
10	Pipeline	4
11	Recreational – Boating	1
12	Recreational – Fishing	3
13	Recreational - Wildlife Viewing	2
14	Recreational - Other (e.g., surfing)	2
15	Marine Transportation - High Intensity	4
16	Marine Transportation - Moderate Intensity	3
17	Marine Transportation - Low to Moderate Intensity	2
18	Marine Transportation - Low Intensity	1
19	Marine Transportation - Navigation Aid	2
20	Fishing - Closure Areas	4
21	Fishing - Other Gear Types	3
22	Fishing – Line	4
23	Fishing – Pots	3
24	Fishing – Trap	3
25	Fishing – Trawls	3
26	Fishing – Trolling	3

The wrecks category includes data on shipwrecks that are attractive to recreational divers and may also have cultural significance. Such sites are often a hazard to fishing gear, so fishermen are not typically a user group in the vicinity of a wreck. Thus, if it is possible to install a renewable energy project in the water column with a wreck (e.g., using floating infrastructure) without hindering access for cultural or recreational enjoyment, then the conflict ranking would be low. However, assuming it is not possible to build there, and that removal would cause loss of tourism income from divers and additional issues if the wreck is on the National Register of Historic Places, a default ranking of 4 is assigned (Wiggin et al. 2009).

The habitat category includes data on essential fish habitats, critical habitats, seabird colonies, seal and sea lion haul-out and rookery locations, kelp canopy, and corals. These are not necessarily prohibitive the way protected areas are, but there may be advocacy on behalf of the species involved. This is especially a condition of the technology to be sited and the specific species of a sensitive habitat (e.g., wind energy would be more contentious for sensitive bird colonies, while wave or tidal energy would be more contentious for species in the water column) (Wiggin et al. 2009). Because the habitat data cover all of Oregon's offshore waters and may be compatible depending on the species and technologies involved, a default ranking of 1 is assigned.

The protected category includes data on Marine Managed Areas, Marine Protected Areas, Marine Reserves and Wildlife Refuges which are designed to protect the ecosystem. Establishment of these areas is usually a time consuming process with its own conflict mitigation procedures and enforcing agencies are likely not going to give them up for development easily. In fact, ocean development is explicitly prohibited in Marine Reserves, potentially prohibited in Marine Protected Areas, and politically prohibitive in MMAs (Oregon Department of Fish and Wildlife 2012). Given these obstacles, a default ranking of 4 is assigned.

The Native American category includes data on commercial fishing, cultural areas and reservation locations. Siting renewable energy in these locations could lead to loss of hunting and gathering grounds, identity, and tradition (Industrial Economics, Inc. 2012). Because they are willing to negotiate when properly approached as a sovereign nation by the U.S. government, a default ranking of 3 is assigned (Conway 2012).

The research category includes data on sampling locations for scientific research. Siting renewable energy in these locations would interrupt the time series of data collected to date by scientists, and without continued monitoring, their data loses much value (Industrial Economics, Inc. 2012). Because time series data are critical, and because the process of establishing a research station often requires negotiation among government agencies, a default ranking of 4 is assigned (Industrial Economics, Inc. 2012).

The military category includes data on Coast Guard and Navy stations and operating areas. These are required to maintain ocean safety and for military practice. Because overriding defense activities would be difficult, and because the military currently exercises its right to close waters to other activities, a default ranking of 4 is assigned (Industrial Economics, Inc. 2012).

The disposal or dump category locations are close to shore for economic reasons but may have unstable geology and hazardous or explosive waste and thus may not be ideal for infrastructure installment (Wiggin et al. 2009; Industrial Economics, Inc. 2012). If selected, companies currently disposing materials in the area would need to find another site; because this is a difficult process, a default ranking of 4 is assigned.

Dredge category locations are valued by the companies operating therein, but there are sufficient stocks offshore and given the projected increase in demand for the minerals, they could likely find another site if displaced by renewable energy development (McGrath 2004). A default ranking of 2 is assigned.

Both the cable and pipeline data categories represent sensitive ocean space uses because they are very expensive. Therefore, costs would be high if a new project were to obstruct cables or pipelines to prevent maintenance and repairs or even cause damage (Industrial Economics, Inc. 2012). Given the costs involved, a default ranking of 4 is assigned to existing cables and pipelines.

The recreational boating community would likely treat a renewable energy development as merely another obstacle, because they generally have freedom to move as they please in the near shore where they recreate, provided the development is not in a well-established sailboat race area (Eardley and Conway 2011; Industrial Economics, Inc. 2012). If the installation is large, such as a wind farm with several turbines, boats could likely navigate through the farm, provided they stay 35m from the turbines (Wiggin et al. 2009). Due to their flexibility, a default ranking of 1 is assigned to this category.

The recreational fishing community currently fishes in limited space and would prefer to preserve its existing space use but their fishing is conditionally compatible with development, as certain developments could serve as fish aggregation devices and increase yield (Industrial Economics, Inc. 2012). Because negotiation would determine compatibility, a default ranking of 3 is assigned to this category.

The recreational wildlife viewing community could be impacted by renewable energy development if it drives away wildlife or hinders aesthetics of the viewing area (Eardley and Conway 2011; Industrial Economics, Inc. 2012). Because the outcome is site and technology-specific, a default ranking of 2 is assigned to this category.

The recreational (other) category includes surfing, kayaking, swimming, etc. These user groups greatly value access to the Oregon coast and could be detrimentally impacted if development restricts access or causes negative changes to wave form where surfing and other beach activities occur (Eardley and Conway 2011). Because development is conditionally compatible, a default ranking of 2 is assigned to this category.

The marine transportation data category includes Automatic Identification System (AIS) data which tracks commercial vessels greater than 300 gross tons, shipping lanes, and towlanes. The shipping industry is concerned with efficient, cost effective, and safe transportation which is largely provided by the established shipping lanes in use, this is especially important given the projected increase in container shipping (Industrial Economics, Inc. 2012). Because collision risk and hardship in changing transportation patterns likely decreases with decreasing traffic density, the separate categories of high intensity, moderate intensity, low to moderate intensity, and low intensity are given default rankings of 4, 3, 2, and 1, respectively.

The navigation aids category includes buoys and beacons that ensure maritime safety, but could potentially be moved if necessary – so a default ranking of 2 is assigned.

Areas permanently closed to fishing are attractive sites for development to fishermen (because it is ocean space they would not need to sacrifice) but potentially unattractive sites to scientists (because they may be studying the effects of the fishing closure on the ecosystem) (Industrial Economics, Inc. 2012). Temporary, or seasonal closures such as the rockfish conservation areas are less attractive sites for development to fishermen, because they could become accessible fishing grounds again in the future (Conway 2012). Because development in a closure area may require significant negotiation on behalf of species or the ecosystem, with scientists, or with fishermen, a default ranking of 4 is assigned.

Generally, commercial fishers compete for space and further crowding of the ocean by renewable energy development can cause issues such as loss of fishing grounds, increased likelihood of gear entanglement, and increased operating costs associated with fuel and refrigeration of catch until returning to shore (Wiggin et al. 2009; Kotowicz 2012). Potential benefits to fishing from development include increased biodiversity and density of fish that benefit from a de facto closure around the installation, although more research is necessary to determine if the increased noise during construction and operation would drive fish away and decrease catch per unit effort (Wiggin et al. 2009; Industrial Economics, Inc. 2012). Economics drives fishing behavior. Thus if current fishing grounds are profitable then they are highly valuable, but fish move and fishermen require the flexibility to follow the fish, with enough space to operate their gear (Smith and Wilen 2003; Industrial Economics, Inc. 2012).

While mistrust and fear are hurdles for cooperation, commercial fishermen are willing to negotiate and want to be included in the process (Bonzon, Fujita, and Black 2005; Conway et al. 2009, 2010; Conway 2012; Gopnik et al. 2012).

Because of this, a default ranking of 3 is assigned to the other gear types data category. Rankings are assigned to gear groups as follows, based on the findings of Conway, Pomeroy, and Hall-Arber (2012). The line fishing gear group targets species like halibut, which are very habitat specific and move around less than other species of fish. Because giving up favored fishing grounds is more difficult for this gear group, a default ranking of 4 is assigned. The pot gear group targets species like crab that have a lot of suitable habitat. Because this makes negotiation easier, a default ranking of 3 is assigned. The trap gear group similarly values existing grounds but is willing to negotiate, so a default ranking of 3 is assigned. The trawl gear group targets highly mobile species like shrimp and groundfish and is concerned with having enough space and flexibility to fish; a default ranking of 3 is assigned. The troll gear group also targets highly mobile species like tuna and salmon that react to water temperature and currents, they are also concerned with having space and flexibility; a default ranking of 3 is assigned.

3.5 Conflict analysis

Following completion of data collection and creation, a total of 488 data layers with coverage of Washington, Oregon or California were compiled from 32 sources (Appendix B, Table B1). Within the study area for this analysis, a subset of 197 shapefiles covered state or federal waters of Oregon. Each of these was re-examined to ensure it was appropriate for this analysis. Inappropriate data for this analysis includes shapefiles that do not show presence of space use (e.g., demarcations, lease blocks), only occur on the shore (e.g., point source pollution locations) or contain too much complexity and must first be split into multiple shapefiles to show the various space uses it includes (e.g., AIS data that must be symbolized to view varying levels of shipping density). Shapefiles that combined data across categories were split into two or more shapefiles. Shapefiles that duplicated others were removed. The commercial logbook fishing data were reprocessed in order to group all commercial fishing data by gear type for increased flexibility of conflict ranking. Following data clean-up, a total of 127 shapefiles in 26 categories were selected for use in this analysis (Appendix B, Table B2).

A grid size of 1 nm^2 was chosen for this analysis. Other options were considered in light of the impact of the modifiable areal unit problem (MAUP) on analysis results (Longley et al. 2011). For example, the OCS lease blocks used by BOEM could be appropriate given the utility of results for the agency, but they are almost 3 nm on a side, which is a coarse scale for examining only Oregon's offshore waters. Using a small grid size (e.g., 30 meters) however, might imply greater precision than actually present in the data, and would make interpretation of the resulting surface more difficult. The use of a 1 nm^2 grid provides a compromise on resolution issues and facilitates comparison with similar work done for the Oregon Territorial Sea Plan (TSP). The tool "Create Constant Raster" in the Spatial Analyst toolbox was used to create an integer raster with a 1 nm cell size, with an extent just beyond Oregon's waters in order to avoid incomplete cells. This grid is used as the extent and snap raster in the environment settings of the analysis tool.

Prior to running the analysis tool, the input data must be prepared. This is a one time process; there are no subjective parameters. This process takes just under 1 hour and 45 minutes to run. A Python script ("ArcGIS interface module" and "Prepare category rasters," Appendix C) executes the following pseudo code, and saves progress to a log text file, along with any errors:

Loop through a folder containing subfolders into which all input points, lines and polygons are organized by category; and for each subfolder:

1. Create a subfolder of the same name in a top folder named "Clipped."
2. For each file in the input subfolder:

   a. Clip to Oregon waters and save to the new subfolder of “Clipped.”
   b. Add a field called “RasVal” to the clipped version.
   c. Calculate “RasVal” equal to 1 so that the resulting raster has a value of 1 wherever this use is present.
   d. Determine shapefile type and execute appropriate conversion tool to raster (using the full raster grid as the snap raster and extent setting so that all resulting rasters line up), and save to a scratch folder.
3. Convert NoData values to 0 for all individual rasters for the category in the scratch folder.
4. Add the individual rasters (which now have values of 0 or 1) to obtain a single raster for the category.
5. Reclassify the resulting raster to change values greater than 0 to 1 so that the raster shows only presence of absence of space use, as opposed to the number of overlapping input shapefiles in a given cell, and save to a folder called “Rasters.”
6. Define projection of the output raster.
7. Delete the scratch folder before moving on to the next subfolder for processing.

The analysis tool takes as its inputs the single value category rasters produced by the preparation code. The analysis tool was written in Python and imported to an ArcGIS Toolbox script, in which users may enter parameters – the ranking of each space use category by its potential for conflict with renewable energy development (Figure 10). Default values for each parameter are included, as justified in section 3.4. The analysis tool multiplies each category raster by the user-specified ranking and then adds the 26 categories together to derive an output surface showing the total potential for conflict in each nm^2. This process takes between 15 seconds (saving to local machine) and 2.5 minutes (saving to server) to run. The script (“Weighted Overlay,” Appendix C) makes use of the same ArcGIS Interface Module as the raster preparation script to execute the following pseudo code, and saves progress to a log text file, along with any errors:

1. Obtain user inputs for the output folder and raster name, and analysis weights from the ArcGIS tool.

2. Create folder for outputs (if the folder already exists, it is first deleted).

3. Execute map algebra to multiply each raster in the input folder by its appropriate weight and save the result to the output folder.

4. Execute map algebra to sum all 26 rasters in the output folder to obtain a total raster and save with the user defined name to the output folder.

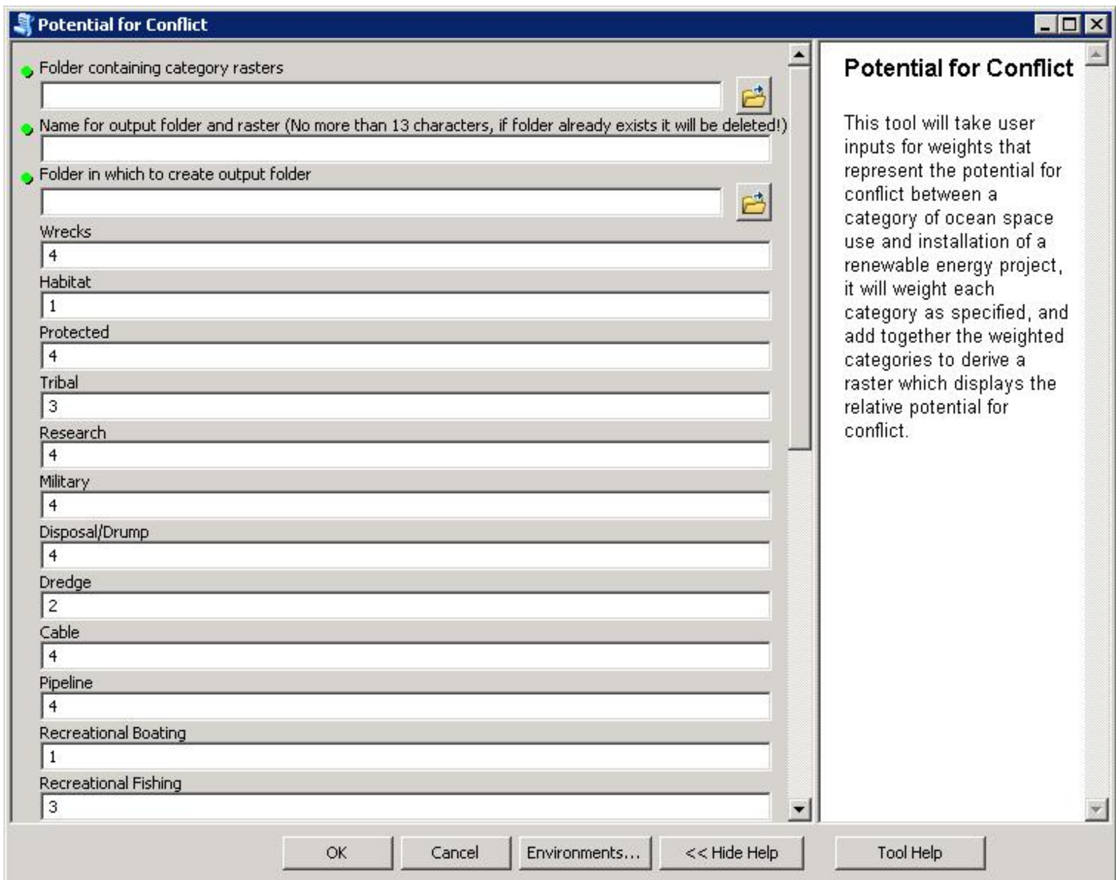

Figure 10. Screenshot of the analysis tool created to allow user inputs to the conflict analysis model.

3.6 Uncertainty assessment

Uncertainty in a GIS is often overlooked by end users as a consequence of its powerful analysis and attractive cartographic outputs, which lend a false sense of security (Jankowski and Nyerges 2001; UCGIS 2002). While the scientific community has consistently acknowledged uncertainty, development and practice of the theory and techniques to measure it has not kept pace with the rapid development of the field of GIS (Mowrer and Congalton 2000). A visualization of uncertainty for this model is presented to guard against inappropriate use of results and communicate what is known about input data quality. Ideally, error in the input data would be calculated using comparison to coordinates of randomly selected true data points, as discussed in section 2.3. Because this is not possible for this analysis, examination of the metadata was used as a proxy. The metadata of all 127 shapefiles collected, created, or digitized were re-read and clues as to uncertainty associated with each were noted, with the goal of using the notes to assign a subjective buffer distance to each to represent its 95 percent threshold. Because all input data are converted to a 1 nm^2 grid prior to analysis, the positional accuracy is .5 nm^2 at best, so for comparison to model results this buffer distance would be appropriate for any shapefiles missing lineage information related to spatial, temporal, or attribute accuracy (Bolstad 2005). While this method doesn't convey actual error, the value of the discrepancy between the digital and real coordinates of the input data, it does convey uncertainty through a visualization of the relative discrepancy between representations and reality (UCGIS 2002).

The amount and specificity of positional accuracy information in the metadata was variable. Some records lacked any mention of accuracy or even a lineage to provide clues as to its creation, while many included descriptions of shortcomings and a disclaimer that accuracy was not assessed and the data should be used with caution. Only those that contained information on positional accuracy were considered closely to determine a specific buffer distance. Input shapefiles that included metadata with clues as to horizontal positional accuracy are discussed in Table 4. The table includes 42 of the 127 shapefiles used for analysis. None of the metadata addressed vertical accuracy. Thus, the 2D model results show overlapping space usage that may not occur at the same depth, information relevant but unavailable for this analysis.

Table 4. Notes on positional accuracy of input shapefiles gleaned from the metadata.

Shapefile data source, and number of shapefiles	*Positional accuracy notes*	*Buffer distance to use*
Coast Guard AIS Data (4)	Records accurate to 10 meters, data recorded in 1/10,000 minute precision, aggregated to 5 nm cells	Because only the gridded data were provided, a buffer of ½ the cell resolution is appropriate: .25 nm.
ODFW, CDFG, and PacFIN Logbook data (14)	10 minute cells provided to avoid loss of data due to the rule of 3	Because only the gridded data were provided, a buffer of ½ the cell resolution is appropriate: 5 nm.
PaCOOS (1 - Oregon Islands National Wildlife Refuges)	Not for legal use or where accuracy must be better than USGS 7.5' mapping standards.	According to the standard (90 percent of tested points must be accurate within 1/50th of an inch), an appropriate buffer distance is 40 feet.
PaCOOS (1 – Pinniped Haul Out)	Heads up digitizing on 0.5m resolution 2005 color digital orthophoto quadrangles of points to represent a specific spot or a general area.	An appropriate buffer distance could be .5m but the buffer should also account for the lack of specificity in the boundary of the haul out area.
PaCOOS (1 – Seabird colonies)	Digitized centroid of seabird colonies from USGS 1:24,000 topo maps.	Assuming the map met USGS 7.5' mapping standards, an appropriate buffer distance would be 40 feet. However, the buffer should also account for the fact that only the centroid of the colonies is included.
Results of social science research (19)	Features drawn using markers with tips ranging in thickness from .4 mm to 1 mm on a 1:180,000 nautical chart	Perfectly drawn features would have an error between .039 and .097 nm due to the precision of the marker used; additional error should be added to account for photographing, georeferencing, and digitizing the drawn features (discussed below).
U.S. Navy (2)	Each coordinate used to create the shapefiles has a resolution of 1/100 of a minute	An appropriate buffer distance is .01 nm.

While the issues in the discussion that follows are not unique to the social science research spatial data, they are addressed because these data were created as part of this project. Uncertainty of the digital results from the ethnographic research stems from participation bias, lack of precision in drawing on the maps, and digitizing error. During ethnographic research, those willing to draw on the mylar sheets were mostly recreational and commercial fishermen, their efforts driven by a desire to provide corrections to the inaccurate data on the initial maps (Industrial Economics, Inc. 2012). They drew their space use broadly, often focusing on where they would go to catch a specific species of fish, regardless of current closures in place (Industrial Economics, Inc. 2012). Thus, this would be the cause of any logical inconsistency between digitized fishing grounds and existing closures. Interviewees also emphasized that any unmarked areas should not be seen as open to development, nor should marked areas be seen as closed to development (Industrial Economics, Inc. 2012). Interviewees drew shapes to the best of their knowledge. Accuracy in drawing depended on willingness to draw precise areas, understanding that the scale was 1:180,000 on the paper maps, and even the thickness of the pen used. Effort was made during digitizing to trace each comment as closely as possible or use automated methods when applicable, but this combined with the process of photographing the maps and georeferencing each photo likely introduced additional uncertainty. The results were groundtruthed to some degree through presentation at stakeholder meetings, and corrections were incorporated, but the feedback was given under the same assumption that the maps should depict space use with a broad brush.

Following examination of the metadata, only the logbook data require a buffer greater than .5 nm. Thus, a buffer of 5 nm is used for the 14 logbook shapefiles and a buffer of .5 nm is used for all others. A python script was written to duplicate the folder and subfolders of input data while buffering each input shapefile on both sides of every feature, and dissolving to remove buffer overlap (Appendix C, “Buffer”). The raster preparation code was run on the buffered input shapefiles (Appendix C, “Prepare buffered category rasters”). The output rasters were used to run the conflict analysis model with all parameters set to one. The result represents the extent of uncertainty of the model inputs. A difference raster was created by subtracting normal analysis results (with all parameters set to one) from the uncertainty result, to show only the uncertain areas not actually included in a normal model run.

4 Results

4.1 Conflict analysis model results

Model results when all parameters are given a value of one are shown in Figure 11. This image shows the relative density of ocean space use, as opposed to potential for conflict. Values (number of categories with space use in a given nm^2 cell) range from 1 to 17 with a mean of 6.97 and a standard deviation of 1.65. The visualization shows that there is higher space use closer to shore and there is no portion of the study area without at least one category of ocean space use. The most frequent cell value is 6 categories of use, and 99.7% of the cells represent at least 6 categories of use (Figure 12). In Figure 11 the orange color representing 6 uses appears as a background for the outer portion of the study area, through which yellow lines (7 or 8 uses) representing cables, pipelines, and research transects protrude from the coastal zone.

