A REVIEW AND SUMMARY OF HUMAN USE MAPPING IN THE MARINE AND COASTAL ZONE

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1. Executive Summary

This report describes the results of a project that researched and synthesized methods and approaches to map human uses of the coastal and marine environment. The purpose of this project is to inform the NOAA Coastal Services Center's (CSC's) understanding of the current state of knowledge of human use mapping approaches.

CSC requested this report and its accompanying spreadsheet in response to information needs pursuant to (1) the adoption of the national framework and ocean policy task force final recommendations for conducting coastal and marine spatial planning (CMSP) within a unified national structure and (2) the transition to an ecosystem-based approach to coastal resource management. This report has been written and organized for use by policy bodies, such as the National Ocean Council, as well as federal and state agencies and regional organizations involved in day-to-day CMSP and decision-making.

People participate in a variety of activities in the coastal and marine environment. Some of these activities consume resources, such as fishing and energy development. Other activities rely on ocean resources, but do not consume them, such as swimming, bird watching, and kayaking. Humans have always relied on the renewable and non-renewable resources provided by the ocean, but only recently, with the adoption of ecosystem-based management, are humans and their needs considered an integral part of coastal ecosystems. Surprisingly, there is little spatial information available on human activities in the coastal and marine zones compared to environmental information. However, there are several promising efforts to map human uses in the United States, in particular California, New England, and Hawaii.

This study divided human uses into three broad categories, consistent with NOAA's Marine Protected Areas (MPA) Center: ***military and industrial uses*** such as energy, mining, and military zones; ***consumptive uses*** such as fishing; and ***non-consumptive activities*** not involving resource extraction, such as most recreational uses.

This project involved an extensive literature review of methods and approaches documented in peer-reviewed articles, reports, and studies undertaken between 1990 and 2010. While this research included a significant number of sources (over 110 in all), it was by no means an exhaustive review of all available information. It was intended to capture a representative sampling of current practices to identify common methods for mapping human uses in the coastal and marine environment. The literature review was supplemented by personal communication with knowledgeable practitioners. Key findings of this research are summarized below.

Common Approaches to Collecting and Mapping Human Use Data

Approaches to collecting and mapping human use data varied across the range of human uses. The policy and management context for the collection of human use data is one of the biggest factors influencing the methodology that is selected and the level of information available. For example, most military and industrial uses are regulated and require site-specific analyses as part of the permitting process. While the regulatory process provides relatively detailed information and a system for documenting the information, in some instances personnel from government agencies (the Department of Defense) or private firms (utility companies) must be contacted directly to obtain location data. Consumptive uses (fishing) are increasingly regulated, and state and federal agencies have increasingly focused on monitoring locations of these uses. Data are most often collected to understand economic, cultural, and social values associated with fishing. They are also used in marine protected area design (California's Marine Life Protection Act) and are beginning to be used in more comprehensive ocean plans (Massachusetts and Rhode Island). Methods used to collect and map fishing activity include individual interviews, group workshops, mail and online surveys, aerial surveys, and onboard vessel monitoring. Non-consumptive uses are the least regulated category of uses, but there are increasing efforts to collect spatial data for CMSP and economic valuation projects through intercept surveys, opt-in surveys, aerial surveys, and workshops.

Common Technology Used

State and federal agencies and non-governmental organizations use group workshops to collect data on consumptive, non-consumptive, and/or military and industrial uses. These workshops occasionally involve the use of paper maps, but increasingly, they use **participatory geographic information systems (GIS)**. Participatory GIS involves some form of GIS software, **digital whiteboards, tablets**, and projectors. Participants help identify and map locations where certain uses occur. Post-workshop processing also involves GIS software. In addition to participatory GIS methods, online data collection is facilitated via interactive websites that allow users access to maps for data input. For online data collection efforts such as online surveys and user-driven websites, Google Maps and Google Earth are the mapping applications of choice. Aerial surveys and on-board vessel tracking (e.g., automatic identification systems [AIS], vessel traffic service [VTS]) usually involve the **Global Positioning System (GPS)**.