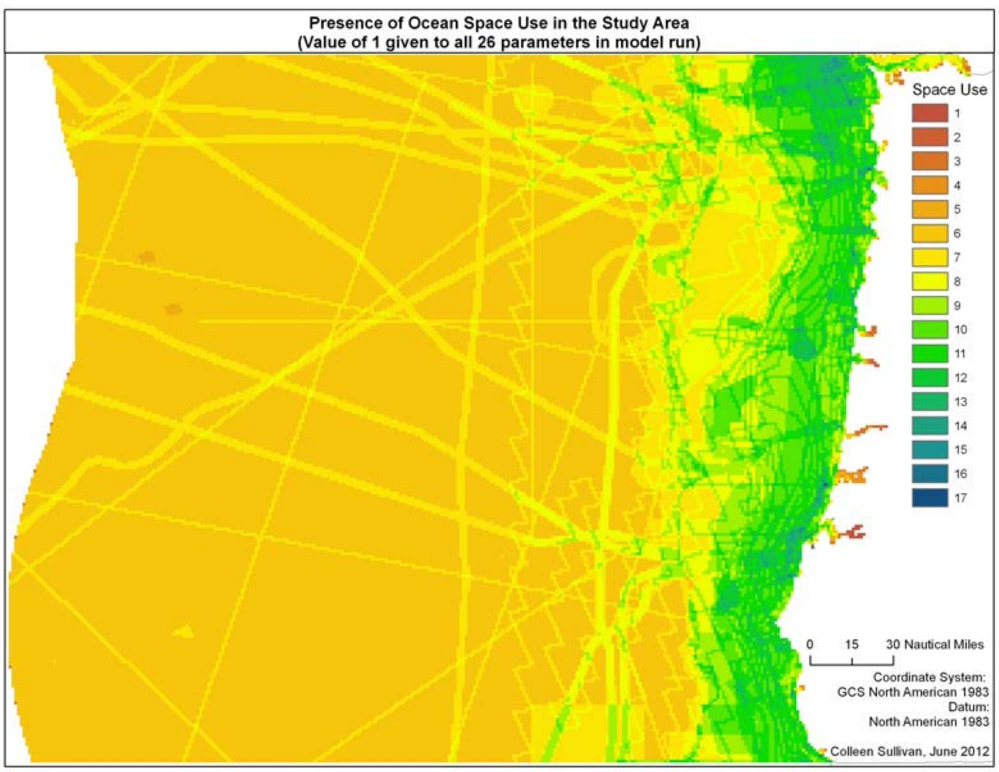

Figure 11. Results of the conflict analysis model when all 26 parameters are set to 1. Values range from 1 to 17, indicating the number of overlapping categories of ocean space use present in each cell.

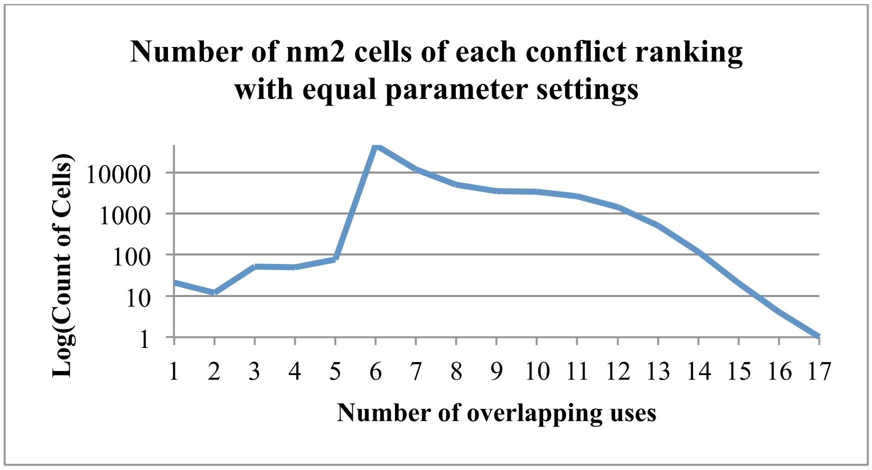

Figure 12. Count of cells with each value from 1 to 17 seen in the equal settings model run. The vertical axis uses a log scale due to the wide spread of values.

The Cell Statistics tool in ArcGIS 10.0 was used for a bivariate analysis to compare the overlap of each of the 26 category rasters to the other 25, and values were recorded in Table 5. The gray cells of the diagonal through the matrix show the total area for that category only. According to Table 5, the six categories of ocean space use with the greatest coverage in the study area are: Fishing – Trolling, Habitat, Military, Fishing - Closure Areas, Protected, and Marine Transportation - Low Intensity. The six categories of ocean space use with the least coverage in the study area are: Disposal/Dump, Fishing – Trap, Marine Transportation - Navigation Aid, Dredge, Wrecks, and Pipeline. To ease interpretation of the overlap values in Table 5, Table 6 shows by column the percentage of each category's total area overlapped by other categories. This was calculated for each cell of Table 5 as: (row category area of overlap with column category/column category total area) * 100. For example, the upper right-hand cell of Table 5 shows that Wrecks and Fishing – Trolling share 47 nm^2 of overlap. The total area occupied by Trolling is 73,927 nm^2. Thus, Table 6 shows for this column the calculation: (47/73,927)*100 = .06%. Wrecks overlap with .06% of the total area of Trolling. A cell value of 100% in Table 6 indicates that all area occupied by the category of that column is also occupied by the category of that row. High overlap indicates that two uses are commonly found in the same location.

Table 5. Matrix of total area of overlap (nm^2) between each category raster and all others. Values in gray cells are the area of that category only. Values are mirrored across this diagonal because, for example, the intersection of 6 with 8 is the same as the intersection of 8 with 6. Row and column labels correspond to categories in Table 2.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	47	47	17	7	27	40	6	11	1	0	24	44	28	27	26	8	13	13	10	8	6	30	46	0	47	47
2	47	73875	61427	1202	18410	73207	430	115	8734	12	5215	8898	773	996	6435	11049	18267	45284	121	64688	1409	9705	15069	121	15927	73875
3	17	61427	61427	136	6840	61234	377	41	7114	5	414	1043	355	414	3326	5326	11744	44473	50	60921	75	2238	2763	110	3595	61427
4	7	1202	136	1202	973	1011	60	54	167	5	442	838	69	74	757	376	195	85	53	361	822	663	1202	0	1202	1202
5	27	18410	6840	973	18410	18280	139	17	4208	2	4827	7768	296	306	3675	7209	9677	2329	28	10250	1265	8135	13100	23	13439	18410
6	40	73207	61234	1011	18280	73218	424	46	8695	3	5084	8408	477	565	6141	10997	18172	45004	45	64677	1347	9487	14561	121	15393	73218
7	6	430	377	60	139	424	430	40	43	1	61	97	30	27	107	103	264	27	19	369	52	45	97	0	99	430
8	11	115	41	54	17	46	40	115	2	5	38	110	44	54	105	5	7	14	66	11	26	17	110	0	110	115
9	1	8734	7114	167	4208	8695	43	2	8734	1	575	978	45	54	758	1392	3286	4289	4	7584	296	1139	1876	0	2125	8734
10	0	12	5	5	2	3	1	5	1	12	0	12	5	9	10	0	0	2	6	0	0	2	12	0	12	12
11	24	5215	414	442	4827	5084	61	38	575	0	5216	5197	224	199	1654	1546	3559	468	36	2425	649	4271	5204	0	5206	5216
12	44	8898	1043	838	7768	8408	97	110	978	12	5197	8901	726	864	2831	3130	5157	1020	117	3476	1112	6396	8849	0	8892	8901
13	28	773	355	69	296	477	30	44	45	5	224	726	776	648	190	123	223	423	53	103	41	518	745	0	751	776
14	27	996	414	74	306	565	27	54	54	9	199	864	648	1009	208	76	306	621	58	122	56	580	889	0	909	1009
15	26	6435	3326	757	3675	6141	107	105	758	10	1654	2831	190	208	6436	2101	1598	796	101	3950	721	2338	3898	116	4566	6436
16	8	11049	5326	376	7209	10997	103	5	1392	0	1546	3130	123	76	2101	11053	2224	41	8	6952	639	4081	6970	20	7233	11053
17	13	18267	11744	195	9677	18172	264	7	3286	0	3559	5157	223	306	1598	2224	18268	856	11	13881	252	5440	7505	0	7615	18268
18	13	45284	44473	85	2329	45004	27	14	4289	2	468	1020	423	621	796	41	856	45310	23	44518	124	737	1091	0	1128	45310
19	10	121	50	53	28	45	19	66	4	6	36	117	53	58	101	8	11	23	121	11	16	27	117	0	117	121
20	8	64688	60921	361	10250	64677	369	11	7584	0	2425	3476	103	122	3950	6952	13881	44518	11	64688	410	4666	6043	110	6871	64688
21	6	1409	75	822	1265	1347	52	26	296	0	649	1112	41	56	721	639	252	124	16	410	1409	1075	1399	11	1389	1409
22	30	9705	2238	663	8135	9487	45	17	1139	2	4271	6396	518	580	2338	4081	5440	737	27	4666	1075	9711	8609	12	8719	9711
23	46	15069	2763	1202	13100	14561	97	110	1876	12	5204	8849	745	889	3898	6970	7505	1091	117	6043	1399	8609	15076	36	14538	15076
24	0	121	110	0	23	121	0	0	0	0	0	0	0	0	116	20	0	0	0	110	11	12	36	121	71	121
25	47	15927	3595	1202	13439	15393	99	110	2125	12	5206	8892	751	909	4566	7233	7615	1128	117	6871	1389	8719	14538	71	15934	15934
26	47	73875	61427	1202	18410	73218	430	115	8734	12	5216	8901	776	1009	6436	11053	18268	45310	121	64688	1409	9711	15076	121	15934	73927

Table 6. Matrix of percentages of total area of each ocean space use in a column overlapped by the other 25. Calculated using Table 5 as: (row category area of overlap with column category/column category total area) * 100. Row and column labels correspond to categories in Table 2. High overlap indicates that two uses are commonly found in the same location.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	100	0.06	0.03	0.58	0.15	0.05	1.40	9.57	0.01	0.00	0.46	0.49	3.61	2.68	0.40	0.07	0.07	0.03	8.26	0.01	0.43	0.31	0.31	0.00	0.29	0.06
2	100	100	100	100	100	99.98	100	100	100	100	99.98	99.97	99.61	98.71	99.98	99.96	99.99	99.94	100	100	100	99.94	99.95	100	99.96	99.93
3	36.17	83.15	100	11.31	37.15	83.63	87.67	35.65	81.45	41.67	7.94	11.72	45.75	41.03	51.68	48.19	64.29	98.15	41.32	94.18	5.32	23.05	18.33	90.91	22.56	83.09
4	14.89	1.63	0.22	100	5.29	1.38	13.95	46.96	1.91	41.67	8.47	9.41	8.89	7.33	11.76	3.40	1.07	0.19	43.80	0.56	58.34	6.83	7.97	0.00	7.54	1.63
5	57.45	24.92	11.14	80.95	100	24.97	32.33	14.78	48.18	16.67	92.54	87.27	38.14	30.33	57.10	65.22	52.97	5.14	23.14	15.85	89.78	83.77	86.89	19.01	84.34	24.90
6	85.11	99.10	99.69	84.11	99.29	100	98.60	40.00	99.55	25.00	97.47	94.46	61.47	56.00	95.42	99.49	99.47	99.32	37.19	99.98	95.60	97.69	96.58	100	96.60	99.04
7	12.77	0.58	0.61	4.99	0.76	0.58	100	34.78	0.49	8.33	1.17	1.09	3.87	2.68	1.66	0.93	1.45	0.06	15.70	0.57	3.69	0.46	0.64	0.00	0.62	0.58
8	23.40	0.16	0.07	4.49	0.09	0.06	9.30	100	0.02	41.67	0.73	1.24	5.67	5.35	1.63	0.05	0.04	0.03	54.55	0.02	1.85	0.18	0.73	0.00	0.69	0.16
9	2.13	11.82	11.58	13.89	22.86	11.88	10.00	1.74	100	8.33	11.02	10.99	5.80	5.35	11.78	12.59	17.99	9.47	3.31	11.72	21.01	11.73	12.44	0.00	13.34	11.81
10	0.00	0.02	0.01	0.42	0.01	0.00	0.23	4.35	0.01	100	0.00	0.13	0.64	0.89	0.16	0.00	0.00	0.00	4.96	0.00	0.00	0.02	0.08	0.00	0.08	0.02
11	51.06	7.06	0.67	36.77	26.22	6.94	14.19	33.04	6.58	0.00	100	58.39	28.87	19.72	25.70	13.99	19.48	1.03	29.75	3.75	46.06	43.98	34.52	0.00	32.67	7.06
12	93.62	12.04	1.70	69.72	42.19	11.48	22.56	95.65	11.20	100	99.64	100	93.56	85.63	43.99	28.32	28.23	2.25	96.69	5.37	78.92	65.86	58.70	0.00	55.81	12.04
13	59.57	1.05	0.58	5.74	1.61	0.65	6.98	38.26	0.52	41.67	4.29	8.16	100	64.22	2.95	1.11	1.22	0.93	43.80	0.16	2.91	5.33	4.94	0.00	4.71	1.05
14	57.45	1.35	0.67	6.16	1.66	0.77	6.28	46.96	0.62	75.00	3.82	9.71	83.51	100	3.23	0.69	1.68	1.37	47.93	0.19	3.97	5.97	5.90	0.00	5.70	1.36
15	55.32	8.71	5.41	62.98	19.96	8.39	24.88	91.30	8.68	83.33	31.71	31.81	24.48	20.61	100	19.01	8.75	1.76	83.47	6.11	51.17	24.08	25.86	95.87	28.66	8.71
16	17.02	14.96	8.67	31.28	39.16	15.02	23.95	4.35	15.94	0.00	29.64	35.16	15.85	7.53	32.64	100	12.17	0.09	6.61	10.75	45.35	42.02	46.23	16.53	45.39	14.95
17	27.66	24.73	19.12	16.22	52.56	24.82	61.40	6.09	37.62	0.00	68.23	57.94	28.74	30.33	24.83	20.12	100	1.89	9.09	21.46	17.89	56.02	49.78	0.00	47.79	24.71
18	27.66	61.30	72.40	7.07	12.65	61.47	6.28	12.17	49.11	16.67	8.97	11.46	54.51	61.55	12.37	0.37	4.69	100	19.01	68.82	8.80	7.59	7.24	0.00	7.08	61.29
19	21.28	0.16	0.08	4.41	0.15	0.06	4.42	57.39	0.05	50.00	0.69	1.31	6.83	5.75	1.57	0.07	0.06	0.05	100	0.02	1.14	0.28	0.78	0.00	0.73	0.16
20	17.02	87.56	99.18	30.03	55.68	88.33	85.81	9.57	86.83	0.00	46.49	39.05	13.27	12.09	61.37	62.90	75.99	98.25	9.09	100	29.10	48.05	40.08	90.91	43.12	87.50
21	12.77	1.91	0.12	68.39	6.87	1.84	12.09	22.61	3.39	0.00	12.44	12.49	5.28	5.55	11.20	5.78	1.38	0.27	13.22	0.63	100	11.07	9.28	9.09	8.72	1.91
22	63.83	13.14	3.64	55.16	44.19	12.96	10.47	14.78	13.04	16.67	81.88	71.86	66.75	57.48	36.33	36.92	29.78	1.63	22.31	7.21	76.30	100	57.10	9.92	54.72	13.14
23	97.87	20.40	4.50	100	71.16	19.89	22.56	95.65	21.48	100	99.77	99.42	96.01	88.11	60.57	63.06	41.08	2.41	96.69	9.34	99.29	88.65	100	29.75	91.24	20.39
24	0.00	0.16	0.18	0.00	0.12	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.18	0.00	0.00	0.00	0.17	0.78	0.12	0.24	100	0.45	0.16
25	100	21.56	5.85	100	73.00	21.02	23.02	95.65	24.33	100	99.81	99.90	96.78	90.09	70.94	65.44	41.68	2.49	96.69	10.62	98.58	89.78	96.43	58.68	100	21.55
26	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Results of the model, run with the default settings described in section 3.4 are shown in Figure 13. The resulting rankings of potential for conflict range from 3 to 51 with a mean of 20.56 and a standard deviation of 5.38. The most frequent ranking value is 17, and 99.7% of the cells represent a value of at least 17 (Figure 14). Most patterns visible in the output of this run look similar to the result of the equal settings run, but categories given a higher potential for conflict are highlighted. For example, the area immediately to the east of the zig-zag line down the center of the image has the same value as the area to the west in the equal settings run (6) but has a higher potential for conflict in the default settings run (18 as opposed to 17). This is because the zig-zag line marks the transition from “Low to Moderate Intensity Marine Transportation” on the east (default setting = 2) to “Low Intensity Marine Transportation” on the west (default setting = 1).

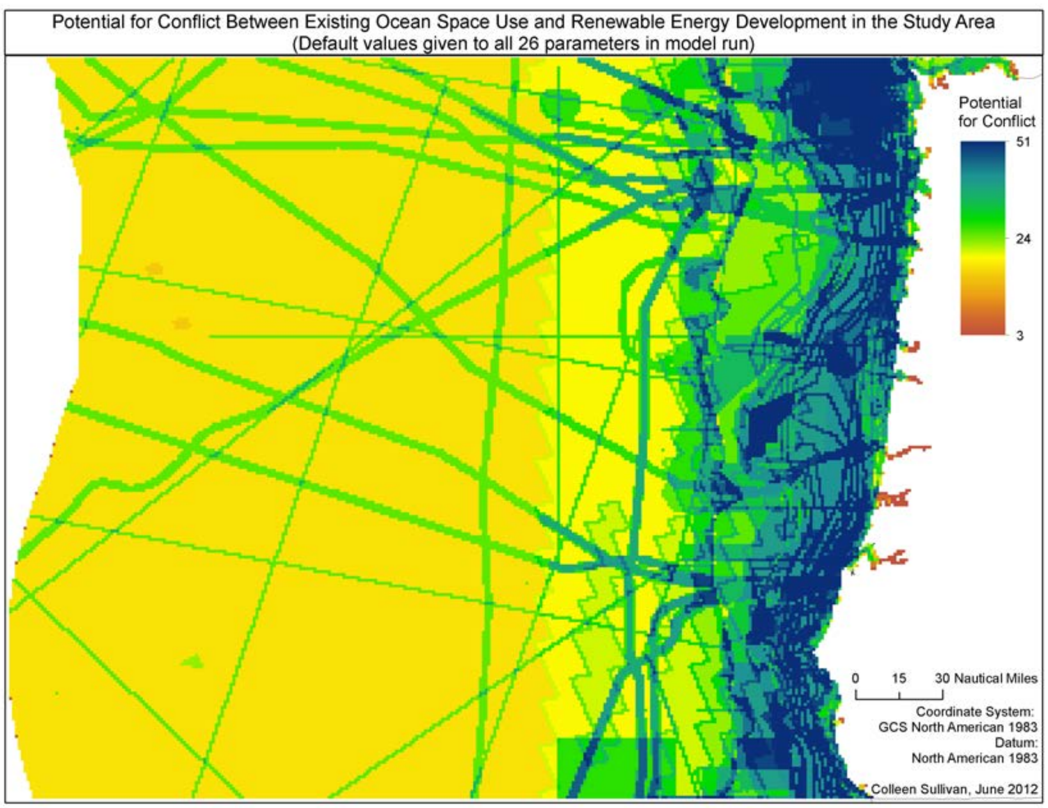

Figure 13. Results of the analysis model when run with default parameters. The map shows relative potential for conflict. Values range from 3 (red) to 51 (dark blue), more contentious areas for development have a higher potential for conflict.

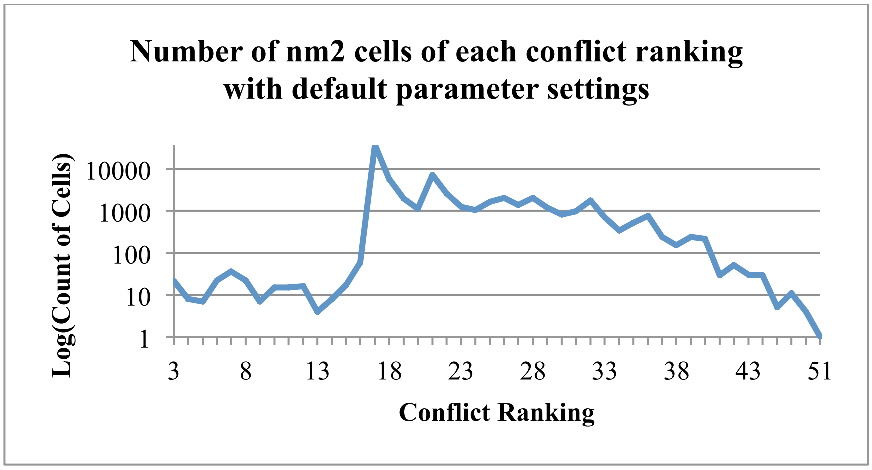

Figure 14. Count of cells within each value of the default settings model run. The vertical axis uses a log scale due to the wide spread of the values.

At the scale of the study area, it is difficult to discuss characteristics of specific places. In order to demonstrate the utility of results when zoomed to certain locations, and to illustrate potential applications of the conflict analysis model, results are compared to sites of existing wave energy permit applications, and to Oregon Wave Energy Trust (OWET) priority areas for development.

Figure 15 shows the sites off the coast of Oregon for which permit applications have been submitted to the Federal Energy Regulatory Commission, overlaid on the model results using the default parameters. Figure 16 and Figure 17 show the distribution of model results within each permit boundary, these graphs were generated using the Zonal Histogram tool in ArcMap 10.0 and colors correspond to the legend of Figure 15. Table 7 lists the individual categories of ocean space use represented by the model results in each permit area. Results show that the Florence permit application appears to have the lowest overall potential for conflict and still has 15 different types of ocean space use occurring in cells overlapped by the permit location. The Coos Bay permit application has a high potential for conflict according to model results, with 14 different types of ocean space use present. The higher conflict associated with one fewer use group is due to the presence of a protected area (Cape Arago proposed marine reserve) and a fishing closure area (rockfish conservation area) both of which were given high rankings for conflict potential.

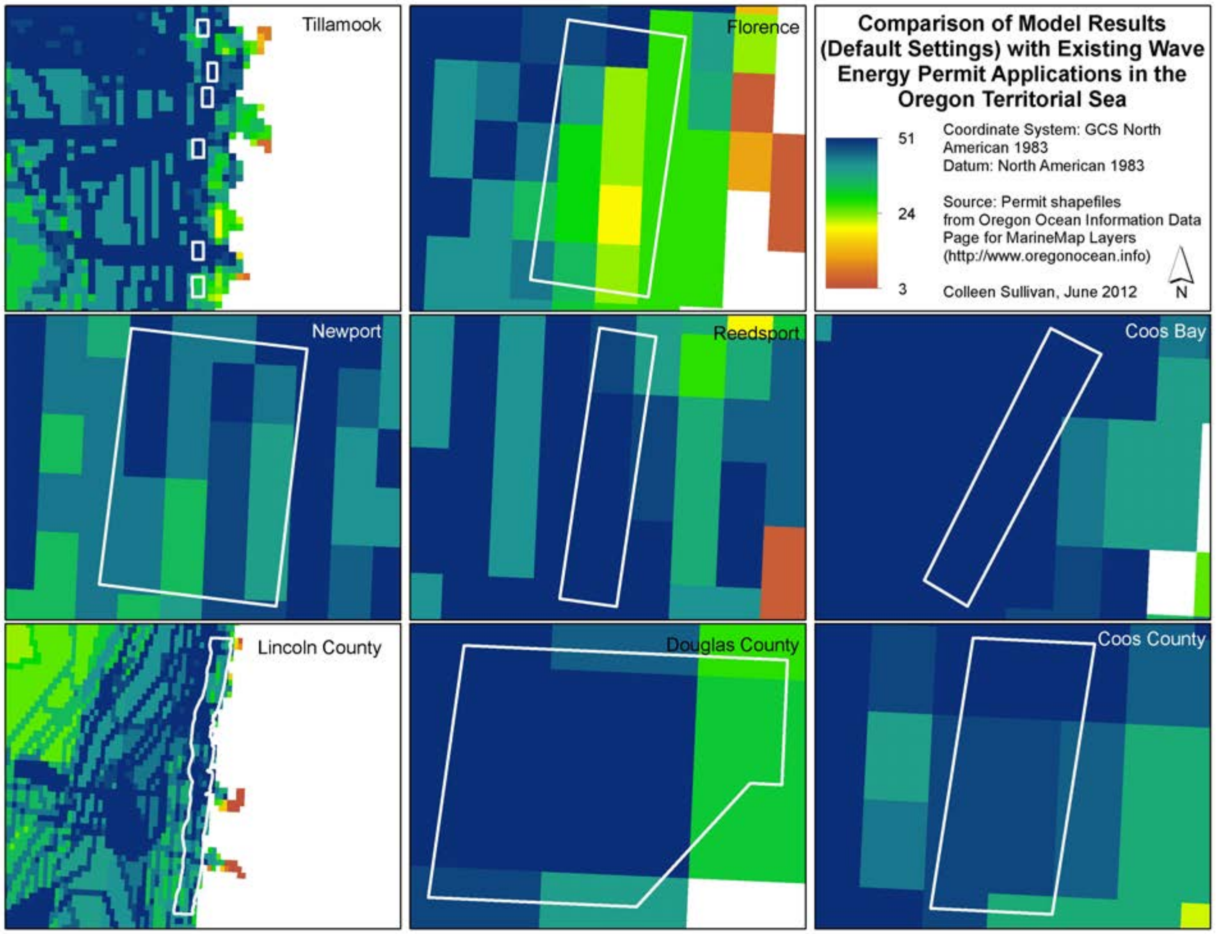

Figure 15. Comparison of model results and existing sites of wave energy permit applications in Oregon. Application boundaries appear in white, overlaid on the continuous grid of conflict values, which range from 3 (red) to 51 (dark blue). The Florence application has the lowest overall potential for conflict, while the Coos Bay application has the highest overall potential for conflict. Exact uses present in each area are shown in Table 7.

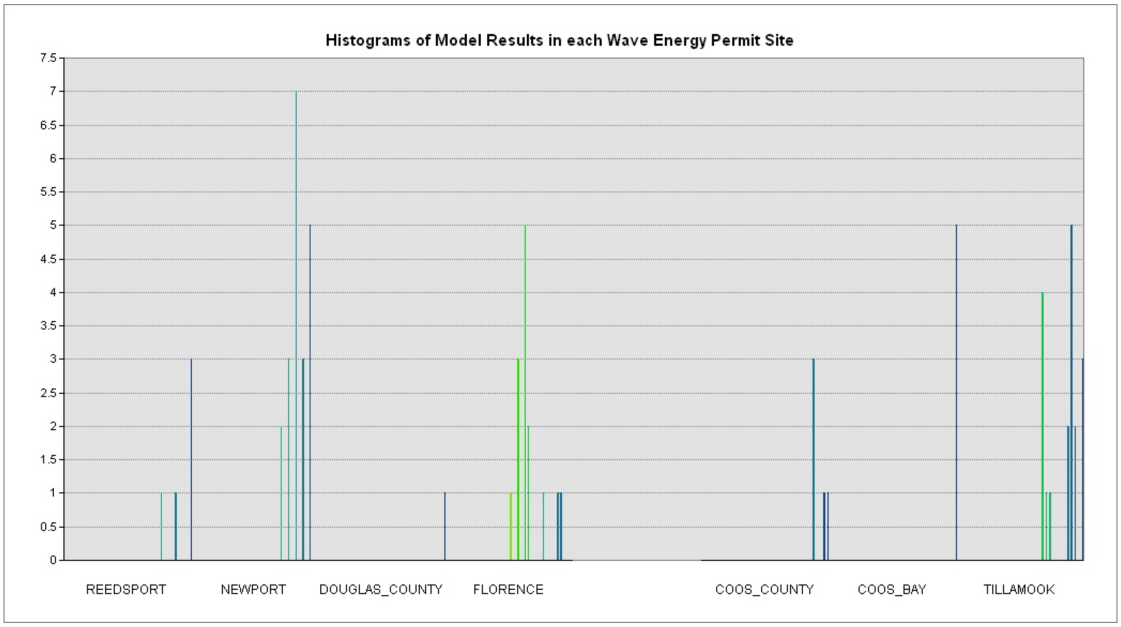

Figure 16. Histograms of model results in each wave energy application site shown in Figure 15, excluding Lincoln County. Colors correspond to the legend of Figure 15 and the graph shows the site-specific density of different conflict rankings.

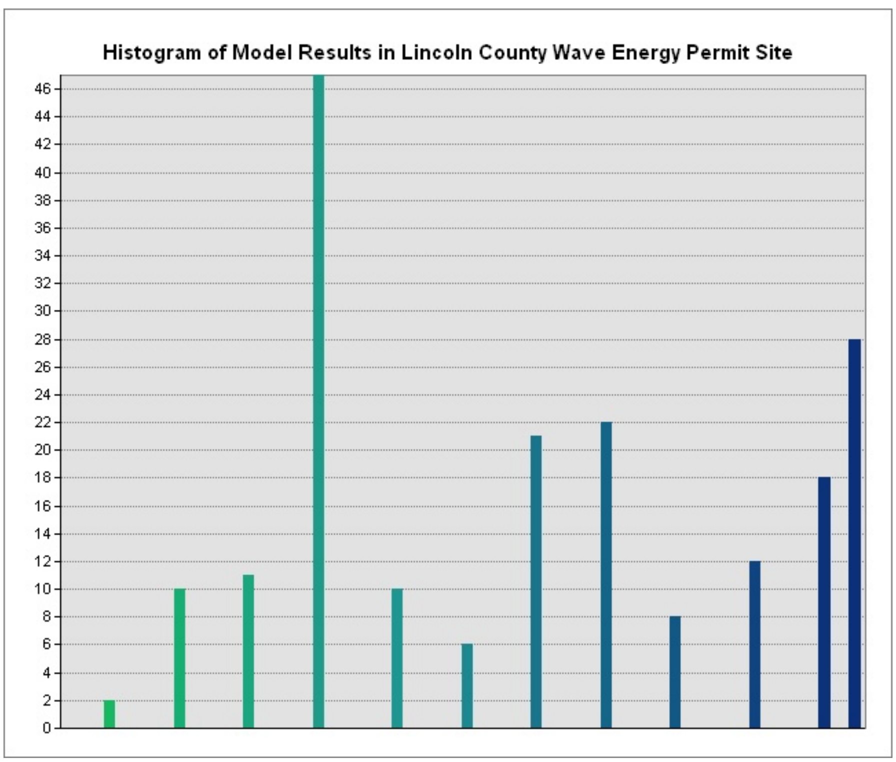

Figure 17. Histogram of model results within the Lincoln County preliminary wave energy site. Colors correspond to the legend of Figure 15 and the graph shows the site-specific density of different conflict rankings.

Table 7. Categories of ocean space use represented by model results shown in Figure 15 in sites of existing wave energy permit applications.

Location	*Stakeholders represented in model results*
Tillamook	Habitat, Protected, Military, Marine Trans (1, 2, 3, 4), Cable, Research, Commercial fishing (line, pots, closure, troll, trawl), Recreational (Fishing, Boating, Other)
Newport	Habitat, Military, Marine Trans (2, 3, 4), Research, Commercial fishing (line, pots, closure, troll, trawl), Recreational (Fishing, Boating, Wildlife Viewing, Other)
Lincoln County	Protected, Habitat, Military, Disposal/Dump, Dredge, Wrecks, Navigation Aids, Marine Trans (1, 2, 3, 4), Research, Commercial fishing (line, pots, closure, troll, trawl), Recreational (Fishing, Boating, Wildlife Viewing, Other)
Florence	Habitat, Military, Marine Trans (1, 2, 4), Cable, Research, Commercial fishing (pots, closure, troll, trawl), Recreational (Fishing, Boating, Wildlife Viewing, Other)
Reedsport	Habitat, Protected, Military, Marine Trans (1, 2), Research, Commercial fishing (line, pots, closure, troll, trawl), Recreational (Fishing, Boating)
Douglas County	Protected, Habitat, Military, Disposal/Dump, Dredge, Navigation Aids, Marine Trans (1, 2, 4), Research, Commercial fishing (pots, troll, trawl), Recreational (Fishing, Wildlife Viewing, Other)
Coos Bay	Protected, Habitat, Military, Marine Trans (2, 3, 4), Research, Comm. fishing (closure, line, pots, troll, trawl), Rec. (Fishing, Boating)
Coos County	Protected, Habitat, Military, Marine Trans (1), Research, Commercial fishing (line, pots, closure, troll, trawl), Recreational (Fishing, Boating, Wildlife Viewing, Other)

OWET is a nonprofit that supports wave energy development in Oregon. To support the Oregon TSP the organization funded creation of spatial data to rank both technical and economic feasibility of wave energy development off the coast of Oregon (Manson, Halsey, and Radil 2012). The economically feasible areas (those realistically suitable for development given funding constraints) are a subset of the technically feasible areas (those suitable based on physical features), as they are limited by electric grid infrastructure (Manson, Halsey, and Radil 2012). Factors considered in the MCDA included depth, distance from shore, seabed type, and distance to transmission lines, among others. The range of results were divided using natural breaks into 5 categories of suitability for each of coastal, mid-water, and deep-water technology types. These results were provided to the Oregon Department of Land

Conservation and Development (DLCD) in hopes that inclusion in the planning process would increase the likelihood that feasible areas from an industry standpoint are included in any areas designated for development in the revision of the TSP (Manson, Halsey, and Radil 2012).

OWET acknowledges that some areas most suitable for development may also conflict with existing ocean space use. To illustrate an application of model results, zonal statistics were computed for each feasibility zone to determine the minimum, maximum, mean, and standard deviation of the conflict values (resulting from default settings) for cells overlapped by each (Table 6). A subset of the complex polygon result for coastal technology is shown in Figure 18 to illustrate its overlap with model results off the coast of Newport, one of the areas OWET recommends for development.

Table 6. Conflict ranking statistics for each characterization of wave energy development feasibility.

a) Coastline converter and coastal surge devices

	Area (mi^2)	Min	Max	Mean	St. Dev.
Top 6%	10.8	22	51	32.1	5.3
Top 12%	10.6	22	41	30.6	4.1
Top 21%	14.9	18	41	31.0	4.8
Top 38%	38.9	18	45	29.1	5.5
All Other Values (>0)	97.5	18	44	28.8	4.8

b) Mid-depth devices

	Area (mi^2)	Min	Max	Mean	St. Dev.
Top 6%	81.3	18	51	31.2	5.0
Top 11%	79.6	18	51	30.7	5.6
Top 20%	125.2	18	51	30.2	5.4
Top 41%	356.9	18	43	30.6	4.9
All Other Values (>0)	1479.5	18	47	31.6	4.6

c) Deep water devices

	Area (mi^2)	Min	Max	Mean	St. Dev.
Top 5%	108.9	23	43	33.5	4.6
Top 11%	143.9	20	51	32.9	4.3
Top 20%	186.1	19	47	32.3	4.6
Top 41%	490.1	18	51	31.7	4.5
All Other Values (>0)	1706.1	18	47	31.7	4.1

Zonal statistics show that the areas with the highest suitability for development according to industry standards are also the areas with the highest average potential for conflict for both the coastal (32.1) and deep water (33.5) technology types. The opposite is also true for these two categories. The lowest category of suitability corresponds with the lowest conflict ranking value for coastal (28.8) and deep water (31.7) technology types. With two exceptions, the total area increased with decreasing suitability for all three technology types.

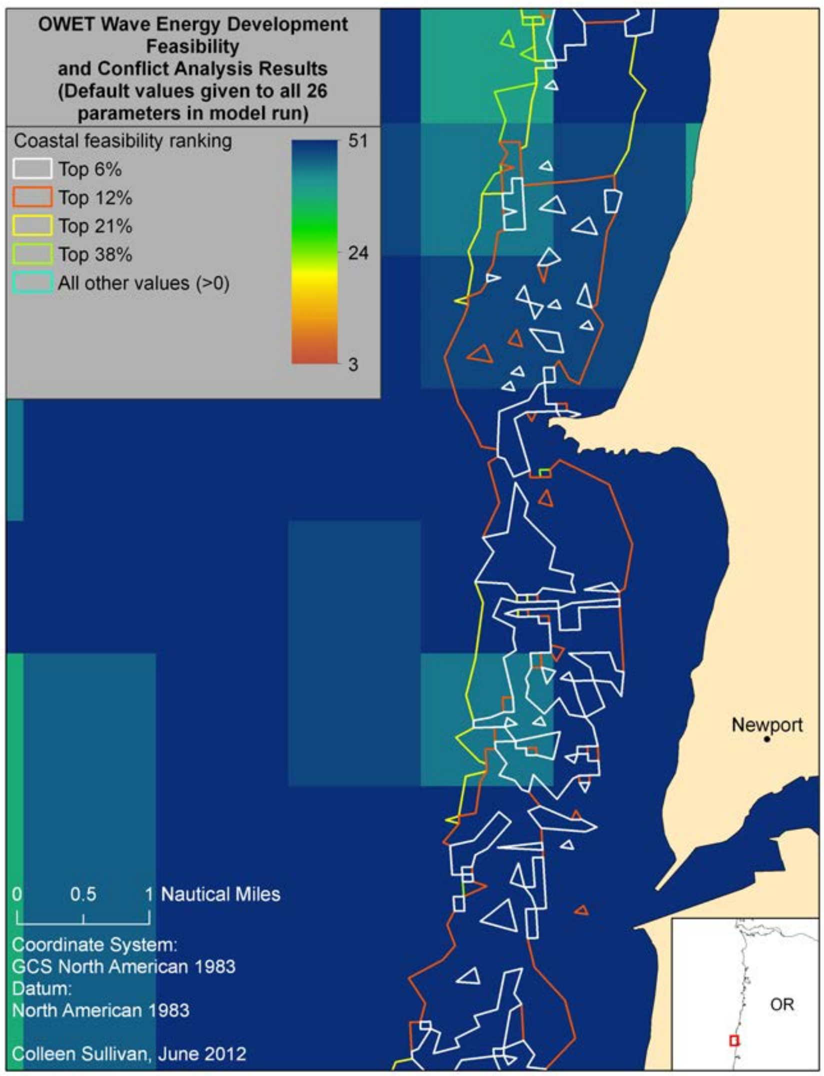

Figure 18. Subset of OWET development feasibility data off the coast of Newport, OR overlaid on conflict analysis results. Feasibility data are symbolized with complex

hollow adjacent polygons intended to show relative suitability for development while conflict analysis results appear as a continuous grid in the background. The same symbology is used for model results as with Figure 13 for the sake of comparison, but in this section values range only from 26 (light green) to 41 (dark blue). This example helps illustrate the direct relationship between highest feasibility for development (white polygons) and highest potential for conflict (dark blue cells).

4.2 Uncertainty analysis of model results

As described in section 2.3, there are several factors that contribute to uncertainty of analysis results. Drawing from the theory previously discussed, the methods described in section 3.6 were used to run an uncertainty analysis. The buffered input data were used to run the model with all parameters set to 1. The same was done with normal input data (Figure 11) and this result was subtracted from the buffered result to produce the difference raster shown in Figure 19. A graph of the number of cells with each difference value is shown in Figure 20.

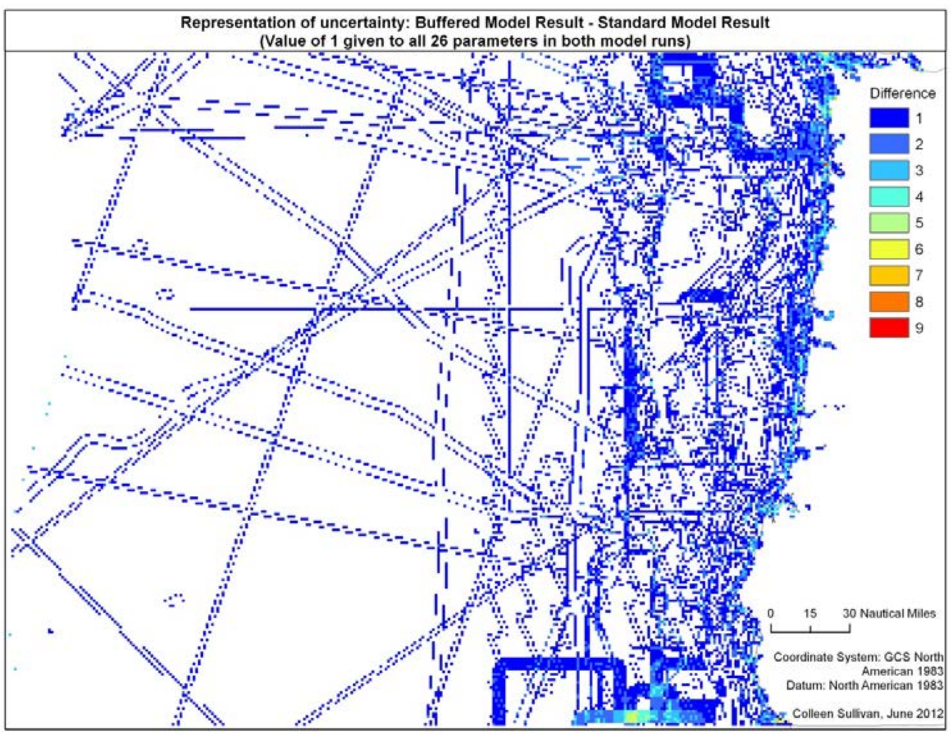

Figure 19. Difference raster which represents uncertainty in conflict analysis results by showing the discrepancy between the input data used for the model and the full extent of its uncertainty. Values range from 1 to 9, with 12% of the study area showing a difference of 1 (dark blue cells).

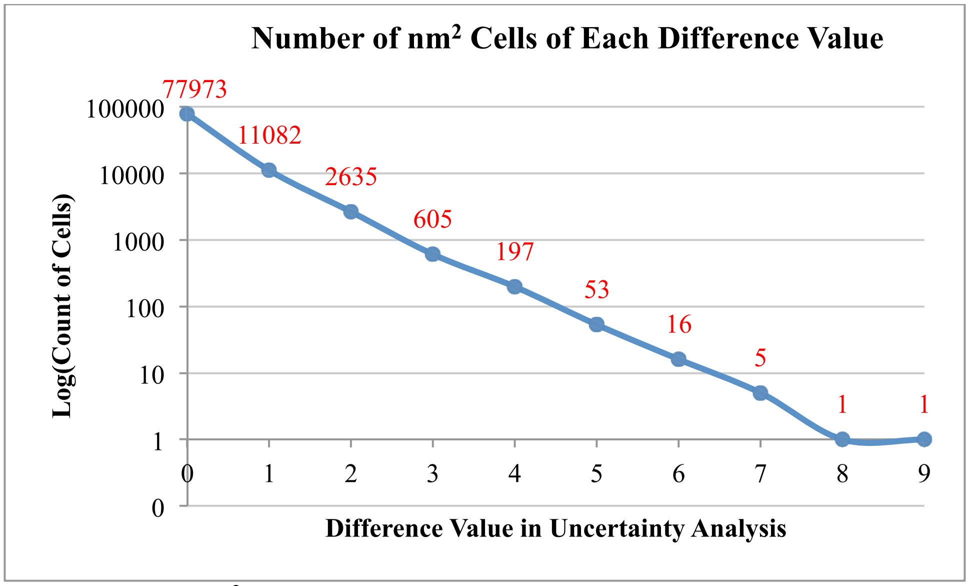

Figure 20. Count of nm^2 cells of each difference value shown in Figure 19. The graph uses a log scale on the vertical axis due to the spread of the values, and actual counts are shown in red above each data point. The count of cells decreases with increasing uncertainty.

Differences range from 1 to 9, indicating that buffering the input data to reflect uncertainty in their exact extent may increase the number of categories of ocean space use in a given 1 nm^2 cell by up to 9. Therefore, while results may indicate that a given grid requires planners to reach out to a certain number of stakeholder groups, that number could be off by up to 9 stakeholder groups due to uncertainty associated with the input data. Results show that 12% of the study area has a difference value of 1, the next highest difference value is 2, which covers 3% of the study area. The differences occur along data boundaries, thus closer to shore where there are many overlapping and complex shapefiles, there is also a greater concentration of difference values greater than 0. There is only 1 cell each with a difference value of 8 or 9, both of which occur near the northern Oregon shore (Figure 21).