Mapping Challenges

Mapping challenges largely depend on the level of detail needed and the intended uses of the maps produced. Generally, non-consumptive uses face the greatest data collection and mapping challenges. These uses are for the most part unregulated, so there is little documentation that can be obtained by reviewing records. In addition these uses tend to shift spatially and temporally and thus are difficult to track. Even when intercept or online surveys are used to gather information from users, data on the quality and intensity of use (variations due to weather, time of year, shoreline conditions) are often lacking. Some data collection efforts, such as mapping recreational beach use, can be biased toward popular, highly sampled areas, while other non-consumptive uses like recreational boating (motorized and non-motorized) is hard to generalize from intermittent surveys since user activity tends to be random. These challenges can be overcome, in part, by more direct engagement of the user communities. When mapping methods such as participatory GIS are used to gather more detailed information from users, attention must be paid to effectively working with a diverse group of users that may have cultural differences and varying levels of education, interest in participating, and concern over confidentiality. When researchers and coastal resource managers attempt to map consumptive uses, they face some similar challenges. Fishermen may be reluctant to share information on where, when, and how they are fishing for fear of additional restrictions. This is especially the case with illegal fishing methods, which have major impacts but are almost impossible to track. Recreational fishing is similar to recreational boating in that user activity is hard to generalize because of its sporadic nature. Military and industrial uses typically face fewer mapping challenges due to their regulation and relative predictability, but those seeking data may still have difficulty in obtaining particular data sets due to security or proprietary issues.

Gaps

A notable gap exists in mapping non-consumptive uses such as recreational boating, surfing, scuba diving, snorkeling, paddle boarding, spearfishing, and cultural and tribal uses. Although these uses are significant economic generators that involve key ocean stakeholders, most of them are underrepresented in otherwise robust CMS plans such as those developed in Massachusetts and Rhode Island (although it should be noted that information on beach access is typically included in state coastal zone management plans). Several studies have noted a lack of surfing and paddle boarding data specifically, and there is a general lack of information on the quality and intensity of recreational beach uses. Smaller-scale data collection is used to inform management plans for conservation areas or gauge the need for public facilities. Robust datasets are lacking for smaller fisheries and recreational fishing, but efforts like the Florida Fishing Demonstration and the Oregon Recreational Fishing Survey will be used to supplement existing datasets. Likewise, data collected during exercises like Oregon's Recreational Ocean Use Study or Massachusetts' Recreational Boaters Survey will greatly enhance the effectiveness of CMS plans. Gaps on non-consumptive uses can often be attributed to a lack of resources for in-depth survey methods and a lack of regional/national organizing framework to promote data collection and use.

2. Introduction[1]

The newly established National Ocean Policy in the United States has given federal and state agencies an opportunity to comprehensively plan and adaptively manage the future of the nation's marine and coastal zones through **coastal and marine spatial planning (CMSP).** Although the dual mandate of managing for both ocean use and protection is challenging, numerous governmental and non-governmental stakeholders have accepted this challenge and are moving forward with efforts to better incorporate spatial data on human use into their CMSP initiatives.

New England and the Mid-Atlantic are two regions that have begun to address one of the foundations of a successful CMS plan: data. These regions are currently establishing regional data portals (the Mid-Atlantic Regional Council on the Ocean's GIS Portal and the Northeast Regional Data Portal) to house the wide array of information that will support regional CMSP. Although regions are moving forward and assembling data on environmental factors like bathymetry, habitats, sediment types, and species distribution, data on human activities in coastal and marine ecosystems are at best inadequate. Without the appropriate spatial data on current and predicted human uses, the task of developing CMS plans becomes more challenging.

Data on these human uses – how, when, and where they are occurring – are critical to the ecosystem-based management approach outlined in the recent *Final Recommendations of the Interagency Ocean Policy Task Force* (2010). Ecosystem-based management is an approach that includes multiple sectors and stakeholders, examines cumulative impacts, considers humans as integral to the ecosystem, and manages particular services for use by humans (McLeod et al., 2005). This means that regional CMS plans and ecosystem-based management efforts will need to include, at minimum, baseline data on human uses and the impacts of those uses.

In the past, researchers have tended to collect data on human use of the coast in reaction to environmental problems. Data collection usually did not involve mapping. For example, in 1990, the steam tanker *American Trader* discharged over 400,000 gallons of crude oil off the coast of Huntington Beach, California. The state of California was challenged to determine the economic value of the public's loss of recreational beach use across 14 miles of beach for over a month. As studies progressed, it became clear that valuing recreational use was no simple task, however in order to effectively manage the coastal environment, the data were critical (Chapman and Hanemann, 2001). The *American Trader* case created a foundation for debate in California, a state that today continues to collect data on beachgoing in attempts to value recreational uses – uses that have been traditionally overlooked in ocean and coastal planning efforts.

Generally, military, industrial, and consumptive human use data are more readily available than non-consumptive, recreational use data. Existing authority and regulations have provided some foundations for mapping of human uses related to military and industry (including renewable energy more recently) (McKendry, 2009). The National Marine Sanctuaries Act, American Antiquities Act, Endangered Species Act, Marine Mammal Protection Act, Coastal Zone Management Act, Deepwater Port Act, Outer Continental Shelf Lands Act, Natural Gas Act, Federal Power Act, Magnuson-Stevens Fishery Conservation and Management Act, Ports and Waterways Safety Act, Ocean Dumping Act, Clean Water Act, Rivers and Harbors Act, Submerged Lands Act, and National Environmental Policy Act all contribute to mapping of military, industrial, and consumptive uses. Many of these statutory and/or regulatory provisions affecting the coastal and marine environment

[1] Words or phrases in bold have been defined in a glossary (Appendix A).

contain place-based mechanisms, tools for establishing activity restrictions, consultation requirements, and permitting and licensing processes (Environmental Law Institute, 2009).

Human use mapping has gained increasing attention with the new push for CMSP and the experiences of states and other nations that have already gone through the process of developing CMS plans. In the future there is likely to be increasing pressures from new and existing ocean uses and CMSP that takes into consideration all human activities can help reduce conflicts. Assembling data to accurately inform ecosystem-based management of the coastal and marine environment will allow for anticipation of conflicts and sustainable solutions.

This project provides an up-to-date, user-friendly, practitioners' resource on human use mapping efforts in the coastal and marine environment. From this research we characterize human use mapping methods, identify technical considerations, document the challenges and successes of various approaches, and provide recommendations based on efforts underway in the United States and internationally. This synthesis is an important first step toward establishing human use data as a critical component of CMSP and ecosystem-based management.

Context for Mapping Human Uses

The pace of technology advancements has been swift over the past two decades, and technological devices have become smaller, more widely available, user-friendly, and cost-feasible. Mapping projects that once relied on participant observation can now be conducted using highly portable GPS tracking devices and easy-to-use GIS software. In addition, several companies such as Google and Microsoft now publically provide high-resolution imagery of much of the Earth's surface that can be used in conjunction with face-to-face interviews of fishermen and other marine resource users in mapping projects.

Turner (2003) provides a concise summation of trends observed from a review of the technical literature that contains, among other applications, human use mapping. The human use mapping literature examined for this report suggest that researchers and policy-makers understood early on that the expansiveness of the ocean and the remoteness of some coasts called for use of GIS and remote sensing tools. The state of the craft in coastal human use mapping is, therefore, as strong as it is for any application. However, gaps do remain. For example, while data tends to be most widely available and mapped for permitted and fixed uses (shipping, renewable energy infrastructure, and military zones), data for other important uses, especially non-consumptive, recreational uses, either are lacking – as is the case for many U.S. regions – or do not exist in appropriate spatial formats. The gap in this dataset can often be attributed to the resource-intensive survey methods required to gather the appropriate information and a lack of regional/national organizing frameworks to promote its collection and use.