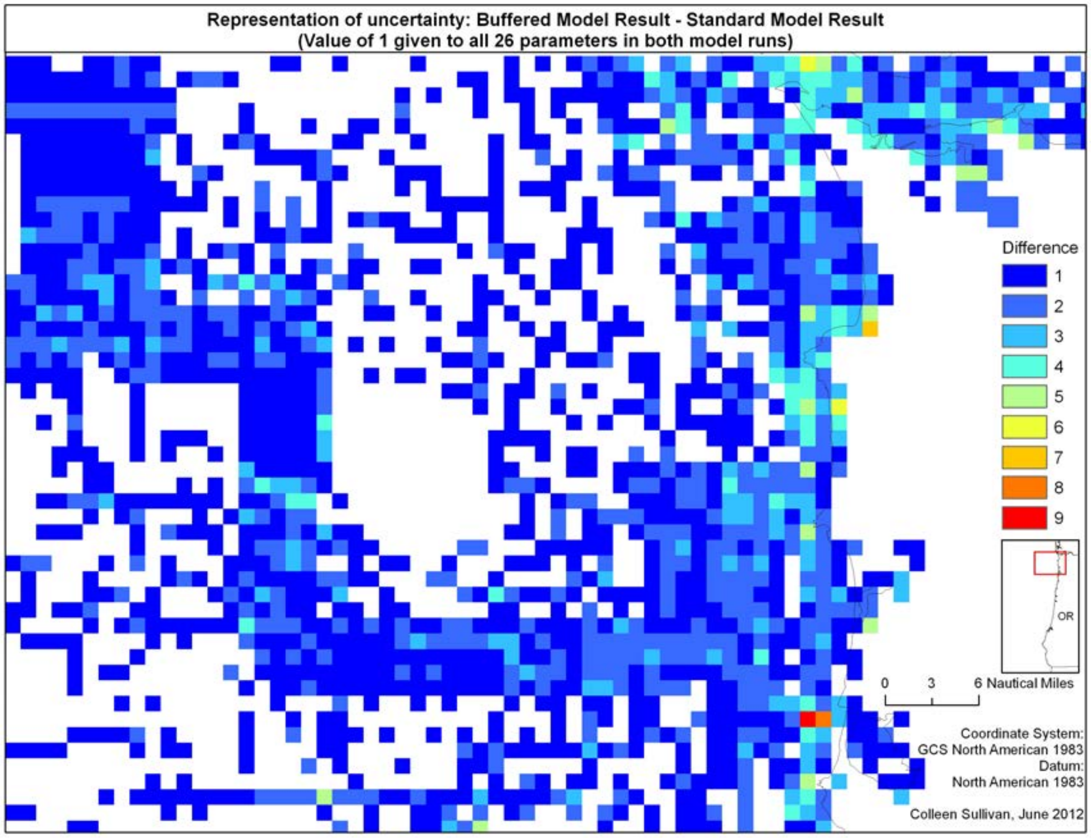

Figure 21. Northern Oregon coast portion of the difference raster shown in Figure 19, which represents uncertainty associated with the conflict analysis results. The figure shows a zoomed portion of Figure 19 to highlight the location of the single cells with values of 8 and 9, which appear orange and red.

Additionally, the method chosen for conversion of the input data to raster overestimates the area of space use because if any portion of a point, line, or polygon overlaps a cell, then the cell is given a value of 1 in the output. Thus, shapefiles representing use that occurs over only 100 m of ocean space can create the impression that its nm^2 block has a higher potential for conflict than it does in reality. For demonstration, a difference raster was calculated to compare the results of this method with a method that underestimates the area of space use for polygons, in which if a polygon does not cover the center of the cell, then it is not included in the output. This option is not available for points or lines; their influence remains the same in the comparison that follows. Use of this method causes eight entire polygon shapefiles (and unknown additional features of other polygons) to be excluded from the analysis because they result in an empty raster. The two methods were used to generate input rasters, and the model was run with each set, with all parameters set to 1. The result of subtracting the underestimation from the overestimation is shown in Figure 22.

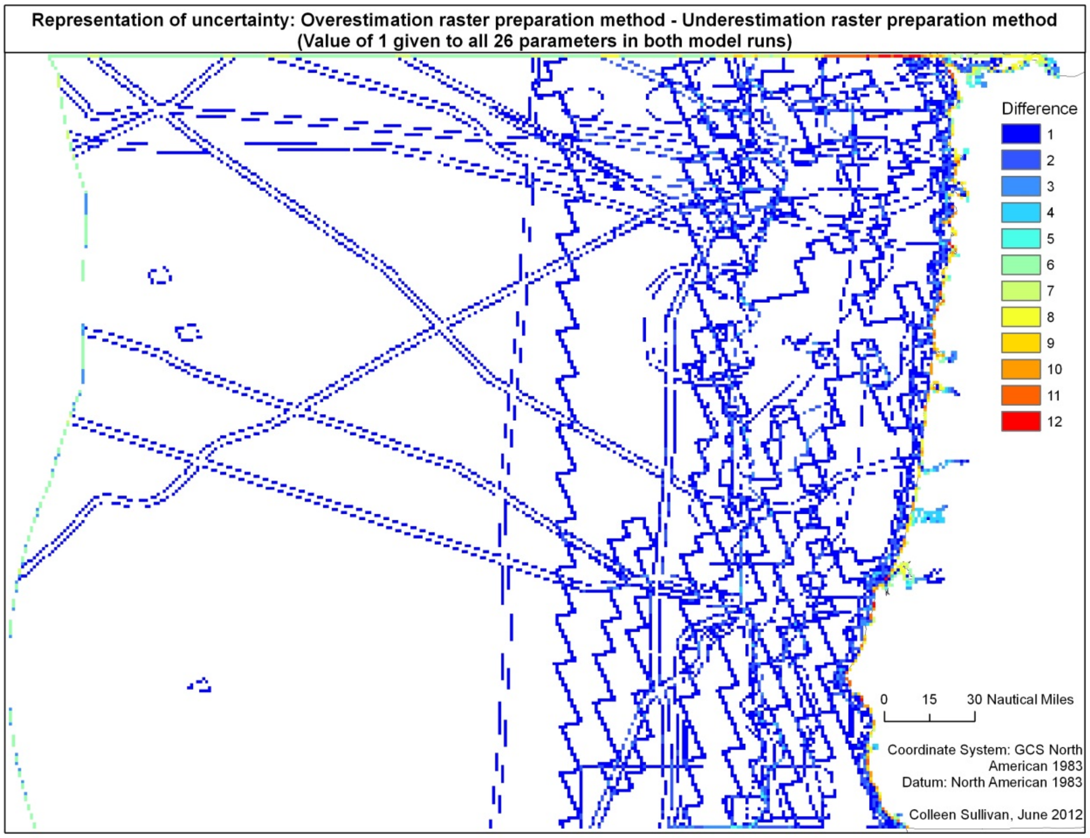

Figure 22. Difference raster which represents uncertainty associated with the method for conversion from shapefile to raster. Values range from 1 to 12, indicating the number of overlapping ocean space uses omitted in a given cell when the underestimation method is used for conversion of input data to raster. Because the areas shown are excluded when the underestimation method is used, the overestimation method was chosen to be conservative.

As shown, the overestimation method increases the number of space use categories in a given cell by up to 12 compared to the underestimation method. Differences between the two methods represent a single category of space use for 9% of the study area (dark blue cells). A total of 20 cells represent differences of 12 categories of use which amounts to .02% of the study area (red cells). These are more visible in the closer view of the northern Oregon coast (Figure 23). The overestimation method was used in light of uncertainty associated with the input data, and because it is safer to assume there is a higher, rather than lower, number of stakeholders interested in a given section of the ocean.

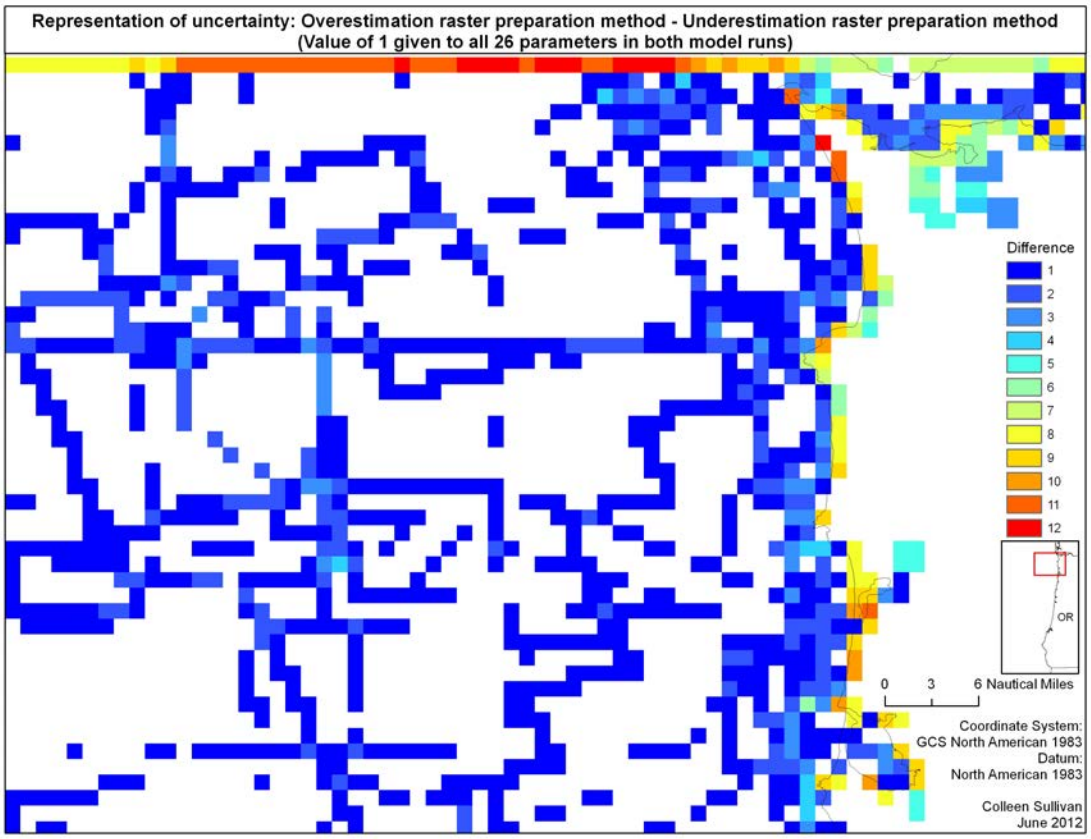

Figure 23. Northern Oregon coast portion of the difference raster in Figure 22, which represents uncertainty associated with the method for conversion from shapefile to raster. This figure is included to show a zoomed subset of Figure 22. Because the areas shown are excluded when the underestimation method is used, the overestimation method was chosen to be conservative.

5 Discussion

Q.1 Within the study area off the coast of Oregon, where are stakeholders currently using ocean space and how many uses overlap?

The map containing all input data (Figure 9) shows the ocean as a busy place with an overwhelming overlay of different ocean space uses. The image is informative in the sense that it conveys the fallacy of viewing the ocean as a vast and open frontier, but it does not efficiently convey where use occurs and just how much overlap is present (Ehler and Douvere 2009). Model results when all input parameters are set to 1 demonstrate the extent of overlap among categories of ocean space use (Figure 11). There are as many as 17 different uses occurring in a single nm^2 area, and most of Oregon's offshore waters have at least 6 overlapping uses (Figure 12). The likelihood is high that the 6 base categories of ocean space use in a given cell correspond with the categories that cover the greatest area: Fishing – Trolling, Habitat, Military, Fishing - Closure Areas, Protected, and Marine Transportation - Low Intensity (Table 5). Comparison of the overlap between each category combination with total areas of a given category (Table 6) generally shows high percentages for these 6 categories. Space use is most concentrated between the coast and approximately 30 nm at sea; a consequence of those activities limited by depth (e.g., recreational use), increased shipping density as vessels approach and depart major ports, and the increased fuel costs associated with traveling further from shore. Unfortunately for developers, increasing distance from shore also corresponds to increasing project costs, due in part to the expense of cables necessary to transmit energy back to shore.

Q2. To what extent might existing ocean space use present potential for conflict with renewable energy development?

Results of the model when run with the default parameters described in section 3.4 show not only which areas are heavily used, but generally how contentious their use is (Figure 13). More contentious areas are highlighted in this result as compared to the equal settings result, and most of the study area has a conflict potential of at least 17

(Figure 14). Because the meaning of a ranking value is less straight-forward, discussion of the entire study area is difficult. Two applications of results help illustrate their utility and demonstrate how the tool can be used to inform planning processes currently in progress in Oregon.

In the case of wave energy permit applications, the visualization in Figure 15 provides an efficient indication of the relative density of ocean space uses and their compatibility with development in the vicinity of each. The input data illustrates which stakeholder categories should be included in outreach for further research and conflict mitigation with respect to siting.

In the case of OWET's preferred areas for development for consideration in the Oregon TSP, comparison to model results highlights interesting parallels between areas ideal for development and areas ideal for existing use. Specifically, the direct relationship between high suitability for development and high conflict ranking suggests that factors that determine suitability for development are also factors that determine suitability for existing uses. For example, the suitability model assumes placement within 20 nm of a deep water port is ideal (Manson, Halsey, and Radil 2012). Such proximity may also prove ideal for fishermen that need to deliver catch to processing stations relatively quickly, recreational users that are limited in how far they can travel from a port, and marine transportation that must deliver and pick-up materials at ports. The suitability model also assumes that a seafloor type of sand and mud is best for deep water technologies that need strong anchoring (Manson, Halsey, and Radil 2012). These areas are also valuable to fishermen that target crab and shrimp because they are consistently found in this habitat (Industrial Economics, Inc. 2012). Because these groups currently use areas also suitable for development, and because their categories have high rankings for their potential for conflict with development, the same areas are often both suitable and contentious for development. The model highlights this pattern and informs management of which groups will be resistant to development in a given area.

Q3. How do various types of uncertainty affect analysis results?

Managers must be mindful of uncertainty when using decision support tools in a GIS. For this analysis input data uncertainty was approximated to create a visualization of the potential extent of uncertainty. The areas shown in the difference raster in Figure 19 may prove extra contentious for managers as a result of uncertainty. The visualization is intended to demonstrate how uncertainty can propagate through analysis as error associated with input data, parameters, assumptions, and model structure is compounded during the combination and manipulation of the input data (Crosetto and Tarantola 2001). Uncertainty analysis can measure this propagation, while for more complex models sensitivity analysis can measure the importance of various sources of uncertainty on model outputs (Crosetto and Tarantola 2001). Methods for measuring error propagation vary, but the use of Monte Carlo simulation to add error to inputs and measure the impact on the result is common (Bolstad 2005). Crosetto and Tarantola (2001) demonstrated the use of these analyses in early stages of data collection and model development, in order to best allocate resources to ensure appropriate data quality for particularly sensitive inputs and to choose an appropriate model algorithm.

An alternative to the frequentist approaches to communicating uncertainty in both location and description is the use of subjective probability conveyed through fuzzy sets, in which attributes contain a measure of confidence (Longley et al. 2011). A value between 0 and 1 is given to each value to quantify how likely it is that a given attribute or feature is correct. This method was not used for the current analysis but could prove useful for similar studies.

While the gathered data used to prepare category rasters has significant uncertainty at times, model results are still useful because they are meant to convey which areas of the ocean are known to be particularly controversial. Regardless of uncertainty, further research related to siting a specific project would require in depth study of the particular region of interest. Care should be taken to ensure that stakeholders represented in the model results truly encompass all parties with vested interest in a specific location. The input data and analysis results present a snapshot in time to help visualize the potential for conflict with renewable energy development. The input data includes only information on ocean space use that was available in a spatial format and additionally omits relevant activities on land such as the location of fish processing facilities and dependent coastal communities. Greater spatial and temporal resolution data, along with extensive outreach and conflict mitigation, would be necessary to site a specific project.

Q4. What are the implications of these findings for EBM of the ocean?
Not only are there no gaps in the study area where no ocean space use occurs, there is extensive overlap among existing uses and high potential for conflict with permanent offshore renewable energy installations. Consequently, there is no obvious location most suitable for siting a development. The conflict analysis tool can help management understand the picture of ocean space use, but it will not provide a clear action plan when used in isolation. Use of model results to visualize overlapping space use and the stakeholders with vested interest in each area is an example of how use of the model may help to responsibly practice EBM, which requires consideration of all ocean space uses. In addition to providing a visualization of areas that may be more or less contentious for development, the input data detail the specific stakeholder groups that managers must reach out to when a site is selected for investigation. A full understanding of the competing uses of space in a given area will help managers to recognize potential compatibilities and achieve multiple objectives during siting.

Model results clearly show higher space use closer to shore, in the same locations desired for wave energy development. Fortunately, testing the technology can occur on land, for example wave energy prototypes can be tested at the Wave Energy Linear Test Bed in the Wallace Energy Systems & Renewables Facility (WESRF) led by Annette von Jouanne and Ted Brekken at Oregon State University (WESRF 2008). This facility is one of a kind, however, and testing must still occur in the ocean prior to broad scale development. Plans are in motion to develop test berth sites in Oregon but developers are frustrated by the difficulty of obtaining such sites close to shore in a timely manner, which would allow cost effective development of the technologies they could later move further out into harsher weather conditions (Geerlofs et al. 2012). Conflict analysis model results could help renewable energy developers and coastal resource managers understand the interests at stake along the coast and assist them in finding a mutually acceptable outcome.

Model results can help managers set appropriate goals. Goals should include the full suite of ecosystem services offered by the ocean (Rosenberg and Sandifer 2009). Specifically, rather than simply aiming to maximize extractive value of offshore oil stores or wind energy potential to meet the nation's energy demand, the U.S. government must also provide stewardship for ecosystem services. These may include fishery stocks, nutrient cycling, recreational activities, and cultural practices. A balanced approach to development will likely also help maintain resilience, which refers to the ability of an ecosystem to resist change following a disturbance (Leslie and Kinzig 2009). To this end, goals could aim to improve diversity of species and habitats in the ocean, to reduce anthropocentric influences on disturbance regimes, and to monitor interactions among components and scales of the marine ecosystem (Leslie and Kinzig 2009). Bolstering resilience is smart. Doing so effectively reduces the potential consequences of failure in other areas of management by reducing the threshold that separates two ecosystem phases (Leslie and Kinzig 2009).

Results should also be generated for broader areas because management is at a disadvantage when designing goals only within jurisdictional boundaries, such as state waters (Rosenberg and Sandifer 2009). In order to establish an achievable goal, management must be able to control factors that determine success or failure of attaining the goal (Rosenberg and Sandifer 2009). This is not possible when the scale of a goal does not match the scale of management. For example, a Native American resource manager could create a goal to maintain fisheries stocks at their current levels. At a small scale, however, this could be an unattainable goal because fish are mobile and may simply relocate just outside of management boundaries. Alternatively, global climate change could create disturbance that the species cannot survive. While no ecosystem is truly closed (and therefore ideal for management purposes) the use of ecoregions is a better alternative to jurisdictional boundaries (U.S. Commission on Ocean Policy 2004). Regional Ocean Partnerships (ROPs) are existing voluntary groups that incorporate tribes, federal agency representatives, states, and fishery management councils of the region in the process of developing coastal and marine spatial plans (National Ocean Council 2012). The national ocean policy implementation plan calls for the national government to support these regional groups (National Ocean Council 2012).

The necessity of recognizing interconnectedness for effective EBM of the oceans further highlights the key role that the U.S. government, with its broad purview, can play. In siting offshore development it is critical to discover compatibilities between current use and proposed projects, to mitigate conflict by involving key stakeholders early and often throughout the siting process, and to synthesize all available information to reach a comprehensive solution (Gopnik et al. 2012). Recognizing interconnectedness improves the chances of achieving multiple objectives through management, and can improve efficiency in the data collection process as well (Rosenberg and Sandifer 2009).

Implicit trade-offs inherent to a management decision often aren't made intentionally, they are consequences of failing to account for the interconnectedness among components of the marine ecosystem (Rosenberg and Sandifer 2009). In order to make trade-offs explicit when making a siting decision, they must be fully understood. Boehlert and Gill (2010) compiled a list of publications that make specific calls for research needs in the realm of environmental impacts of specific offshore renewable energy technologies. For example, we do not understand the magnitude of the effect on marine organisms of magnetic fields emitted by undersea cables that transmit electricity to shore (Boehlert and Gill 2010). Additionally, sector-based management cannot be expected to recognize or address all explicit trade-offs because of its limited view of the situation (Rosenberg and Sandifer 2009). It takes a broader scale perspective to recognize trade-offs and cumulative impacts of management decisions in order to make them truly explicit. Sometimes the trade-offs are more straightforward, such as the decision to invest in general or specific resilience in a given area (Leslie and Kinzig 2009). While investment in specific resilience will bolster protection against a specific disturbance, investment in general resilience will protect against a broader range of possible disturbances (Leslie and Kinzig 2009). Investment decisions necessarily trade off resistance to particular known or unknown hazards, and the consequences of these decisions should be understood and honestly reported.

Because decisions may be required before enough is known to fully account for trade-offs, the technique of adaptive management is useful. Adaptive management uses policies as hypotheses in a management experiment, which allows managers to learn by doing and improve strategies over time (Guichard and Peterson 2009). While this may sound risky, the process is in fact structured. Policies are selected for use only after thorough assessment of currently best available science and modeling of potential outcomes of each policy option (Guichard and Peterson 2009). Policies are then chosen, while acknowledging inherent uncertainty, and adjusted over time based on the lessons learned (Ehler and Douvere 2009).

Managers should also incorporate lessons from economics, such as the use of externality calculations to help convey the trade-offs made in offshore siting decisions (Sukhdev 2011). The ecosystem services provided by the ocean are extremely valuable and affect the entire U.S. economy (Kildow and McIlgorm 2010). By documenting these values, they can then be monitored over time, and changes of value in response to management decisions may be used to better understand the effects of those decisions (Kildow and McIlgorm 2010). The issue is that marine ecosystem services are not always given an explicit value by the market. In these cases the true cost of development decisions are often obscured, when natural capital is consumed that users don't technically have to pay for (Sukhdev 2011).While one can calculate the market value for a pound of Oregon Pink Shrimp, it is less clear what the non-market value of the Pink Shrimp stock is, accounting for sustainability of that stock over time (Kildow and McIlgorm 2010). Assigning market values to non-market services is difficult and methods are still evolving. Current work is not yet comprehensive with respect to the types of assets valued and the geographic regions targeted (Pendleton, Atiyah, and Moorthy 2007). The temporal resolution of these studies is also an issue - as with market values the nonmarket values of these assets change over time and are context specific (Pendleton, Atiyah, and Moorthy 2007). Shortcomings aside, valuing ecosystem services in order to compare policy outcomes is a useful strategy to compare the importance of alternatives to society (Wainger and Boyd 2009). Thus, when aiming to maintain sustainability and resilience, and when it is unclear which management option would make the greatest number of people happy, calculating such a valuation may provide new insight.

In addition to illuminating trade-offs, Smith and Wilen (2003) demonstrated the insight economic analysis provides to explain the behavior of sea urchin fishermen in Northern California in response to establishment of marine reserves. They found that modeling to assess reserve closure scenarios for adaptive management that assume overly simplified fishing behavior is greatly flawed because in reality fishermen target dynamic places that have high value (Smith and Wilen 2003). Consequently, historical and future fishing behavior impacts the potential benefit of placing a marine reserve in a given location and must be carefully considered (Smith and Wilen 2003). In another assessment of closure effectiveness, participatory mapping by fishermen was used to document high value areas for rockfish, which strongly correlated with modeling of ideal rockfish habitats (Ardron and Wallace 2005). Economically significant areas effectively served as a proxy for ideal habitat. Economic analysis can be used to understand current ocean space use, in addition to highlighting the costs and benefits of policy alternatives.