3. Methods

For organizational purposes, this study divided human activities in the coastal and marine zone into three broad categories based on categories used in the MPA Center's California Human Use Atlas project and uses listed in the *Final Recommendations of the Interagency Ocean Policy Task Force* (2010). While compiling this report, it became clear that although sub-categories of human uses can be identified, there is significant overlap and nesting among uses that is difficult to tease out. For example, recreational boating must often occur in order for other uses to be possible, such as recreational fishing (unless done from the shore), diving, and whale watching. Nevertheless, this study selected sub-categories that were relatively broad and could be found across all regions of the United States, as shown in the table below.

Non-consumptive	Consumptive	Military and Industrial
• Conservation • Maritime heritage and archeology • Diving • Tourism • Beach access (swimming, surfing) • Nature and whale watching • Recreational boating (motorized and non-motorized)	• Commercial fishing • Traditional fishing • Recreational fishing (and boating)	• Aquaculture • Renewable energy • Homeland security/defense • Commerce and transportation • Mining • Oil and gas exploration

The examination and summary of human use mapping methods by category began with a review of approximately 30 pieces of literature provided by NOAA CSC. Articles were quickly skimmed to determine if they were relevant enough to a particular human use to warrant a more careful review and/or could provide additional articles for review. A literature and Web search was then performed. The approach to identifying relevant literature was to initially search appropriate electronic reference databases, supplemented by Internet searches, and reviews of government documents and technical reports. Search terms included human uses listed in Table 1 along with additional terms such as "human use mapping," "coastal zone," "conservation," "MPA," "zoning," "marine spatial planning," "recreation," "GIS," "GPS," "remote sensing," "VMS," and "spatial planning." Databases searched included Web of Science, Google Scholar, IngentaConnect, and Social Science Citation Index. Websites of state coastal zone management agencies involved in ocean planning or mapping efforts (Massachusetts, Rhode Island, New York, Maryland, Florida, California, Texas, Washington, and Oregon) were searched for relevant documentation of mapping methods. References in documents or articles identified as relevant were also scanned for additional sources. The searches focused on efforts in the United States, but relevant international studies or reports were included as well.

Once a document was briefly skimmed and deemed relevant, it was entered into an Excel spreadsheet. The spreadsheet includes 16 fields, which were driven by the objectives of the project and the experience of the Massachusetts Ocean Partnership in supporting the development of the Massachusetts Ocean Management Plan. These fields include mapping method, accuracy level, mapping standards, data derivation process, and coastal management implications. Including articles provided by NOAA CSC, the spreadsheet was initially populated with over 120 entries. General articles on CMSP were removed from the spreadsheet and the remaining articles were split into two categories: (1) articles addressing data collection or mapping of a particular human use and (2) guidance or methods documents with little actual data collection, economic studies that had little or no spatial information, or, where noted, studies that were similar in mapping or data collection methods to other studies included in the first category. Articles in the first category were thoroughly reviewed and all fields in the spreadsheet were populated. Articles in the second category were entered into the spreadsheet but fields beyond general information (author, date, study location) were not populated.

During the literature and Web review, individuals were identified for informal interviews. These people were chosen from human use mapping efforts underway in the U.S. and from NOAA CSC recommendations (Appendix B). A set of questions was developed to guide the conversations (Appendix C). Several people who were contacted shared additional literature or reports that were reviewed using the same methods mentioned previously. These personal communications provided this study with valuable insight into ongoing projects and mapping or data collection methods. Notes taken during these conversations were incorporated into this report.

4. Human Use Mapping Methods

The following section reviews human use mapping methods found in the literature, online, and through informal interviews. The information is organized by use (military and industrial, consumptive, and non-consumptive) and describes common approaches, tools used, challenges, and applications. There is some commonality of mapping methods across the three categories of uses; to avoid repetition, each method is only defined once.