The time is ripe for application of these management principles of EBM, especially given the many changes over the last decade to the national regulatory framework governing offshore energy development. Until the Energy Policy Act of 2005, signed into law by President George W. Bush, there was no clear jurisdiction over outer continental shelf (OCS) leases for renewable energy, despite long-standing programs on land for wind energy, managed by the Bureau of Land Management (U.S. Commission on Ocean Policy 2004). Five years later, President Barack Obama established the Interagency Ocean Policy Task Force in 2009, responsible for recommending a national ocean policy for the U.S. The task force completed its recommendations a year later and in July 2010 President Obama signed an Executive Order titled "Stewardship of the Ocean, Our Coasts, and the Great Lakes."

The order outlines a national ocean policy focused on implementing EBM (Interagency Ocean Policy Task Force 2010). Its recommendations detail the necessity of coastal and marine spatial planning to manage the increasingly conflicting uses of ocean space (Interagency Ocean Policy Task Force 2010). Among the numerous goals of the policy is responsible mitigation of conflict between ocean space users and renewable energy development (Interagency Ocean Policy Task Force 2010).

The responsibility to mitigate this conflict falls to BOEM in the Department of the Interior. One of the agency's mandates, according to section 388 of the Energy Policy Act of 2005, is to responsibly allocate lease rights for renewable energy projects (Michel et al. 2007). BOEM is charged with balancing the energy needs of the U.S. with protection of human communities and the environment (U.S. Commission on Ocean Policy 2004; Michel et al. 2007).

BOEM is currently under considerable scrutiny from the government and the public, due to controversy regarding its management of offshore lease blocks, which ultimately resulted in plans to restructure the agency following the Deepwater Horizon oil spill in April 2010 (Hogue 2010). The agency, formerly known as the Minerals Management Service, was renamed the Bureau of Ocean Energy Management, Regulation and Enforcement in May 2010 and began the process of restructuring to separate the three conflicting missions of energy development, safety and environmental enforcement, and royalty revenue collection. To this end, Secretary of the Interior Ken Salazar issued a secretarial order on May 19, 2010 establishing BOEM, a Bureau of Safety and Environmental Enforcement, and an Office of Natural Resources Revenue (U.S. Department of the Interior 2010).

In light of its restructuring and increased oversight, it is particularly important that the agency demonstrates its ability to provide appropriate management of OCS resources. To do so, BOEM must prepare to make responsible decisions about allocation of lease blocks for alternative energy development. The agency currently lacks a decision-making framework that will minimize conflict between stakeholders and avoid loss of economic and cultural value. BOEM must determine who the stakeholders are that use ocean space for commercial, recreational and cultural purposes, where their interests lie, and the best ways to mitigate potential conflict with renewable energy projects. This process is not a simple one, as illustrated by the Cape Wind project off the coast of Massachusetts which took 9 years to transition from initial proposal to lease approval (Phadke 2010).

To implement adaptive management on a national scale, the scope of knowledge necessary requires that BOEM establish an interdisciplinary advisory structure to mimic that in place for fisheries management (Rosenberg and Sandifer 2009). The Outer Continental Shelf Scientific Committee established by Salazar in October 2011 is a promising start to developing such an advisory. This committee should allow BOEM to increase efficiency by tapping regional research progress and improving reliability of science used to make decisions.

Regional governance is also focused on EBM, BOEM works with the ROPs to implement a regional management approach (National Ocean Council 2012). MSP occurs at the state level along both coasts as well. Examples of detailed state plans include the Massachusetts Ocean Plan and the Rhode Island Ocean Special Area Management Plan. Both of these plans were driven by entrepreneurial interest in wind energy development (SeaPlan 2012; R.I. Coastal Resources Management Council 2012; White, Halpern, and Kappel 2012). By focusing on small regions, these states have inventoried the key environmental, economic, and social parameters that should impact siting decisions. In Oregon, the DLCD is updating the TSP (established in 1994) to specifically address the siting of wave energy projects, in accordance with its statewide planning goal 19, which concerns protection of existing ecosystem services (Geerlofs et al. 2012).

On the west coast, the combination of fewer unique governments with the large marine ecosystem of the California current also promotes a more integrated approach to ocean governance. The West Coast Governor's Alliance on Ocean Health (aka WCGA) was founded as an agreement between the governors of Washington, Oregon, and California in September 2006, with the intent of ensuring the stewardship of ocean resources (West Coast Governors' Alliance on Ocean Health 2010). The Alliance now has eleven Action Coordination Teams (ACT) that released specific work plans beginning in May 2010, describing how each will accomplish the goals of the alliance (West Coast Governors' Alliance on Ocean Health 2010). The WCGA Renewable Ocean Energy ACT work plan details how it will explore the available technologies and potential environmental impacts of such projects, and improve eventual siting (West Coast Governors' Alliance on Ocean Health 2010).

The methods used to create the model could be efficiently adapted for application to another region. The python code would merely need to be tweaked to accommodate any differences in data categories. For example, Washington's new law on MSP enacted in March 2010 required its State Ocean Caucus to recommend a framework for implementation (Hennessey and the State Ocean Caucus 2011). Because funding MSP is an issue in Washington (it must come from external or federal sources), this analysis would provide an efficient visualization of the social landscape of Washington's territorial sea and federal waters (Hennessey and the State Ocean Caucus 2011). The understanding of where overlapping ocean space use occurs, combined with the wealth of ecological data the state already has, could guide future data collection efforts and research priorities for the state in order to appropriately allocate available funds.

A broader scale application of the conflict analysis model may be appropriate for the Renewable Ocean Energy ACT of the WCGA, which is responsible for researching the feasibility of offshore development and its environmental impacts. The conflict model could be useful to highlight the factors already contributing to cumulative impacts on a given section of the ocean as well as the relative presence of potential barriers to development. For a development to be profitable it must secure sufficient funding not only to install the infrastructure, but to afford the siting process. The potential for conflict with existing space use is one component of development feasibility and the model could help communicate this component to the ACT. The ROPs could also benefit from expanding the model inputs to visualize conflict at a regional level, perhaps with a coarser grid such as the BOEM lease blocks.

At the federal level, BOEM can use model results to help prepare responsible decisions concerning lease blocks on the OCS. As with the state and regional levels, it would use results for an initial understanding of the social landscape and to target stakeholders for outreach during the decision-making process. BOEM may also benefit from tapping research done in state waters and by regional bodies such as the WCGA to avoid duplication of efforts and to reduce stakeholder fatigue.

The relatively new framework of EBM does not provide step-by-step instructions for proper decisions concerning offshore lease development for renewable energy, but it is currently a shared vision for management at the federal, regional, and state levels.

BOEM can provide strong managerial leadership in the siting process, assist coordination of siting efforts across the country, improve dialogue and conflict mitigation measures, and use its broad purview to streamline national renewable energy development (Rosenberg et al. 2009). Recognizing the goals of EBM and working with ROPs on both coasts may prove important to ensure that the scale of goals matches the scale of management because ecosystem processes are not confined to jurisdictional boundaries. Meanwhile, making use of results of the conflict analysis model (and adapting for use in broader areas) could provide key insights into the bigger picture of ocean space use.

Suggestions for further research

Modifications to the model could be used to expand its utility. First, input data could be added to include coastal interests in the ocean, perhaps by highlighting areas particularly important to specific coastal communities due to their fish processing stations, tourism industry, or resident fishermen population. Input data could also be added to reflect renewable energy development feasibility, much like OWET did to create their preferences for development. Regardless of any additions, the existing category rasters should be updated because the input data used for this analysis was a snapshot in time. Updates will help ensure results accurately portray the distribution of current stakeholder interests. In addition to updating the data using spatial data clearinghouses, additional stakeholder research would be helpful. Maintaining relationships with stakeholders for this purpose will also improve the energy siting process, because stakeholders will have been involved in MSP early and often.

Second, a web map with the analysis tool would allow community members to experiment with their own rankings and generate outputs to show potential for conflict and relative density of ocean space use. Including the input category rasters would allow them to explore what is known about current ocean space use and improve awareness of the bigger picture of stakeholder interests at sea. This would improve transparency and encourage public participation in the ocean management process.

Users may also eventually volunteer local knowledge that they feel is missing from the visualization, much like the participatory mapping exercises used in this research.

Third, the model could be adapted for use at different scales with varying cell sizes as appropriate. The ROPs may wish to use the BOEM lease blocks to examine relative density of ocean space use and potential for conflict at a regional scale, while the OR DLCD may wish to use a small grid size to examine only the TSP. This could then be compared to areas they plan to designate for Goal 19 protection under the revised TSP.

Finally, model results can spark further research questions. For example, the six uses with the highest coverage in the study area appear to overlap extensively. Their relationship could be studied to learn from their ability to colocate. It is possible that the stakeholder groups demonstrate conflict mitigation strategies unknown to ocean management officials.

6 Conclusion

The ocean has long been a rich resource for U.S. citizens and now represents an opportunity for significant development of wind, wave, and tidal energy (U.S. Commission on Ocean Policy 2004). In addition to strong entrepreneurial interest in renewable energy projects and accompanying technological advances, the regulatory climate surrounding renewable energy has also improved in the last decade. Offshore renewable energy development in Oregon, specifically, has significant momentum. Research, development, and testing of the technology for offshore wind, wave, and tidal projects is well underway. Meanwhile, Oregon's governor supports a ban on offshore oil drilling due to its environmental impacts, and there is government support for renewable energy development at both the state and federal level (Conway et al. 2009, 2010).

However, given the significant economic, ecologic, and social importance of the oceans, responsible management is critical in order to optimize the necessary trade-offs (Conway et al. 2009, 2010). To this end state, regional, and federal management currently supports the implementation of EBM for the oceans and the use of MSP as a tool to aid offshore energy development. Regional and state planning efforts have already made significant strides in implementing EBM and their examples provide useful lessons in structuring adaptive management for future endeavors. Consequently, at the federal level BOEM can take advantage of the plethora of research on these topics, the support of the National Ocean Policy, and the increasing utility of a GIS for multicriteria analysis to produce defensible lease block allocation decisions that make trade-offs explicit and have the support of a majority of involved stakeholders.

As one scientist interviewed in this research put it, "The ocean is huge, but how huge it feels depends on how concentrated any resource is" (Conway 2012, 49). The addition of renewable energy to the current social landscape of the ocean shrinks the resource base for many categories of ocean space use. The results demonstrate that mitigation of conflict between development and existing space use is not merely a best practice supported by current policy, but a necessity. Ultimately, the potential for conflict is highly dependent on the technology to be installed, and the specific location selected. The visualization of conflict presented herein can serve useful in the initial step of scoping areas for development and identifying the stakeholders necessary to include in the process. This conflict analysis tool can assist management in using MSP and working toward EBM.

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Appendices

A. GIS Analysis: Exported python scripts from ModelBuilder models used to batch process digitized shapefiles from ethnographic interview results.

Exported script of ModelBuilder model made to assist digitizing of ethnographic interview results that involved a depth range in fathoms. This model adapts the method for data area delineation from LiDAR points. A point shapefile of a depth range in fathoms was used as the input (Figure 5).

Exported python script:

```
# ---------------------------------------------------------------------------
# FathomsToShp.py
# Created on: 2012-04-13 13:54:21.00000
#   (generated by ArcGIS/ModelBuilder)
# Usage: FathomsToShp <v10_180> <temp5>
# Description:
# ---------------------------------------------------------------------------

# Import arcpy module
import arcpy

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")

# Script arguments
v10_180 = arcpy.GetParameterAsText(0)
if v10_180 == '#' or not v10_180:
    v10_180 = "10_180" # provide a default value if unspecified

temp5 = arcpy.GetParameterAsText(1)
if temp5 == '#' or not temp5:
    temp5 = "C:\\Documents and Settings\\sullicol\\My
Documents\\ArcGIS\\Default.gdb\\temp5" # provide a default value if unspecified

# Local variables:
temp1 = v10_180
temp2 = temp1
temp3 = temp2
temp4 = temp3
Input_true_raster_or_constant_value = "1"

# Process: Point to Raster
arcpy.PointToRaster_conversion(v10_180, "FID", temp1, "COUNT", "NONE",
"0.036")
```

```
# Process: Con
arcpy.gp.Con_sa(temp1, Input_true_raster_or_constant_value, temp2, "", "")

# Process: Expand
arcpy.gp.Expand_sa(temp2, temp3, "1", "1")

# Process: Shrink
arcpy.gp.Shrink_sa(temp3, temp4, "1", "1")

# Process: Raster to Polygon
arcpy.RasterToPolygon_conversion(temp4, temp5, "SIMPLIFY", "Value")
```

Exported script of ModelBuilder model - In this first step each digitized shapefile is dissolved on the ID field (preserving multi-part features) to prevent duplication of comments added in following steps (Figure 6).

Exported python script:

```
# ---------------------------------------------------------------------------
# Dissolve.py
# Created on: 2012-04-13 13:51:49.00000
#   (generated by ArcGIS/ModelBuilder)
# Usage: Dissolve <v124_18620_ApproximateClosedArea_shp>
# Description:
# ---------------------------------------------------------------------------

# Import arcpy module
import arcpy

# Script arguments
v124_18620_ApproximateClosedArea_shp = arcpy.GetParameterAsText(0)
if v124_18620_ApproximateClosedArea_shp == '#' or not
v124_18620_ApproximateClosedArea_shp:
    v124_18620_ApproximateClosedArea_shp =
"Y:\\MMS\\Ethnography\\All_Projected\\124_18620_ApproximateClosedArea.shp" #
provide a default value if unspecified

# Local variables:
v106_18620_HighConcHalibut_Di_shp = v124_18620_ApproximateClosedArea_shp

# Process: Dissolve
arcpy.Dissolve_management(v124_18620_ApproximateClosedArea_shp,
v106_18620_HighConcHalibut_Di_shp, "Id", "", "MULTI_PART",
"DISSOLVE_LINES")
```

Exported script of ModelBuilder model - In this second step a text field (length 254) called 'Comment' is added to each digitized shapefile (Figure 7).

Exported python script:

```
# ---------------------------------------------------------------------------
# AddField.py
# Created on: 2012-04-13 13:44:06.00000
#   (generated by ArcGIS/ModelBuilder)
# Usage: AddField <v189_18620_Power_shp>
# Description:
# ---------------------------------------------------------------------------

# Import arcpy module
import arcpy

# Script arguments
v189_18620_Power_shp = arcpy.GetParameterAsText(0)
if v189_18620_Power_shp == '#' or not v189_18620_Power_shp:
    v189_18620_Power_shp =
"Y:\\MMS\\Ethnography\\All_Projected_07072011SupplementCarries\\189_18620_P
ower.shp" # provide a default value if unspecified

# Local variables:
v189_18620_Power_shp__2_ = v189_18620_Power_shp

# Process: Add Field
arcpy.AddField_management(v189_18620_Power_shp, "Comment", "TEXT", "", "",
"254", "", "NON_NULLABLE", "NON_REQUIRED", "")
```

Exported script of ModelBuilder model - In this third step the 'Comment' field is calculated using approved text appropriate to each digitized shapefile (Figure 8).

Exported python script:

```
# ---------------------------------------------------------------------------
# AddAttribute.py
# Created on: 2012-04-13 13:45:44.00000
#   (generated by ArcGIS/ModelBuilder)
# Usage: AddAttribute <v189_18620_Power_shp> <Expression>
# Description:
# ---------------------------------------------------------------------------

# Import arcpy module
import arcpy
```

```
# Script arguments
v189_18620_Power_shp = arcpy.GetParameterAsText(0)
if v189_18620_Power_shp == '#' or not v189_18620_Power_shp:
    v189_18620_Power_shp =
"Y:\\MMS\\Ethnography\\All_Projected_07072011SupplementCarries\\189_18620_P
ower.shp" # provide a default value if unspecified

Expression = arcpy.GetParameterAsText(1)
if Expression == '#' or not Expression:
    Expression = "\"Power access\"" # provide a default value if unspecified

# Local variables:
alt_energy_future_dominant__2_ = v189_18620_Power_shp
Field_Name = "Comment"

# Process: Calculate Field
arcpy.CalculateField_management(v189_18620_Power_shp, Field_Name,
Expression, "VB", "")
```

B. Input Data Sources

Table B1. List of the 32 sources of spatial data on ocean space use on the west coast of the U.S., and number of layers from each downloaded during the initial stage of the project.

Source	*Number of Data Layers*
BOEM/NOAA	21
California Ocean Uses Atlas	74
California Department of Fish and Game	10
California Wreck Divers	1
Coast Guard	5
Conway and Pomeroy Social Science Research	37
ESRI	1
iBoattrack	1
Marine Map Consortium	96
MPA.gov	1
National Atlas	1
NOAA ENCDirect	111
NOAA Marine Protected Areas Center	1
NOAA NMFS	2
NOAA NWFSC	6
NOAA ORR	19
Oregon Coastal Atlas	9
Oregon Department of Fish and Wildlife (ODFW)	1
Oregon Department of Land Conservation and Development (DLCD)	41
Oregon Geospatial Enterprise Office (GEO)	1
Oregon SeaGrant	1
Pacific Coast Marine Habitat Program	3
Pacific States/British Columbia Oil Spill Task Force	1
PaCOOS	31
PSMFC/PacFIN	5
The Nature Conservancy	1
U.S. Army Corps of Engineers	1
U.S. Navy	2
Washington Department of Ecology	1
Washington Department of Fish and Wildlife (WDFW)	1
Washington Recreation and Conservation Office (WA RCO)	1
Washington State Department of Natural Resources (WA DNR)	1

Table B2. List of the 127 shapefiles used in this analysis.
All descriptions for data from NOAA ENCDirect are direct quotes from the CARIS S-57 ENC Object Catalouge, Edition 3.1.2: http://www.caris.com/S-57/frames/S57catalog.htm.

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
Cable	APPROACH_HARBOR_CBLSUB_line_wc	Cable, submarine (An assembly of wires or fibers, or a wire rope or chain which has been laid underwater or buried beneath the seabed (Hydrographic Service, Royal Australian Navy))	NOAA ENCDirect	Polygon	7/11/2001 - 12/29/2010
Cable	COASTAL_CBLSUB_line_wc	Cable, submarine (An assembly of wires or fibers, or a wire rope or chain which has been laid underwater or buried beneath the seabed (Hydrographic Service, Royal Australian Navy))	NOAA ENCDirect	Polygon	7/11/2001 - 12/29/2010
Cable	GENERAL_CBLSUB_line_wc	Cable, submarine (An assembly of wires or fibers, or a wire rope or chain which has been laid underwater or buried beneath the seabed (Hydrographic Service, Royal Australian Navy))	NOAA ENCDirect	Polygon	7/11/2001 - 12/29/2010
Disposal/ Dump	APPROACH_HARBOR_DMPGRD_POLYGON_poly_wc	Dumping ground (A sea area where dredged material or other potentially more harmful material, e.g., explosives, chemical waste, is deliberately deposited. (Derived from IHO Chart Specifications, M-4).)	NOAA ENCDirect	Polygon	7/11/2001 - 12/29/2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
Disposal/ Dump	COASTAL_DMPGRD_POLYGON_poly_wc	Dumping ground (A sea area where dredged material or other potentially more harmful material, e.g., explosives, chemical waste, is deliberately deposited. (Derived from IHO Chart Specifications, M-4).)	NOAA ENCDirect	Polygon	7/11/2001 - 12/29/2010
Disposal/ Dump	GENERAL_DMPGRD_POLYGON_poly_wc	Dumping ground (A sea area where dredged material or other potentially more harmful material, e.g., explosives, chemical waste, is deliberately deposited. (Derived from IHO Chart Specifications, M-4).)	NOAA ENCDirect	Polygon	7/11/2001 - 12/29/2010
Dredge	APPROACH_HARBOR_DRGARE_poly_wc	Dredged Area (An area of the bottom of a body of water which has been deepened by dredging. (IHO Dictionary, S-32, 5th Edition, 1462))	NOAA ENCDirect	Polygon	7/11/2001 - 12/29/2010
Dredge	USACE_DredgeDisposal_FullStudy	Dredged Material Disposal	U.S. Army Corps of Engineers	Polygon	Unknown
fish_ Closure	efh_700fm_polygons	Final Rule EFH EIS Polygons (EFH 700 Fathom Polygons)	PaCOOS	Polygon	5/11/2006
fish_ Closure	efh_consarea_polygons	Final Rule EFH EIS Polygons (EFH Conservation Area Polygons)	PaCOOS	Polygon	5/11/2006
fish_ Closure	rca_2009to2010_m	Recreational Rockfish conservation area boundaries (created using Groundfish Fishery Management	NOAA NMFS	Line	2009-2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		Data Available Online)			
fish_ Closure	yrca_2009to2010	Recreational Yelloweye rockfish conservation area boundaries (created using Groundfish Fishery Management Data Available Online)	NOAA NMFS	Polygon	2009-2010
fish_Line	CDFG_HookNLine_05to09	OSU created these shapefiles using CDFG Fishing data originally in Excel	California Department of Fish and Game	Polygon	2005-2009
fish_Line	Ethnography_CommFish_Halibut_pg_wc	Commercial Fishing - Halibut	Conway Social Science Research	Polygon	2011
fish_Line	Ethnography_CommFish_Sablefish_pg_wc	Commercial Fishing - Sablefish	Conway Social Science Research	Polygon	2011
fish_Line	ODFW_HooknLine BottomLongline	Oregon, Washington & Northern CA commercial fishing data in 10 min blocks	Oregon Department of Fish and Wildlife (ODFW)	Polygon	1996-2009
fish_Other	CDFG_OtherLandings_05to09	OSU created these shapefiles using CDFG Fishing data originally in Excel	California Department of Fish and Game	Polygon	2005-2009
fish_Other	ODFW_Other	Oregon, Washington & Northern CA commercial fishing data in 10 min blocks	Oregon Department of Fish and Wildlife (ODFW)	Polygon	1996-2009
fish_Pots	CDFG_CrabPotLandings_05to09	OSU created these shapefiles using CDFG Fishing data originally in Excel	California Department of Fish and Game	Polygon	2005-2009
fish_Pots	Ethnography_CommFish_Crab_pg_wc	Commercial Fishing - Crab	Conway Social Science Research	Polygon	2011

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
fish_Pots	Ethnography_CommFish_SpotPrawn_pg_wc	Commercial Fishing - Spot Prawn	Conway Social Science Research	Polygon	2011
fish_Pots	Ethnography_CommFish_Sablefish_pg_wc_POT	Commercial Fishing - Sablefish	Conway Social Science Research	Polygon	2011
fish_Traps	CDFG_Trap_05to09	OSU created these shapefiles using CDFG Fishing data originally in Excel	California Department of Fish and Game	Polygon	2005-2009
fish_Trawl	CDFG_TrawlLandings_05to09	OSU created these shapefiles using CDFG Fishing data originally in Excel	California Department of Fish and Game	Polygon	2005-2009
fish_Trawl	Ethnography_CommFish_Groundfish_pg_wc	Commercial Fishing - Groundfish	Conway Social Science Research	Polygon	2011
fish_Trawl	Ethnography_CommFish_Shrimp_pg_wc	Commercial Fishing - Shrimp	Conway Social Science Research	Polygon	2011
fish_Trawl	ODFW_Trawl	Oregon, Washington & Northern CA commercial fishing data in 10 min blocks	Oregon Department of Fish and Wildlife (ODFW)	Polygon	1996-2009
fish_Trawl	PacFIN_0509_CoastalPelagic_Activity	Oregon, Washington & California summary groundfish trawl data in 10 min blocks	PSMFC/ PacFIN	Polygon	2005-2009
fish_Trawl	PacFIN_0509_Groundfish_Activity	Oregon, Washington & California summary groundfish trawl data in 10 min blocks	PSMFC/ PacFIN	Polygon	2005-2009
fish_Trawl	PacFIN_0509_Highl	Oregon, Washington & California	PSMFC/ PacFIN	Polygon	2005-2009

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
	yMigratory_Activity	summary groundfish trawl data in 10 min blocks			
fish_Trawl	PacFIN_0509_Other SpNoMgt_Activity	Oregon, Washington & California summary groundfish trawl data in 10 min blocks	PSMFC/ PacFIN	Polygon	2005-2009
fish_Troll	CDFG_TrollLandin gs_05to09	OSU created these shapefiles using CDFG Fishing data originally in Excel	California Department of Fish and Game	Polygon	2005-2009
fish_Troll	Ethnography_Comm Fish_Salmon_pg_wc	Commercial Fishing - Salmon	Conway Social Science Research	Polygon	2011
fish_Troll	Ethnography_Comm Fish_Tuna_pg_wc	Commercial Fishing -Tuna	Conway Social Science Research	Polygon	2011
fish_Troll	ODFW_Troll	Oregon, Washington & Northern CA commercial fishing data in 10 min blocks	Oregon Department of Fish and Wildlife (ODFW)	Polygon	1996-2009
Habitat	altb02	EFH EIS HAPC estuaries from "The Draft Environmental Impact Statement (DEIS) for Essential Fish Habitat (EFH) Designation and Minimization of Adverse Impacts for the Pacific Coast Groundfish Fishery Management Plan"	PaCOOS	Polygon	2/2005
Habitat	altb04	EFH EIS HAPC seagrass from "The Draft Environmental Impact Statement (DEIS) for Essential Fish Habitat (EFH) Designation and Minimization of Adverse Impacts	PaCOOS	Polygon	2/2005

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		for the Pacific Coast Groundfish Fishery Management Plan"			
Habitat	altb06	EFH EIS HAPC rocky reefs from "The Draft Environmental Impact Statement (DEIS) for Essential Fish Habitat (EFH) Designation and Minimization of Adverse Impacts for the Pacific Coast Groundfish Fishery Management Plan"	PaCOOS	Polygon	2/2005
Habitat	AltB3_CanopyKelp _PMFSC_2004	(1) Alternative B.3 (Canopy Kelp) for West Coast Groundfish Essential Fish Habitat draft EIS, PSMFC,2004	Oregon Coastal Atlas	Polygon	2/1/2005
Habitat	BIO_CatalogOregon SeabirdColonies_PO INTS_USFWS_200 7	Locations and attributes of 393 seabird colonies of Oregon (USFWS)	PaCOOS	Point	5/19/2008
Habitat	efh_polygons	Final Rule EFH EIS Polygons (EFH Polygons)	PaCOOS	Polygon	5/11/2006
Habitat	invert_race	(3) Biogenic Habitat -> Presence of Structure-Forming Invertebrates (anemones, corals, or sponges) from West Coast Trawl Surveys	Pacific Coast Marine Habitat Program	Point	1984-2001
Habitat	MarbledM_CritHab _USFWS_1996	Marbled Murrelet critical habitat lands per ESA (USFWS)	PaCOOS	Polygon	5/13/1996
Habitat	Modern_Kelp_Surve ys_ODFW_90_96_9 9	Canopy kelp of Oregon	PaCOOS	Polygon	1990, 1996-1999

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
Habitat	NMFS_Corals_1980to2007	Lat/Long/Depth of instances of cold water/deep sea corals from bottom trawl surveys done by AFSC & NWFSC	PaCOOS	Point	1980-2007
Habitat	Pinniped_Haulout_ODFW_2007	Seal and Sea Lion haul-out and rookery locations	PaCOOS	Point	3/5/2008
Habitat	seagrass_pub	(2) Biogenic Habitat -> Public Seagrass Compilation for West Coast Essential Fish Habitat (EFH)	Pacific Coast Marine Habitat Program	Polygon	1987-2003
Habitat	WSPlover_CritHab_USFWS_2005	Snowy Plover critical habitat lands per ESA (USFWS)	PaCOOS	Polygon	10/18/2005
MarineTrans_1	AISGridYr2009_1to60	2009 U.S. Coast Guard AIS Data	Coast Guard	Polygon	2009
MarineTrans_2	AISGridYr2009_61to239	2009 U.S. Coast Guard AIS Data	Coast Guard	Polygon	2009
MarineTrans_3	AISGridYr2009_240to479	2009 U.S. Coast Guard AIS Data	Coast Guard	Polygon	2009
MarineTrans_4	AISGridYr2009_GTOE480	2009 U.S. Coast Guard AIS Data	Coast Guard	Polygon	2009
MarineTrans_4	APPROACH_HARBOR_FAIRWY_poly_wc	Fairway (That part of a river, harbor and so on, where the main navigable channel for vessels of larger size lies. It is also the usual course followed by vessels entering or leaving harbors, called 'ship channel'. (International Maritime Dictionary, 2nd Ed.))	NOAA ENCDirect	Polygon	7/11/2001 - 12/29/2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
MarineTrans_4	APPROACH_HARBOR_NAVLNE_line_wc	Navigation line (A navigation line is a straight line extending towards an area of navigational interest and generally generated by two navigational aids or one navigational aid and a bearing. (Service Hydrographique et Océanographique de la Marine, France))	NOAA ENCDirect	Line	7/11/2001 - 12/29/2010
MarineTrans_4	APPROACH_HARBOR_RECTRC_LINE_line_wc	Recommended track (A track recommended to all or only certain vessels. (IHO Dictionary, S-32, 5th Edition, 5576))	NOAA ENCDirect	Line	7/11/2001 - 12/29/2010
MarineTrans_4	COASTAL_ISTZNE_poly_wc	Inshore traffic zone (A routing measure comprising a designated area between the landward boundary of a traffic separation scheme and the adjacent coast, to be used in accordance with the provisions of the International Regulations for Preventing Collisions at Sea. (IHO Dictionary, S-32, 5th Edition, 2457))	NOAA ENCDirect	Polygon	7/11/2001 - 12/29/2010
MarineTrans_4	COASTAL_NAVLNE_line_wc	Navigation line (A navigation line is a straight line extending towards an area of navigational interest and generally generated by two navigational aids or one navigational aid and a bearing. (Service Hydrographique et Océanographique	NOAA ENCDirect	Line	7/11/2001 - 12/29/2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		de la Marine, France))			
MarineTrans_4	COASTAL_RECTRC_LINE_line_wc	Recommended track (A track recommended to all or only certain vessels. (IHO Dictionary, S-32, 5th Edition, 5576))	NOAA ENCDirect	Line	7/11/2001 - 12/29/2010
MarineTrans_4	Ethnography_CommNonFish_Shipping_pg_wc	Commercial Nonfishing - Shipping	Conway Social Science Research	Polygon	2011
MarineTrans_4	Ethnography_CommNonFish_Towlane_ln_wc	Commercial Nonfishing - Towlane	Conway Social Science Research	Line	2011
MarineTrans_4	s_mmc_S_MMC_shipping_lanes	Shipping Lanes	BOEM/ NOAA	Line	Metadata unavailable
MarineTrans_4	Towlanes_WASG_2007	"Gentleman's agreement" b/w fishermen and towers, not legal but 'voluntary' participation, annual meetings, Crab fishermen will not put crab pots in the lanes (if they do, liable to be destroyed) Attributes include "Label": year-round, summer only, advisory only	Oregon Coastal Atlas	Line	1987-2007
Military	APPROACH_HARBOR_CGUSTA_point_wc	Coastguard station (Watch keeping stations at which a watch is kept either continuously, or at certain	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		times only. (IHO Chart Specifications, M-4))			
Military	COASTAL_CGUSTA_point_wc	Coastguard station (Watch keeping stations at which a watch is kept either continuously, or at certain times only. (IHO Chart Specifications, M-4))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
Military	Navy_Northwest_airspace	Offshore airspace within Navy Northwest Training Range Complex. Additional NWTRC inshore airspace not included.	U.S. Navy	Polygon	4/2011
Military	Navy_Northwest_OPAREA	General shape of Pacific Northwest Operating Area (OPAREA).	U.S. Navy	Polygon	2008-9/2010
NavAid	APPROACH_HARBOR_BCNLAT_point_wc	Lateral beacon (A lateral beacon is used to indicate the port or starboard hand side of the route to be followed. They are generally used for well defined channels and are used in conjunction with a conventional direction of buoyage. (UKHO NP 735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	APPROACH_HARBOR_BCNSPP_point_wc	Special purpose beacon (A special purpose beacon is primarily used to indicate an area or feature, the nature of which is apparent from reference to a chart, Sailing Directions or Notices to Mariners.	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		(UKHO NP 735, 5th Edition))			
NavAid	APPROACH_HARBOR_BOYLAT_point_wc	Buoy, lateral (A lateral buoy is used to indicate the port or starboard hand side of the route to be followed. They are generally used for well defined channels and are used in conjunction with a conventional direction of buoyage. (UKHO NP 735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	APPROACH_HARBOR_BOYSAW_point_wc	Buoy, safe water (A safe water buoy is used to indicate that there is navigable water around the mark. (UKHO NP735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	APPROACH_HARBOR_BOYSPP_point_wc	Buoy, special purpose (A special purpose buoy is primarily used to indicate an area or feature, the nature of which is apparent from reference to a chart, Sailing Directions or Notices to Mariners. (UKHO NP 735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	APPROACH_HARBOR_DAYMAR_point_wc	Daymark (The identifying characteristics of an aid to navigation which serve to facilitate its recognition against a daylight viewing background. On those structures that do not by themselves present an adequate viewing area to be seen at the required distance, the	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		aid is made more visible by affixing a daymark to the structure. A daymark so affixed has a distinctive color and shape depending on the purpose of the aid. (IHO Dictionary, S-32, 5th Edition, 1248))			
NavAid	APPROACH_HARBOR_FOGSIG_point_wc	Fog signal (A warning signal transmitted by a vessel, or aid to navigation, during periods of low visibility. Also, the device producing such a signal. (IHO Dictionary, S-32, 5th Edition, 1890))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	APPROACH_HARBOR_LIGHTS_point_wc	Light (A luminous or lighted aid to navigation. (adapted from IHO Dictionary, S-32, 5th Edition, 2766))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	COASTAL_BCNLAT_point_wc	Lateral beacon (A lateral beacon is used to indicate the port or starboard hand side of the route to be followed. They are generally used for well defined channels and are used in conjunction with a conventional direction of buoyage. (UKHO NP 735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	COASTAL_BCNSPP_point_wc	Special purpose beacon (A special purpose beacon is primarily used to indicate an area or feature, the nature of which is apparent from reference to a chart, Sailing	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		Directions or Notices to Mariners. (UKHO NP 735, 5th Edition))			
NavAid	COASTAL_BOYLAT_point_wc	Buoy, lateral (A lateral buoy is used to indicate the port or starboard hand side of the route to be followed. They are generally used for well defined channels and are used in conjunction with a conventional direction of buoyage. (UKHO NP 735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	COASTAL_BOYSPP_point_wc	Buoy, special purpose (A special purpose buoy is primarily used to indicate an area or feature, the nature of which is apparent from reference to a chart, Sailing Directions or Notices to Mariners. (UKHO NP 735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	COASTAL_DAYMAR_point_wc	Daymark (The identifying characteristics of an aid to navigation which serve to facilitate its recognition against a daylight viewing background. On those structures that do not by themselves present an adequate viewing area to be seen at the required distance, the aid is made more visible by affixing a daymark to the structure. A daymark so affixed has a distinctive	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		color and shape depending on the purpose of the aid. (IHO Dictionary, S-32, 5th Edition, 1248))			
NavAid	COASTAL_FOGSIG_point_wc	Fog signal (A warning signal transmitted by a vessel, or aid to navigation, during periods of low visibility. Also, the device producing such a signal. (IHO Dictionary, S-32, 5th Edition, 1890))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	COASTAL_LIGHTS_point_wc	Light (A luminous or lighted aid to navigation. (adapted from IHO Dictionary, S-32, 5th Edition, 2766))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	GENERAL_BOYLAT_point_wc	Buoy, lateral (A lateral buoy is used to indicate the port or starboard hand side of the route to be followed. They are generally used for well-defined channels and are used in conjunction with a conventional direction of buoyage. (UKHO NP 735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	GENERAL_BOYSAW_point_wc	Buoy, safe water (A safe water buoy is used to indicate that there is navigable water around the mark. (UKHO NP735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	GENERAL_BOYSPP_point_wc	Buoy, special purpose (A special purpose buoy is primarily used to indicate an area or feature, the	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		nature of which is apparent from reference to a chart, Sailing Directions or Notices to Mariners. (UKHO NP 735, 5th Edition))			
NavAid	GENERAL_DAYMAR_point_wc	Daymark (The identifying characteristics of an aid to navigation which serve to facilitate its recognition against a daylight viewing background. On those structures that do not by themselves present an adequate viewing area to be seen at the required distance, the aid is made more visible by affixing a daymark to the structure. A daymark so affixed has a distinctive color and shape depending on the purpose of the aid. (IHO Dictionary, S-32, 5th Edition, 1248))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	GENERAL_FOGSIG_point_wc	Fog signal (A warning signal transmitted by a vessel, or aid to navigation, during periods of low visibility. Also, the device producing such a signal. (IHO Dictionary, S-32, 5th Edition, 1890))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	GENERAL_LIGHTS_point_wc	Light (A luminous or lighted aid to navigation. (adapted from IHO Dictionary, S-32, 5th Edition, 2766))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
NavAid	OVERVIEW_BOY	Buoy, safe water (A safe water buoy	NOAA ENCDirect	Point	7/11/2001 -

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
	SAW_point_wc	is used to indicate that there is navigable water around the mark. (UKHO NP735, 5th Edition))			12/29/2010
NavAid	OVERVIEW_BOY SPP_point_wc	Buoy, special purpose (A special purpose buoy is primarily used to indicate an area or feature, the nature of which is apparent from reference to a chart, Sailing Directions or Notices to Mariners. (UKHO NP 735, 5th Edition))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
Pipeline	APPROACH_HAR BOR_PIPSOL_LIN E_line_wc	Pipeline submarine/on land (A submarine or land pipeline is a pipeline lying on or buried under the seabed or the land.)	NOAA ENCDirect	Line	7/11/2001 - 12/29/2010
Pipeline	COASTAL_PIPSOL _LINE_line_wc	Pipeline submarine/on land (A submarine or land pipeline is a pipeline lying on or buried under the seabed or the land.)	NOAA ENCDirect	Line	7/11/2001 - 12/29/2010
Protected (MMA, MPA, MR, WR)	MPA_Inventory_Sit es_March_2010	Complete MPA coverage	MPA.gov	Polygon	3/22/2010
Protected (MMA, MPA, MR, WR)	MR_AreasofWork_ 2010	Marine Reserved areas at Redfish Rocks and Otter Rock	Oregon Department of Land Conservation and Development (DLCD)	Polygon	11/1/2009 - 11/1/2011
Protected	OR_Islands_NWR_	Oregon Islands National Wildlife	PaCOOS	Polygon	5/27/2003

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
(MMA, MPA, MR, WR)	USFWS_2003	Refuges			
Protected (MMA, MPA, MR, WR)	PNWC_Protected_Areas_TNC_2005	Protected Areas in the Pacific Northwest (TNC)	The Nature Conservancy	Polygon	12/1/2005
Rec_ Boating	Ethnography_Noncomm_Boating_pg_wc	Noncommercial - Boating	Conway Social Science Research	Polygon	2011
Rec_ Boating	or_beach_boat_access_pts	Beach and Boat Access Points	Oregon Geospatial Enterprise Office (GEO)	Point	3/31/1989
Rec_ Boating	Panel_Lasttrip_Boating_PU	(Last trip) Sailing, power boating, personal water crafts, windsurfing, kite boarding, charter trips, tow-in surfing activities in OR (Ecotrust created this shapefile using internet survey results)	Oregon Department of Land Conservation and Development (DLCD)	Polygon	2009-2010
Rec_ Fishing	Ethnography_Noncomm_Crab_pg_wc	Noncommercial - Crab	Conway Social Science Research	Polygon	2011
Rec_ Fishing	Ethnography_Noncomm_Groundfish_pg_wc	Noncommercial - Groundfish	Conway Social Science Research	Polygon	2011
Rec_ Fishing	Ethnography_Noncomm_Halibut_pg_wc	Noncommercial - Halibut	Conway Social Science Research	Polygon	2011
Rec_ Fishing	Ethnography_Noncomm_Sablefish_pg_wc	Noncommercial - Sablefish	Conway Social Science Research	Polygon	2011
Rec_ Fishing	Ethnography_Nonco	Noncommercial - Salmon	Conway Social	Polygon	2011

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
	mm_Salmon_pg_wc		Science Research		
Rec_ Fishing	Ethnography_Noncomm_Tuna_pg_wc	Noncommercial - Tuna	Conway Social Science Research	Polygon	2011
Rec_Other	ORSeaGrant_SurfSpots	Oregon surfing locations	Oregon SeaGrant	Point	7/3/2011
Rec_Other	OptIn_Cumulative_Ocean_PU	Kayak, Surfing, Swimming, Scuba, Snorkeling, Skimboarding activities in OR (Ecotrust created this shapefile using internet survey results)	Oregon Department of Land Conservation and Development (DLCD)	Polygon	2009-2010
Rec_Other	OptIn_Cumulative_Shore_PU	Beach going, scenic enjoyment, storm watching, biking/hiking, off-road vehicles, photography activities in OR (Ecotrust created this shapefile using internet survey results)	Oregon Department of Land Conservation and Development (DLCD)	Polygon	2009-2010
Rec_Other	Panel_Lasttrip_Ocean_PU	(Last trip) Kayak, Surfing, Swimming, Scuba, Snorkeling, Skimboarding activities in OR (Ecotrust created this shapefile using internet survey results)	Oregon Department of Land Conservation and Development (DLCD)	Polygon	2009-2010
Rec_Other	Panel_Lasttrip_Shore_PU	(Last trip) Beach going, scenic enjoyment, storm watching, biking/hiking, off-road vehicles, photography activities in R (Ecotrust created this shapefile using internet survey results)	Oregon Department of Land Conservation and Development (DLCD)	Polygon	2009-2010

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
Rec_ Wildlife	OptIn_Cumulative_ Wildlife_PU	Bird watching, tide pooling, whale watching activities in OR (Ecotrust created this shapefile using internet survey results)	Oregon Department of Land Conservation and Development (DLCD)	Polygon	2009-2010
Rec_ Wildlife	Panel_Lasttrip_Wild life_PU	(Last trip) Bird watching, tide pooling, whale watching activities in OR (Ecotrust created this shapefile using internet survey results)	Oregon Department of Land Conservation and Development (DLCD)	Polygon	2009-2010
Research	NOAA_ScientistsFa voriteSampleSpots	Coordinates of 80 'favorite' sampling locations for NOAA scientists in the Pacific Northwest off of Oregon and California.	NOAA NWFSC	Point	1/6/2011
Research	NRI_Lines	Research lines off the coast have been consistently sampled over time. These lines are geographically specific, however, samples are made intermittently along these lines. Therefore, there are no continuous observations or samples taken along the lines, but they do provide a track for cruises to make samples.	Oregon Department of Land Conservation and Development (DLCD)	Line	7/9/2011
Research	NRI_Points_Final	Research points, which are locations along the shoreline and in the nearshore that continuously measure data at a certain location. There are two main types of points of research	Oregon Department of Land Conservation and Development (DLCD)	Point	7/9/2011

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		in Oregon and they are buoys/moorings and fixed shoreline platforms. This dataset shows all of the marine research points in the nearshore environment off the Oregon coast that were included in the Nearshore Research Inventory. All of the marine research points are associated with long-term monitoring projects, and are important assets for the research community since they are continually collected data in the nearshore environment.			
Research	NRI_Polygons_Fina l	Marine research areas. The marine research areas included in the inventory are polygons off the coast where research is conducted. In some cases, multiple types of research are conducted in the same area for the same project, and these were marine reserve areas. In other cases, the geographic area of research was made larger than the actual area for security purposes, or because the exact area of the research was not specifically identified, and these were	Oregon Department of Land Conservation and Development (DLCD)	Polygon	7/9/2011

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		categorized as generalized areas.			
Research	NRI_Stations_Final	Fixed shore stations, nearshore sampling stations, observation stations, and intertidal sampling stations. Unlike buoys/moorings and shoreline research platforms, research stations do not continually have something taking measurements at that location. The stations are places in the nearshore environment that are sampled repeatedly, but not continuously.	Oregon Department of Land Conservation and Development (DLCD)	Point	7/9/2011
Research	NRI_Transects	Research transects off the coast of Oregon - lines of research where data are continuously collected along the line.	Oregon Department of Land Conservation and Development (DLCD)	Line	7/9/2011
Research	NWFSC_2009_AcousticSurveyTransects	Biennial joint U.S.-Canadian acoustic survey for Pacific hake	NOAA NWFSC	Line	6/28/2009-8/22/2009
Research	NWFSC_BPAPlumeSurvey	NWFSC BPA Plume station locations	NOAA NWFSC	Point	1/1/2011
Research	NWFSC_PelagicFishSurveys_SAIP	NWFSC Pelagic Fish Survey Stock Assessment Improvement Program (SAIP) station locations	NOAA NWFSC	Point	1/1/2011
Research	WCGBTS_SurveyExtent_2010_poly	Sampling extent (as of 2003) for West Coast Groundfish Survey	NOAA NWFSC	Polygon	1/4/2011