4.1. Military and Industrial Uses: Oil and Gas, Offshore Renewable Energy, Commerce and Transportation, Military, Aquaculture, Telecommunications Cables, Sand and Gravel

Military and industrial uses often serve as baseline elements in the few existing coastal CMS plans in the United States and the numerous plans in existence in Europe. They enjoy a "first come, first served" mapping status in that many of them have been mapped historically, making them an easy addition to comprehensive ocean maps. For example, the U.S. Coast Pilot has in some form published sailing directions for over 200 years (NOAA Office of Coast Survey[2]). In Germany's spatial plans for the North Sea and the Baltic Sea, navigation routes serve as the basic framework with which other uses must align themselves (Federal Ministry of Transport, Building and Urban Development, 2009).

Unlike many non-consumptive (and even some consumptive) uses, military and industrial uses are regulated, are site-specific, and stay constant in space and time. The mapping methods for these uses are for the most part simple, involving permitting agencies receiving applications from developers for licenses or permits. For example, **lease blocks** guide oil and gas leasing in state and federal waters. The blocks are similar to delineating land parcels in the terrestrial environment. The Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE) has oversight responsibility for oil and gas leasing activities within the Outer Continental Shelf (OCS) and maps leasing blocks in federal waters. The agency prepares a five-year schedule of proposed lease sales that shows the size, timing, and location of potential leasing activity as precisely as possible (MMS, 2010) (see "Oil and Gas" section below). BOEMRE therefore knows the potential location of all oil and gas activities in federal waters and controls whether lease blocks are available for development or not.

While oil and gas infrastructure is highly regulated and (once in existence) static in location, not all military and industrial uses are mapped or have data as readily available. Some data are less easily mapped due to the proprietary nature of the data or for security concerns – e.g., military zones, dredging tracks, and cable corridors. These data are not publically available and often require contacting utility or military personnel directly if detailed data is required (MA EOEEA, 2009; RI CRC, 2010; G. Wikel, personal communication).

Common Approaches

In both domestic (Massachusetts and Rhode Island) and international CMSP efforts, military and industrial uses are derived from existing data layers – in the United States, most commonly NOAA nautical charts. Other sources for this information include the **Federal Register** and agency-specific databases. When data related to these uses are not available from existing nautical charts, personal communication with agencies or industry is usually necessary.

[2] Historical Map and Chart Collection: http://www.nauticalcharts.noaa.gov/csdl/ctp/abstract.htm.

Analysis and mapping of existing data: Many human use mapping efforts and studies merely collect and analyze existing data from known data sets (Itami et al., 2003; Brody et al., 2004; Halpern et al., 2009; Selkoe et al., 2009; Stelzenmuller et al., 2010; see spreadsheet for additional references). Most human use studies begin with an analysis of existing data, and sometimes the data are robust enough to answer the researchers' questions and further data gathering is not required. Existing data on consumptive, military and industrial, and if available non-consumptive uses can be gathered from various state agencies (Coastal Zone Management, Division of Fisheries and Wildlife, etc.) similar to what occurred in Massachusetts and Rhode Island's recent CMSP efforts (2009 and 2010), Ohio's Coastal Atlas and Wind Turbine Placement Favorability Analysis (2009), and Ecotrust's MarineMap (2010). In New York, Maryland, and other states with burgeoning coastal atlases, gathering and centralizing existing ocean use data and identifying data gaps is one of the first steps to CMSP (New York Ocean and Great Lakes Ecosystem Conservation Council, 2008; Cortina, 2010).