Category (n=26)	*Shapefile Name*	*Description*	*Source*	*Data Type*	*Time Period*
		conducted annually by NWFSC, monitors trends in distribution/abundance of groundfish, especially those of management concern [See metadata for detailed methods]			
Native American	Ethnography_CommFish_Tribal_pg_wc	Commercial Fishing - Native American	Conway Social Science Research	Polygon	2011
Native American	indlandp020	Cultural	National Atlas	Polygon	Unknown
Native American	s_mmc_S_MMC_Coastal_reservations	Reservation polygon data	BOEM/ NOAA	Polygon	Metadata unavailable
Wrecks	COASTAL_WRECKS_POINT_point_wc	Wreck (The ruined remains of a stranded or sunken vessel which has been rendered useless. (IHO Dictionary, S-32, 5th Edition, 6027))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
Wrecks	GENERAL_WRECKS_POINT_point_wc	Wreck (The ruined remains of a stranded or sunken vessel which has been rendered useless. (IHO Dictionary, S-32, 5th Edition, 6027))	NOAA ENCDirect	Point	7/11/2001 - 12/29/2010
Wrecks	s_mmc_S_MMC_Wrecks_Obstuctions_AWOIS	Wrecks (presumably created using NOAA's Wrecks and Observations dataset (http://www.nauticalcharts.noaa.gov/hsd/awois.html))	BOEM/ NOAA	Point	Metadata unavailable

C. GIS Analysis: Python Scripts

```
###########################################################################
#   ArcGIS Interface Module
#
#   This module contains classes to interface with ArcGIS and includes selected tools
#   of the following toolboxes:
#   - Spatial Analyst Tools
#   - Conversion Tools
#   - Data Management Tools
#   - Analysis Tools
#   - ArcPy Classes
#
#   The classes provide insulation from ArcGIS changes, as well as friendlier error
#   messages to the main code executing specific tasks because each tool is enclosed in
#   a try except block and will return information on which tool failed, as well as the
#   error messages provided by ArcGIS and by Python.
#
#   Modified from code created by Jim Graham and posted to his class website:
#
http://ibis.colostate.edu/DH.php?WC=/WS/Jim/Geo599/08_3_AnArcGISIntrfaceClass
.html
#
#   Author: Colleen Sullivan
#   Date:   6/2012
###########################################################################
# The arcpy library is accessed and overwriting of files is enabled
import arcpy
arcpy.env.overwriteOutput=True

###########################################################################
# Class to interface with the SPATIAL ANALYST TOOLS toolbox
###########################################################################
class SAInterface:

  ###################################################################
  # Constructor for the spatial analyst interface class
  ###################################################################
  # Called when the class is created
  def __init__(self):
    # Ensure the spatial analyst extension is checked out to prevent errors
    arcpy.CheckOutExtension("Spatial")
```

```
#################################################################
# Create constant value (0) raster (Spatial Analyst Tools ->
# Raster Creation -> Create Constant Raster)
#################################################################
def CreateRas(self,Extent):
    try:
        TheRaster=arcpy.sa.CreateConstantRaster("0","INTEGER","0.0004",Extent)
        return(TheRaster)
    except Exception, err:
        raise RuntimeError("** Error: Create Constant Raster Failed ("+str(err)+")")

#################################################################
# Convert NoData values to 0
#################################################################
def ConvertNoData(self,Input):
    try:
        from arcpy.sa import *
        TheRaster = Con(IsNull(Input),0,Input)
        return(TheRaster)
    except Exception, err:
        raise RuntimeError("** Error: Convert NoData Failed ("+str(err)+")")

#################################################################
# Map algebra (code modified from:
# http://forums.arcgis.com/threads/27808-Calculate-sum-of-2334-raster-layers)
#################################################################
def MapAlgebra(self, TheList):
    try:
        from arcpy.sa import *
        i = 0
        for TheFile in TheList:
            if i == 0:
                TheRaster = arcpy.Raster(TheFile)
                i+=1
            else:
                TheRaster = TheRaster + arcpy.Raster(TheFile)
                i+=1
        return(TheRaster)
    except Exception, err:
        raise RuntimeError("** Error: Map Algebra Failed ("+str(err)+")")

#################################################################
# Weighted overlay addition
#################################################################
```

```
    def WeightedOverlayAddition(self, Folder):
        try:
            from arcpy.sa import *
            TheRaster = arcpy.Raster(Folder+"cable")
            TheRaster = TheRaster + arcpy.Raster(Folder+"disposaldump")
            TheRaster = TheRaster + arcpy.Raster(Folder+"dredge")
            TheRaster = TheRaster + arcpy.Raster(Folder+"fish_closure")
            TheRaster = TheRaster + arcpy.Raster(Folder+"fish_line")
            TheRaster = TheRaster + arcpy.Raster(Folder+"fish_other")
            TheRaster = TheRaster + arcpy.Raster(Folder+"fish_pots")
            TheRaster = TheRaster + arcpy.Raster(Folder+"fish_traps")
            TheRaster = TheRaster + arcpy.Raster(Folder+"fish_trawl")
            TheRaster = TheRaster + arcpy.Raster(Folder+"fish_troll")
            TheRaster = TheRaster + arcpy.Raster(Folder+"habitat")
            TheRaster = TheRaster + arcpy.Raster(Folder+"marinetrans_1")
            TheRaster = TheRaster + arcpy.Raster(Folder+"marinetrans_2")
            TheRaster = TheRaster + arcpy.Raster(Folder+"marinetrans_3")
            TheRaster = TheRaster + arcpy.Raster(Folder+"marinetrans_4")
            TheRaster = TheRaster + arcpy.Raster(Folder+"military")
            TheRaster = TheRaster + arcpy.Raster(Folder+"navaid")
            TheRaster = TheRaster + arcpy.Raster(Folder+"pipeline")
            TheRaster = TheRaster + arcpy.Raster(Folder+"protected")
            TheRaster = TheRaster + arcpy.Raster(Folder+"rec_boating")
            TheRaster = TheRaster + arcpy.Raster(Folder+"rec_fishing")
            TheRaster = TheRaster + arcpy.Raster(Folder+"rec_other")
            TheRaster = TheRaster + arcpy.Raster(Folder+"rec_wildlife")
            TheRaster = TheRaster + arcpy.Raster(Folder+"research")
            TheRaster = TheRaster + arcpy.Raster(Folder+"tribal")
            TheRaster = TheRaster + arcpy.Raster(Folder+"wrecks")
            return(TheRaster)
        except Exception, err:
            raise RuntimeError("** Error: Weighted Overlay Final Map Algebra Failed
("+str(err)+")")

    ##################################################################
    # Multiplication Map algebra (code modified from:
    # http://forums.arcgis.com/threads/27808-Calculate-sum-of-2334-raster-layers)
    ##################################################################
    def MultMapAlgebra(self, Input, weight):
        try:
            from arcpy.sa import *
            intweight = int(weight)
            TheRaster = arcpy.Raster(Input)
            TheRaster = TheRaster * intweight
```

```
            return(TheRaster)
        except Exception, err:
            raise RuntimeError("** Error: Multiplication Map Algebra Failed
("+str(err)+")")

    ##################################################################
    # Convert values greater than 0 in the output raster to 1
    ##################################################################
    def Reclass(self,Input):
        try:
            from arcpy.sa import *
            TheRaster = Reclassify(Input, "Value", RemapRange([[1,25,1]]))
            return(TheRaster)
        except Exception, err:
            raise RuntimeError("** Error: Reclass failed: ("+str(err)+")")

##########################################################################
# Class to interface with CONVERSION TOOLS toolbox
##########################################################################
class ConInterface:

    ##################################################################
    # Convert a polygon to a raster (Conversion Tools -> To Raster -> Polygon to
    # Raster)
    ##################################################################
    def PolygonToRaster(self,Input,Output,SnapRas):
        try:
            # First set environment settings to include
            # a snapraster so all rasters line up, then
            # run the conversion tool
            arcpy.env.snapRaster = SnapRas
            arcpy.env.extent = "-129.163686 41.997525 -123.363686 46.430858"
arcpy.PolygonToRaster_conversion(Input,"RasVal",Output,"MAXIMUM_AREA","R
asVal","1.66666666666667E-02")

        except Exception, err:
            raise RuntimeError("**Error: Polygon to Raster Failed("+str(err)+")")

    ##################################################################
    # Convert a polyline to a raster (Conversion Tools -> To Raster -> Polyline to
    # Raster)
    ##################################################################
    def PolylineToRaster(self,Input,Output,SnapRas):
        try:
```

```
            # First set environment settings to include a snapraster so all rasters line up,
            # then run the conversion tool
            arcpy.env.snapRaster = SnapRas
            arcpy.env.extent = "-129.163686 41.997525 -123.363686 46.430858"

arcpy.PolylineToRaster_conversion(Input,"RasVal",Output,"MAXIMUM_COMBINE
D_LENGTH","NONE","1.66666666666667E-02")
        except Exception, err:
            raise RuntimeError("**Error: Polyline to Raster Failed("+str(err)+")")

    ##################################################################
    # Convert a point to a raster (Conversion Tools -> To Raster -> Point to Raster)
    ##################################################################
    def PointToRaster(self,Input,Output,SnapRas):
        try:
            # First set environment settings to include a snapraster so all rasters line up,
            # then run the conversion tool
            arcpy.env.snapRaster = SnapRas
            arcpy.env.extent = "-129.163686 41.997525 -123.363686 46.430858"

arcpy.PointToRaster_conversion(Input,"RasVal",Output,"MOST_FREQUENT","NO
NE","1.66666666666667E-02")
        except Exception, err:
            raise RuntimeError("**Error: Point to Raster Failed("+str(err)+")")

########################################################################
# Class to interface with DATA MANAGEMENT TOOLS toolbox
########################################################################
class DMInterface:

    ##################################################################
    # Add a field to an attribute table (Data Management Tools -> Fields -> Add Field)
    ##################################################################
    def AddField(self,Input):
        try:

arcpy.AddField_management(Input,"RasVal","SHORT","#","#","#","#","NON_NUL
LABLE","NON_REQUIRED","#")
        except Exception, err:
            raise RuntimeError("**Error: Add Field Failed("+str(err)+")")

    ##################################################################
    # Calculate field in an attribute table (Data Management Tools -> Fields ->
    # Calculate Field)
```

```
    ##################################################################
    def CalculateField(self,Input,Field):
        try:
            arcpy.CalculateField_management(Input,Field,"1","VB","#")
        except Exception, err:
            raise RuntimeError("**Error: Calculate Field Failed("+str(err)+")")

    ##################################################################
    # Define projection as GCS North American 1983 (Data Management Tools ->
    # Projections and Transformations -> Define Projection)
    ##################################################################
    def DefineProj(self, Input):
        try:
arcpy.DefineProjection_management(Input,"GEOGCS['GCS_North_American_1983',
DATUM['D_North_American_1983',SPHEROID['GRS_1980',6378137.0,298.257222
101]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]]")
        except Exception, err:
            raise RuntimeError("**Error: Define Projection Failed("+str(err)+")")

    ##################################################################
    # Copy Raster (Data Management Tools -> Raster -> Raster Dataset -> Copy
    # Raster)
    ##################################################################
    def CopyRaster(self, Input, OutputFolder, ExtentRas):
        try:
            from arcpy.sa import *
            ExtentFile = Raster(ExtentRas)
            ExtentCoords = ExtentFile.extent
            arcpy.env.extent = ExtentCoords
            arcpy.env.snapRaster = ExtentRas

arcpy.CopyRaster_management(Input,OutputFolder+"CR"+Input,"#","#","#","NONE
","NONE","#")
        except Exception, err:
            raise RuntimeError("**Error: Copy Raster Failed("+str(err)+")")

    ##################################################################
    # Copy Shapefile (Data Management Tools -> Features -> Copy Features)
    ##################################################################
    def CopyShapefile(self, Input, Output):
        try:
            arcpy.CopyFeatures_management(Input, Output)
        except Exception, err:
            raise RuntimeError("**Error: Copy Shapefile Failed("+str(err)+")")
```

```
#######################################################################
# Class to interface with ANALYSIS TOOLS toolbox
#######################################################################
class ATInterface:

    ##################################################################
    # Clip a shapefile using the Oregon Waters polygon
    ##################################################################
    def Clip(self, Input, Output):
        try:
arcpy.Clip_analysis(Input,"Z:/MMS/Sullivan/Thesis/Data/Parameters/OR_Waters_For
Clipping.shp",Output,"#")
        except Exception, err:
            raise RuntimeError("**Error: Clip Shapefile Failed("+str(err)+")")

    ##################################################################
    # Buffer a shapefile
    ##################################################################
    def Buffer(self, Input, Output, BufferDist):
        try:
arcpy.Buffer_analysis(Input,Output,BufferDist,"FULL","ROUND","ALL","#")
        except Exception, err:
            raise RuntimeError("**Error: Buffer Shapefile Failed("+str(err)+")")

#######################################################################
# Class to interface with ARCPY CLASSES
#######################################################################
class ArcPyClasses:

    ##################################################################
    # Get the spatial extent of a shapefile
    ##################################################################
    def GetExtentShp(self, Input):
        try:
            desc = arcpy.Describe(Input)
            return (desc.extent.XMin, desc.extent.YMin, desc.extent.XMax,
desc.extent.YMax)
        except Exception, err:
            raise RuntimeError("**Error: Get Shapefile Extent Failed("+str(err)+")")

    ##################################################################
    # Get the spatial extent of a raster
    ##################################################################
    def GetExtent(self, Input):
```

```
        try:
            # Specify the raster to be evaluated
            RasFile = arcpy.Raster(Input)

            # Read the extent property of the raster and return it as the function output
            RasExtent = RasFile.extent
            return (RasExtent.YMax, RasExtent.YMin, RasExtent.XMin,
RasExtent.XMax)
        except Exception, err:
            raise RuntimeError("**Error: Get Raster Extent Failed("+str(err)+")")

    ################################################################
    # Get the arguments from the user inputs in the toolbox
    ################################################################
    def GetArguments(self, Boolean):
        try:
            if (True):
                TheFolder = arcpy.GetParameterAsText(0)
                TheOutputFolder = arcpy.GetParameterAsText(1)
                return (TheFolder, TheOutputFolder)
        except Exception, err:
            raise RuntimeError("**Error: Get Arguments Failed("+str(err)+")")

    ################################################################
    # Get a list of rasters in a folder using a wildcard
    ################################################################
    def GetRasterList(self, Folder, WildCard):
        try:
            arcpy.env.workspace = Folder
            rasterlist = arcpy.ListRasters(WildCard, "")
            return rasterlist
        except Exception, err:
            raise RuntimeError("**Error: Get Raster list Failed("+str(err)+")")

    ################################################################
    # Get the shape of a feature
    ################################################################
    def GetShape(self, Input):
        try:
            desc = arcpy.Describe(Input)
            shape = desc.shapeType
            return shape
        except Exception, err:
            raise RuntimeError("**Error: Get Shape Failed ("+str(err)+")")
```

```
###########################################################################
#   Prepare category rasters
#
#   Batch processing of shapefiles organized in folders, to obtain a single raster for
#   each folder, which shows total presence of shapefiles in each cell (value of 1 for
#   presence, 0 for absence)
#
#   By: Colleen Sullivan
#   Date: 6/2012
###########################################################################

# All of the code occurs in a try/except block to help catch errors
try:
    print("Start")

    # Main folder in a variable to shorten file paths to type later
    TopLevelFolder = "Z:/MMS/Sullivan/Thesis/Data/"

    # A log is kept of processing progress, any errors returned will be saved to this log,
    # first the start time of processing is recorded:
    TheTextFile=open(TopLevelFolder+"BatchShpToRasLog.txt","w")
    import datetime
    now = datetime.datetime.now()
    timestamp = format(now.month) + "/" + format(now.day) + "/" + format(now.year)
+ " " + format(now.hour) + ":" + format(now.minute) + ":" + format(now.second)
    TheTextFile.write("Beginning processing: " + timestamp + "\n\n")

    # A counter is used to guarantee unique intermediate file names, here the value is
    # set to 0
    counter = 0

    # Import the module containing the ArcGIS Interface classes
    import ArcGISInterfaceModule

    # Import the operating system module to allow file/folder creation and loops later
    import os

    # Remove results of the last run before beginning, if they exist, and either way
    # create folders to store results of this run
    import shutil

    if os.path.exists(TopLevelFolder + "BatchShpToRasTemp/"):
        shutil.rmtree(TopLevelFolder + "BatchShpToRasTemp/")
```

```
    if os.path.exists(TopLevelFolder + "Clipped/"):
        shutil.rmtree(TopLevelFolder + "Clipped/")
    os.makedirs(TopLevelFolder + "Clipped/")

    if os.path.exists(TopLevelFolder+"Rasters/"):
        shutil.rmtree(TopLevelFolder+"Rasters/")
    os.makedirs(TopLevelFolder+"Rasters/")

    # To batch process, the code must recognize all of the subfolders of the top level
    # folder (each is its own data category). So, a list of folders is generated and a loop
    # is used to run the code for each shapefile found in each folder. This code was
    # adapted from that on Jim Graham's course website:
    #
http://ibis.colostate.edu/DH.php?WC=/WS/Jim/Geo599/08_5_BatchProcessinWithAr
cGIS.html
    TheList=os.listdir(TopLevelFolder+"Input/")
    for TheFolder in TheList:

        # Create a temporary folder to store intermediate files, the folder will be deleted
        # as the final step of the loop
        TempScratchFolder = TopLevelFolder + "BatchShpToRasTemp/"
        os.makedirs(TempScratchFolder)

        # Create a subfolder in 'Clipped' for this category to store the clipped files
        ClippedPath = TopLevelFolder+"Clipped/"+TheFolder+"/"
        os.makedirs(ClippedPath)

        # Set the processing path
        ProcessingPath = TopLevelFolder+"Input/"+TheFolder+"/"

        TheTextFile.write("Now processing shapefiles in path:" + ProcessingPath +
"\n")
        print("Now processing shapefiles in path:" + ProcessingPath + "\n")

        TheProcessingList=os.listdir(ProcessingPath)
        for TheFile in TheProcessingList:

            # The file name is split from its extension for use in the commands that
            # follow and to determine if it is a .shp, each shapefile name appears multiple
            # times in the list because of its component files, so this ensures each
            # shapefile is only actually processed once.
            TheFileName, TheFileExtension = os.path.splitext(TheFile)
            if (TheFileExtension==".shp"):
                TheTextFile.write("     - Shapefile: " + TheFileName + " -\n")
```

```
# ~~ The Analysis Tools class is accessed ~~
TheInterface=ArcGISInterfaceModule.ATInterface()

# The shapefile is clipped to Oregon State Waters and saved to a separate
# folder to preserve the input data in case the shapefies need to be re-
# processed later
TheInterface.Clip(ProcessingPath+TheFile, ClippedPath+TheFile)
TheTextFile.write("Done with 1 - Clip to new folder\n")

# ~~ The Data Management Tools class is accessed ~~
TheInterface=ArcGISInterfaceModule.DMInterface()

# A field called 'RasVal' is added to the shapefile so it can later be used in
# MapAlgebra
TheInterface.AddField(ClippedPath+TheFile)
TheTextFile.write("Done with 2 - Add Field\n")

# The 'RasVal' field is given a value of 1 so that the converted raster has a
# value of 1 wherever it is present
TheInterface.CalculateField(ClippedPath+TheFile,"RasVal")
TheTextFile.write("Done with 3 - Calculate Field\n")

# ~~ The ArcPy class is accessed ~~
TheInterface = ArcGISInterfaceModule.ArcPyClasses()

# The shapefile type (point, polyline, polygon) is determined to allow
# proper conversion to raster
shape = TheInterface.GetShape(ClippedPath+TheFile)

# ~~ The Conversion Tools class is accessed ~~
TheInterface=ArcGISInterfaceModule.ConInterface()

# The shapefile (shape now known) is converted to a raster using a name
# derived from its original name and a counter, shortened because the
# names must ultimately be no more than 13 characters, a snap raster and
# environment settings are used to ensure that the many outputs line up
# with one another for proper map algebra.
OutName = "r" + format(counter) + TheFile[0:6]

if shape == "Polygon":
    TheInterface.PolygonToRaster(ClippedPath+TheFile,
TempScratchFolder+OutName, TopLevelFolder+"Parameters/fullraster")
elif shape == "Polyline":
```

```
                TheInterface.PolylineToRaster(ClippedPath+TheFile,
TempScratchFolder+OutName, TopLevelFolder+"Parameters/fullraster")
            else:
                TheInterface.PointToRaster(ClippedPath+TheFile,
TempScratchFolder+OutName, TopLevelFolder+"Parameters/fullraster")
            TheTextFile.write("Done with 4 - Convert feature to raster\n")

            # Counter is increased so the next shapefile processed has a unique name
            counter = counter + 1

    TheTextFile.write("(All shapefiles have completed individual processing.
Beginning Map Algebra steps.)\n")

    # In order to calculate cell statistics on our new rasters, they cannot have
    # NoData values

    # ~~ The ArcPy class is accessed ~~
    TheInterface = ArcGISInterfaceModule.ArcPyClasses()

    # The list of rasters in the processed folder is obtained
    TheList = TheInterface.GetRasterList(TempScratchFolder,"*")

    # ~~ The Spatial Analyst Tools class is accessed ~~
    TheInterface = ArcGISInterfaceModule.SAInterface()

    # The list of copied rasters is looped through to convert NoData to 0
    for TheFile in TheList:
        temp = TheInterface.ConvertNoData(TheFile)
        temp.save(TempScratchFolder+"z"+TheFile)
    TheTextFile.write("Done with 5 - All rasters processed to change NoData to 0
values\n")

    # Our raster layers of a single category are now ready for cell statistics to form a
    # single category raster, the next step adds them together

    # ~~ The ArcPy class is accessed ~~
    TheInterface=ArcGISInterfaceModule.ArcPyClasses()

    # The list of rasters without NoData values in the processed folder is obtained
    # (using a wildcard to limit the search)
    TheList = TheInterface.GetRasterList(TempScratchFolder,"z*")

    # ~~ The Spatial Analyst Tools class is accessed ~~
    TheInterface = ArcGISInterfaceModule.SAInterface()
```

```
        # An expression is generated and evaluated to add the rasters together
        temp = TheInterface.MapAlgebra(TheList)
        temp.save(TempScratchFolder+TheFolder)
        TheTextFile.write("Done with 6 - Map algebra complete, final raster
generated\n")

        # Currently the output shows the number of shapefiles that occur in each cell, it
        # needs to show only use or non-use (because the values of use, 1, will later be
        # multiplied by the weight for the category, and then added to the other
        # categories) so the 'Value' field is recalculated to change numbers greater than
        # 0 to 1
        temp = TheInterface.Reclass(TempScratchFolder+TheFolder)
        temp.save(TopLevelFolder+"Rasters/"+TheFolder)
        TheTextFile.write("Done with 7 - Reclassify Raster\n")

        # ~~ The Data Management Tools class is accessed ~~
        TheInterface = ArcGISInterfaceModule.DMInterface()

        # The projection of the created raster is defined so that it matches the shapefiles
        TheInterface.DefineProj(TopLevelFolder+"Rasters/"+TheFolder)
        TheTextFile.write("Done with 8 - Define projection of raster\n")

        # The folder of intermediate files is deleted
        shutil.rmtree(TempScratchFolder)
        TheTextFile.write("Done with 9 - Intermediate files for this category
deleted\n\n")

# In case of error, the code will break to here and return the error message to the log
except Exception, err:
    print("Error. Stopped because: " + str(err))
    TheTextFile.write(str(err)+"\n")

# A final message is printed with the end processing time and the log is closed.
now = datetime.datetime.now()
timestamp = format(now.month) + "/" + format(now.day) + "/" + format(now.year) +
" " + format(now.hour) + ":" + format(now.minute) + ":" + format(now.second)
TheTextFile.write("Completed Script: " + timestamp)
TheTextFile.close
print("End")
```

```
##########################################################################
#   Weighted Overlay
#
#   By: Colleen Sullivan
#   Date: 6/2012
##########################################################################
# All of the code occurs in a try/except block to help catch errors
try:
    print("Start")

    # Import the module containing the ArcGIS Interface classes so we can use its tools
    # and get parameters in the next step
    import ArcGISInterfaceModule

    # Obtain the user inputs and set as parameters:
    # Most likely "Z:/MMS/Sullivan/Thesis/Data/Rasters/"
    TheOriginalFolder = arcpy.GetParameterAsText(0) + "/"
    # Name for the output raster and folder to save the weighted versions of the rasters
    TheOutputName = arcpy.GetParameterAsText(1)
    # Path in which to create the aforementioned folder
    TheOutputFolderPath = arcpy.GetParameterAsText(2)

    if len(TheOutputName) > 13:
        TheOutputName = TheOutputName[0:13]

    # Import the operating system module to allow file/folder creation and loops later
    import os

    # Remove results of the last run before beginning if they exist, and either way
    # create folders to store results of this run
    import shutil

    TheOutputFolder = TheOutputFolderPath + "/" + TheOutputName + "/"
    if os.path.exists(TheOutputFolder):
        shutil.rmtree(TheOutputFolder)

    # Store the user inputs for weights as parameters to use in map algebra
    # Archeological
    Weight_wrecks = arcpy.GetParameterAsText(3)
    # Area of special concern
    Weight_habitat = arcpy.GetParameterAsText(4)
    Weight_protected = arcpy.GetParameterAsText(5)
    Weight_tribal = arcpy.GetParameterAsText(6)
    # Research - sampling locations
```

```
Weight_research = arcpy.GetParameterAsText(7)
# Military
Weight_military = arcpy.GetParameterAsText(8)
# Sand/Gravel Source and Disposal
Weight_disposaldump = arcpy.GetParameterAsText(9)
Weight_dredge = arcpy.GetParameterAsText(10)
# Oil and gas deposits and infrastructure/cables
Weight_cable = arcpy.GetParameterAsText(11)
Weight_pipeline = arcpy.GetParameterAsText(12)
# Recreation activity
Weight_rec_boating = arcpy.GetParameterAsText(13)
Weight_rec_fishing = arcpy.GetParameterAsText(14)
Weight_rec_wildlife = arcpy.GetParameterAsText(15)
Weight_rec_other = arcpy.GetParameterAsText(16)
# Commercial fishing
Weight_fish_closure = arcpy.GetParameterAsText(17)
Weight_fish_line = arcpy.GetParameterAsText(18)
Weight_fish_pots = arcpy.GetParameterAsText(19)
Weight_fish_traps = arcpy.GetParameterAsText(20)
Weight_fish_trawl = arcpy.GetParameterAsText(21)
Weight_fish_troll = arcpy.GetParameterAsText(22)
Weight_fish_other = arcpy.GetParameterAsText(23)
# Marine transportation
Weight_marinetrans_1 = arcpy.GetParameterAsText(24)
Weight_marinetrans_2 = arcpy.GetParameterAsText(25)
Weight_marinetrans_3 = arcpy.GetParameterAsText(26)
Weight_marinetrans_4 = arcpy.GetParameterAsText(27)
Weight_navaid = arcpy.GetParameterAsText(28)

time.sleep(0.001)
os.makedirs(TheOutputFolder)

# A log is kept of processing progress, any errors returned will be saved to this
# log, first the start time of processing is recorded:
TheTextFile=open(TheOutputFolder+"MapAlgebraLog.txt","w")
import datetime
now = datetime.datetime.now()
timestamp = format(now.month) + "/" + format(now.day) + "/" + format(now.year)
+ " " + format(now.hour) + ":" + format(now.minute) + ":" + format(now.second)
TheTextFile.write("Beginning processing: " + timestamp + "\n")

# ---------- PART 1: Weight each raster and save the weighted raster ----------
# ~~ The ArcPy class is accessed ~~
TheInterface = ArcGISInterfaceModule.ArcPyClasses()
```

```
# The list of category rasters is obtained
TheList = TheInterface.GetRasterList(TheOriginalFolder, "*")

# ~~ The Spatial Analyst Tools class is accessed ~~
TheInterface = ArcGISInterfaceModule.SAInterface()

# An if statement is used to give each raster its appropriate weight
for TheFile in TheList:
    if TheFile == "wrecks":
        TheWeight = Weight_wrecks
    elif TheFile == "habitat":
        TheWeight = Weight_habitat
    elif TheFile == "protected":
        TheWeight = Weight_protected
    elif TheFile == "tribal":
        TheWeight = Weight_tribal
    elif TheFile == "research":
        TheWeight = Weight_research
    elif TheFile == "military":
        TheWeight = Weight_military
    elif TheFile == "disposaldump":
        TheWeight = Weight_disposaldump
    elif TheFile == "dredge":
        TheWeight = Weight_dredge
    elif TheFile == "cable":
        TheWeight = Weight_cable
    elif TheFile == "pipeline":
        TheWeight = Weight_pipeline
    elif TheFile == "rec_boating":
        TheWeight = Weight_rec_boating
    elif TheFile == "rec_fishing":
        TheWeight = Weight_rec_fishing
    elif TheFile == "rec_wildlife":
        TheWeight = Weight_rec_wildlife
    elif TheFile == "rec_other":
        TheWeight = Weight_rec_other
    elif TheFile == "fish_closure":
        TheWeight = Weight_fish_closure
    elif TheFile == "fish_line":
        TheWeight = Weight_fish_line
    elif TheFile == "fish_other":
        TheWeight = Weight_fish_other
    elif TheFile == "fish_pots":
```

```
            TheWeight = Weight_fish_pots
        elif TheFile == "fish_traps":
            TheWeight = Weight_fish_traps
        elif TheFile == "fish_trawl":
            TheWeight = Weight_fish_trawl
        elif TheFile == "fish_troll":
            TheWeight = Weight_fish_troll
        elif TheFile == "marinetrans_1":
            TheWeight = Weight_marinetrans_1
        elif TheFile == "marinetrans_2":
            TheWeight = Weight_marinetrans_2
        elif TheFile == "marinetrans_3":
            TheWeight = Weight_marinetrans_3
        elif TheFile == "marinetrans_4":
            TheWeight = Weight_marinetrans_4
        elif TheFile == "navaid":
            TheWeight = Weight_navaid

        # The file and weight are passed to derive an output weighted raster
        temp = TheInterface.MultMapAlgebra(TheOriginalFolder+TheFile, TheWeight)
        temp.save(TheOutputFolder+TheFile)
        TheTextFile.write("Weighted version generated of:"+TheFile+"\n")

    # ---------- PART 2: Add up the weighted rasters: ----------
    # ~~ The Spatial Analyst Tools class is accessed ~~
    TheInterface = ArcGISInterfaceModule.SAInterface()

    # An expression is generated and evaluated to add the rasters together
    temp = TheInterface.WeightedOverlayAddition(TheOutputFolder)
    temp.save(TheOutputFolder+TheOutputName)
    TheTextFile.write("Map algebra complete, final raster generated\n")

# In case of error, the code will break to here and return the error message to the log
except Exception, err:
    print("Error. Stopped.")
    TheTextFile.write(str(err)+"\n")

# A final message is printed with the end processing time and the log is closed.
now = datetime.datetime.now()
timestamp = format(now.month) + "/" + format(now.day) + "/" + format(now.year) +
" " + format(now.hour) + ":" + format(now.minute) + ":" + format(now.second)
TheTextFile.write("Completed Script: " + timestamp)
TheTextFile.close
print("End")
```

```
##########################################################################
#   Buffer input data for uncertainty calculation (5nm for logbook data, .5 nautical mile
#   buffer for others, skip 2 overly complex shapefiles that when buffered don't impact
#   the output)
#
#   By: Colleen Sullivan
#   Date: 6/2012
##########################################################################

# All of the code occurs in a try/except block to help catch errors
try:
    print("Start")

    # Shapefiles to buffer
    ClippedFolder = "Z:/MMS/Sullivan/Thesis/Data/Clipped/"
    BufferedFolder = "Z:/MMS/Sullivan/Thesis/Data/BufferedRasters/Input_Buff/"

    # Import the module containing the ArcGIS Interface classes
    import ArcGISInterfaceModule

    # Import the operating system module to allow file/folder creation and loops later
    import os

    # Remove results of the last run before beginning, if they exist, and either way
    # create folders to store results of this run
    import shutil

    if os.path.exists(BufferedFolder):
        shutil.rmtree(BufferedFolder)
    os.makedirs(BufferedFolder)

    # A log is kept of processing progress, any errors returned will be saved to this
    # log, first the start time of processing is recorded:
TheTextFile=open("Z:/MMS/Sullivan/Thesis/Data/"+"BufferingInputDataLog.txt","w
")
    import datetime
    now = datetime.datetime.now()
    timestamp = format(now.month) + "/" + format(now.day) + "/" + format(now.year)
+ " " + format(now.hour) + ":" + format(now.minute) + ":" + format(now.second)
    TheTextFile.write("Beginning processing: " + timestamp + "\n")

    # To batch process, the code must recognize all of the subfolders of the top level
    # folder (each is its own data category). So, a list of folders is generated and a
    # loop is used to run the code for each shapefile found in each folder. This code
```

```
    # was adapted from that on Jim Graham's course website:
    #
http://ibis.colostate.edu/DH.php?WC=/WS/Jim/Geo599/08_5_BatchProcessinWithAr
cGIS.html
    TheList=os.listdir(ClippedFolder)
    for TheFolder in TheList:

        # Create a subfolder in the folder 'Input_Buff' for this category to store the
        # buffered files
        BufferedSubfolder = BufferedFolder+TheFolder+"/"
        os.makedirs(BufferedSubfolder)

        # Set the processing path
        ProcessingPath = ClippedFolder+TheFolder+"/"

        TheTextFile.write("\nNow processing shapefiles in path:" + ProcessingPath +
"\n")
        print("Now processing shapefiles in path:" + ProcessingPath + "\n")

        # ~~ The Analysis Tools class is accessed ~~
        TheInterface=ArcGISInterfaceModule.ATInterface()

        TheProcessingList=os.listdir(ProcessingPath)
        for TheFile in TheProcessingList:

            # The file name is split from its extension for use in the commands that
            # follow and to determine if it is a .shp, each shapefile name appears
            # multiple times in the list because of its component files, so this
            # ensures each shapefile is only actually processed once.
            TheFileName, TheFileExtension = os.path.splitext(TheFile)
            if (TheFileExtension==".shp"):
                TheTextFile.write("  - Shapefile: " + TheFileName + " -\n")

                filestring = str(TheFileName)
                if filestring.startswith("CDFG") or filestring.startswith("cdfg") or
filestring.startswith("ODFW") or filestring.startswith("PacFIN") == True:
                    # Logbook data are buffered by 5 nm
                    TheInterface.Buffer(ProcessingPath+TheFile,
BufferedSubfolder+TheFile, "5 NauticalMiles")
                    TheTextFile.write("    Buffered by 5 nm\n")

                elif TheFileName == "seagrass_pub" or TheFileName == "altb04":
                    # These two habitat shapefiles are too complex to buffer by
                    # .5 nm, and because they don't impact the output buffered
```

```
                    # raster for the category, they are simply copied to the
                    # buffered input folder without buffering first

                    # ~~ The Data Management Tools class is accessed ~~
                    TheInterface = ArcGISInterfaceModule.DMInterface()

                    # Copy Shapefile is executed
                    TheInterface.CopyShapefile(ProcessingPath+TheFile,
BufferedSubfolder+TheFile)
                    TheTextFile.write("    Copied without buffering\n")

                    # ~~ The Analysis Tools class is accessed so that the other two
                    # options in this loop still work ~~
                    TheInterface=ArcGISInterfaceModule.ATInterface()

                else:
                    # Other data are buffered by .5 nm
                    TheInterface.Buffer(ProcessingPath+TheFile,
BufferedSubfolder+TheFile, "0.5 NauticalMiles")
                    TheTextFile.write("    Buffered by .5 nm\n")

# In case of error, the code will break to here and return the error message to the log
except Exception, err:
    print("*** Error. Stopped." + str(err))
    TheTextFile.write(str(err)+"\n")

# A final message is printed with the end processing time and the log is closed.
now = datetime.datetime.now()
timestamp = format(now.month) + "/" + format(now.day) + "/" + format(now.year) +
" " + format(now.hour) + ":" + format(now.minute) + ":" + format(now.second)
TheTextFile.write("\nCompleted Script: " + timestamp)
TheTextFile.close
print("End")
```

```
##########################################################################
#   Prepare buffered category rasters for the uncertainty analysis, using the
#   BUFFERED input files
#
#   Batch processing of shapefiles organized in folders, to obtain a single raster for
#   each folder, which shows total presence of shapefiles in each cell (value of 1 for
#   presence, 0 for absence)
#
#   By: Colleen Sullivan
#   Date: 6/2012
##########################################################################

# All of the code occurs in a try/except block to help catch errors
try:
    print("Start")

    # Main folder in a variable to shorten file paths to type later...
    TopLevelFolder = "Z:/MMS/Sullivan/Thesis/Data/BufferedRasters/"

    # A log is kept of processing progress, any errors returned will be saved to this
    # log, first the start time of processing is recorded:
TheTextFile=open("Z:/MMS/Sullivan/Thesis/Data/BatchShpToRasLog_Buffered.txt",
"w")
    import datetime
    now = datetime.datetime.now()
    timestamp = format(now.month) + "/" + format(now.day) + "/" + format(now.year)
+ " " + format(now.hour) + ":" + format(now.minute) + ":" + format(now.second)
    TheTextFile.write("Beginning processing: " + timestamp + "\n")

    # A counter is used to guarantee unique file names, here the value is set to 0
    counter = 0

    # Import the module containing the ArcGIS Interface classes
    import ArcGISInterfaceModule

    # Import the operating system module to allow file/folder creation and loops later
    import os

    # Remove results of the last run before beginning, if they exist, and either way
    # create folders to store results of this run
    import shutil

    if os.path.exists(TopLevelFolder + "BatchShpToRasTemp/"):
        shutil.rmtree(TopLevelFolder + "BatchShpToRasTemp/")
```

```
    if os.path.exists(TopLevelFolder + "Clipped/"):
        shutil.rmtree(TopLevelFolder + "Clipped/")
    os.makedirs(TopLevelFolder + "Clipped/")

    if os.path.exists(TopLevelFolder+"Rasters/"):
        shutil.rmtree(TopLevelFolder+"Rasters/")
    os.makedirs(TopLevelFolder+"Rasters/")

    # To batch process, the code must recognize all of the subfolders of the top level
    # folder (each is its own data category). So, a list of folders is generated and a
    # loop is used to run the code for each shapefile found in each folder. This code
    # was adapted from that on Jim Graham's course website:
    #
http://ibis.colostate.edu/DH.php?WC=/WS/Jim/Geo599/08_5_BatchProcessinWithAr
cGIS.html
    TheList=os.listdir(TopLevelFolder+"Input_Buff/")
    for TheFolder in TheList:

        # Create a temporary folder to store intermediate files, the folder will be
        # deleted as the final step of the loop
        TempScratchFolder = TopLevelFolder + "BatchShpToRasTemp/"
        os.makedirs(TempScratchFolder)

        # Create a subfolder in 'Clipped' for this category to store the clipped files
        ClippedPath = TopLevelFolder+"Clipped/"+TheFolder+"/"
        os.makedirs(ClippedPath)

        # Set the processing path
        ProcessingPath = TopLevelFolder+"Input_Buff/"+TheFolder+"/"

        TheTextFile.write("\nNow processing shapefiles in path:" + ProcessingPath +
"\n")
        print("Now processing shapefiles in path:" + ProcessingPath + "\n")

        TheProcessingList=os.listdir(ProcessingPath)
        for TheFile in TheProcessingList:

            # The file name is split from its extension for use in the commands that
            # follow and to determine if it is a .shp, each shapefile name appears
            # multiple times in the list because of its component files, so this
            # ensures each shapefile is only actually processed once.
            TheFileName, TheFileExtension = os.path.splitext(TheFile)
            if (TheFileExtension==".shp"):
                TheTextFile.write("  - Shapefile: " + TheFileName + " -\n")
```

```
# ~~ The Analysis Tools class is accessed ~~
TheInterface=ArcGISInterfaceModule.ATInterface()

# The shapefile is clipped to Oregon State Waters and saved to a
# separate folder to preserve the input data in case the shapefiles need to
# be re-processed later
TheInterface.Clip(ProcessingPath+TheFile, ClippedPath+TheFile)
TheTextFile.write("    Done with 1 - Clip to new folder\n")

# ~~ The Data Management Tools class is accessed ~~
TheInterface=ArcGISInterfaceModule.DMInterface()

# A field called 'RasVal' is added to the shapefile so it can later
# be used in MapAlgebra
TheInterface.AddField(ClippedPath+TheFile)
TheTextFile.write("    Done with 2 - Add Field\n")

# The 'RasVal' field is given a value of 1 so that the converted
# raster has a value of 1 wherever it is present
TheInterface.CalculateField(ClippedPath+TheFile,"RasVal")
TheTextFile.write("    Done with 3 - Calculate Field\n")

# ~~ The ArcPy class is accessed ~~
TheInterface = ArcGISInterfaceModule.ArcPyClasses()

# The shapefile type (point, polyline, polygon) is determined to
# allow proper conversion to raster
shape = TheInterface.GetShape(ClippedPath+TheFile)

# ~~ The Conversion Tools class is accessed ~~
TheInterface=ArcGISInterfaceModule.ConInterface()

# The shapefile (shape now known) is converted to a raster using a
# name derived from its original name and a counter, shortened because
# the names must ultimately be no more than 13 characters, a snap
# raster and environment settings are used to ensure that the many
# outputs line up with one another for proper map algebra.
OutName = "r" + format(counter) + TheFile[0:6]

if shape == "Polygon":
    TheInterface.PolygonToRaster(ClippedPath+TheFile,
TempScratchFolder+OutName,
"Z:/MMS/Sullivan/Thesis/Data/Parameters/fullraster")
```

```
                elif shape == "Polyline":
                    TheInterface.PolylineToRaster(ClippedPath+TheFile,
TempScratchFolder+OutName,
"Z:/MMS/Sullivan/Thesis/Data/Parameters/fullraster")
                else:
                    TheInterface.PointToRaster(ClippedPath+TheFile,
TempScratchFolder+OutName,
"Z:/MMS/Sullivan/Thesis/Data/Parameters/fullraster")
                TheTextFile.write("    Done with 4 - Convert feature to raster\n")

                # Counter is increased so the next shapefile processed has a unique name
                counter = counter + 1

        TheTextFile.write("\n  - All shapefiles of this category have completed
individual processing. Beginning Map Algebra steps. -\n")

        # In order to calculate cell statistics on our new rasters, they cannot have
        # NoData values

        # ~~ The ArcPy class is accessed ~~
        TheInterface = ArcGISInterfaceModule.ArcPyClasses()

        # The list of rasters in the processed folder is obtained
        TheList = TheInterface.GetRasterList(TempScratchFolder,"*")

        # ~~ The Spatial Analyst Tools class is accessed ~~
        TheInterface = ArcGISInterfaceModule.SAInterface()

        # The list of copied rasters is looped through to convert NoData to 0
        for TheFile in TheList:
            temp = TheInterface.ConvertNoData(TheFile)
            temp.save(TempScratchFolder+"z"+TheFile)
        TheTextFile.write("    Done with 5 - All rasters processed to change NoData to
0 values\n")

        # Our raster layers of a single category are now ready for cell statistics to
        # form a single category raster, the next step adds them together

        # ~~ The ArcPy class is accessed ~~
        TheInterface=ArcGISInterfaceModule.ArcPyClasses()

        # The list of rasters without NoData values in the processed folder is obtained
        # (using a wildcard to limit the search)
        TheList = TheInterface.GetRasterList(TempScratchFolder,"z*")
```

```
        # ~~ The Spatial Analyst Tools class is accessed ~~
        TheInterface = ArcGISInterfaceModule.SAInterface()

        # An expression is generated and evaluated to add the rasters together
        temp = TheInterface.MapAlgebra(TheList)
        temp.save(TempScratchFolder+TheFolder)
        TheTextFile.write("    Done with 6 - Map algebra complete, final raster
generated\n")

        # Currently the output shows the number of shapefiles that occur in each cell, it
        # needs to show only use or non-use (because the values of use, 1, will later be
        # multiplied by the weight for the category, and then added to the other
        # categories) so the 'Value' field is recalculated to change numbers >0 to 1
        temp = TheInterface.Reclass(TempScratchFolder+TheFolder)
        temp.save(TopLevelFolder+"Rasters/"+TheFolder)
        TheTextFile.write("    Done with 7 - Reclassify Raster\n")

        # ~~ The Data Management Tools class is accessed ~~
        TheInterface = ArcGISInterfaceModule.DMInterface()

        # The projection of the created raster is defined so that it matches the
        # shapefiles processed
        TheInterface.DefineProj(TopLevelFolder+"Rasters/"+TheFolder)
        TheTextFile.write("    Done with 8 - Define projection of raster\n")

        # The folder of intermediate files is deleted
        shutil.rmtree(TempScratchFolder)
        TheTextFile.write("    Done with 9 - Intermediate files for this category
deleted\n\n")

# In case of error, the code will break to here and return the error message to the log
except Exception, err:
    print("*** Error. Stopped because: " + str(err))
    TheTextFile.write(str(err)+"\n")

# A final message is printed with the end processing time and the log is closed.
now = datetime.datetime.now()
timestamp = format(now.month) + "/" + format(now.day) + "/" + format(now.year) +
" " + format(now.hour) + ":" + format(now.minute) + ":" + format(now.second)
TheTextFile.write("Completed Script: " + timestamp)
TheTextFile.close
print("End")
```