- NOAA nautical charts (both electronic and hardcopy) are the base layers for the majority of offshore wind suitability analyses and state ocean management plans. These charts are kept updated through a variety of sources including the U.S. Coast Guard, boating community updates (Cooperative Charting Program, Adopt-a-Chart[3]), NOAA field work, the U.S. Army Corps of Engineers, and the National Geospatial Intelligence Agency.
- BOEMRE has downloadable spatial data for oil platforms, pipelines, and lease blocks organized by four regions. Only Official Protraction Diagrams (and Supplemental Official OCS Block Diagrams) are considered official records of offshore BOEMRE boundaries; **shapefiles** available for the Gulf of Mexico region are not official.
- NOAA and BOEMRE have developed a mapping system and spatial data portal called the Multipurpose Marine Cadastre (MMC).[4] The MMC contains spatial data and Web map services representing military and industrial uses.
- Geographic coordinates (latitude, longitude) for federal projects are published in the Federal Register.

Interviews: Interviews are used to obtain information directly from stakeholders and allow for a lot of personal "give and take" that is often critical to obtaining new insights into the industry or the user activity. To alleviate proprietary data concerns or security issues that could result from making data publically available, direct communication with private utility companies, ferry operators, dredging companies, and military personnel was necessary when assembling spatial data for the California Ocean Uses Atlas, Massachusetts OMP, and Rhode Island Special Area Management Plan (SAMP).

Analysis and mapping of existing data used for siting: State and federal permitting agencies may require alternative sites analysis for military and industrial use projects. This requires analysis of resource data (e.g., wind speed, tidal ranges, wave heights, sand deposits, underlying geology). Similar siting analyses are conducted for CMS plans.

Participatory GIS in a workshop setting: Selected stakeholders, industry representatives, or industry experts attend a workshop and assist in the development of representative mapping layers. During

[3] U.S. Power Squadrons: http://www.usps.org/national/coch/ and http://www.usps.org/national/coch/CoChPage40.htm.
[4] Multipurpose Marine Cadastre: http://www.marinecadastre.gov.

the MPA Center's human use mapping efforts in California and New England, military personnel and industrial experts participated in the workshops to identify **use footprints.**

Common Technology Used

The type of technology used to characterize military and industrial uses does not vary greatly. Due to the regulation of the majority of these uses, developers are responsible for providing data on use location. A brief overview of the type of technology used in human use data collection and mapping is below:

Collecting Shipping Data: AIS

The International Maritime Organization requires AIS for all ships with gross tonnage of 300 tons or more and all passenger ships regardless of size. Signals are sent from commercial vessels to land-based receivers. When mapped in aggregate, the data provide a realistic and up-to-date view of commercial shipping patterns. The data have been valuable to current CMSP efforts in Massachusetts and Rhode Island, where traditional nautical charts may not always reflect exactly where ships are traveling (Figure 4.3). NOAA CSC and BOEMRE, in partnership with Applied Science Associates, are developing a GIS-based AIS production tool and spatial database. The project is intended to gather, organize, and centrally locate one year of AIS data in a GIS-ready format. The resulting database and production tools will make AIS data more readily available to any organizations looking to incorporate shipping data into ocean planning efforts.

Desktop GIS: Common desktop GIS software is almost always used to **digitize**, process, and display human use data. A GIS allows for management, display, and analysis of data that is geographically referenced. Because military and industrial uses are regulated, coordinates of project areas can be obtained from the appropriate Code of Federal Regulations listing and digitized.

GPS: GPS technology is coupled with on-board vessel monitoring systems to provide commercial shipping data. AIS (see highlight box) transmit ship location data to receivers on land, which can then be brought into a GIS and analyzed. Onboard equipment includes a very high frequency (VHF) transceiver and GPS receiver.

Online maps: Google Earth can be used to locate aquaculture pens in state waters (Halpern et al., 2009; N. Napoli, personal communication). Footprints of oil rigs can be determined in some regions where higher-resolution, offshore imagery is available (Figure 4.1). Online map viewers, such as the Texas Railroad Commission's Public GIS Map Viewer, can be used to display offshore oil wells and lease blocks (see "Oil and Gas" section).

Figure 4.1 Google Earth high-resolution imagery offshore of the Texas coast. Oil platforms are visible.

Common Data Collection, Analysis, and Presentation Challenges

A number of challenges can arise in social science research, and human use studies are no different. These challenges vary depending on the data collection methods used. Some common challenges associated with military and industrial use mapping are listed below:

Working with people: Human use data collection and mapping typically requires a lot of interaction with individuals or stakeholder representatives. For military and industrial use mapping in the MA OMP and RI SAMP, working groups composed of experts were brought together to review data, map uses, and complete site analyses for renewable energy projects. In these situations, individuals must be trusted to accurately represent the interests of their use group and not their personal interests (M. D'Iorio, personal communication).

Proprietary data: Stakeholders or data holders may be hesitant to provide data for human use studies or CMS plans because of concerns over confidentiality. For example, dredge companies mining sand offshore will not release data on their dredge track lines (where the dredge is working throughout the day) for fear of competitors using the information to their advantage (G. Wikel, personal communication). Therefore, the collection, management, and display of proprietary data can be a challenge.

Security issues: Locations of critical infrastructure or military operational areas are issues of national security and will not always be made available or made available at useful scales. For the Massachusetts and Rhode Island ocean plans, statewide transmission line data had to be acquired through direct communication with utility providers who were unwilling to release detailed, high-resolution data. In the Rhode Island SAMP, details on submerged submarine travel lanes were deemed classified and not included (RI CRC, 2010).

Presumed accuracy of existing data: Military and industrial uses rely on the accuracy of data layers representing bathymetry, seafloor geology, or wind speed to site projects. Most CMS plans in the United States and abroad use maps of shipping lanes and military zones as base layers. For example, in the Maryland Coastal Atlas project, the Ohio Coastal Atlas, and the ongoing Hawaii Coastal Use Mapping Project, existing data layers that were either being included in the atlases or were serving as base layers were verified for accuracy through field work and stakeholder input during workshops (Cortina, 2010; A. Levine, B. George, personal communications).

Oil and Gas

The location of oil and gas platforms, wells, and associated infrastructure are mapped by BOEMRE and state agencies. Both federal and state regulators rely on the lease block as the foundation for permits and management. In both BOEMRE and state maps, lease blocks are depicted as grids and platforms are displayed as point data. For example, the Railroad Commission of Texas has developed an online map viewer that displays state lease blocks and includes **point** and **polyline** data representing wells and pipelines. The mapper is connected to permit and production databases (Figure 4.2).

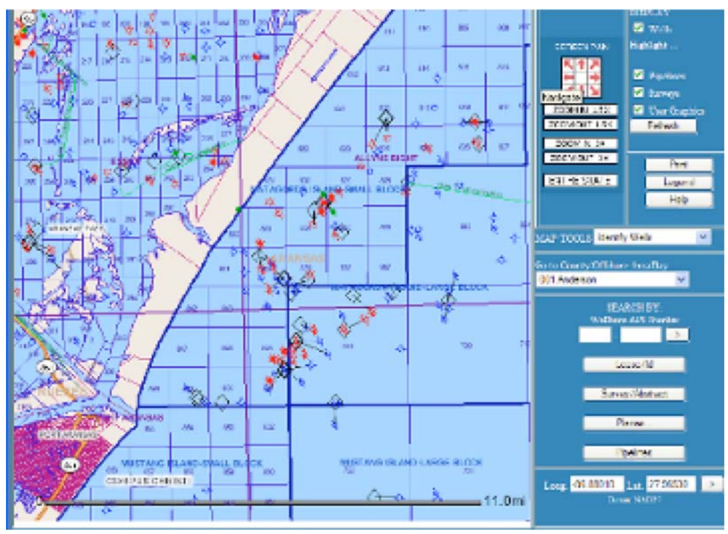

Figure 4.2 Texas Railroad Commission Public GIS Map Viewer (http://gis2.rrc.state.tx.us/public/startit.htm).

Military and industrial uses are regulated and require environmental reviews or impact analyses, but impacts on other human activities like recreational uses are often not considered in these processes. For example, federal oil and gas planning areas, as mapped by BOEMRE, have recently undergone an expanded environmental sensitivity analysis to determine potential ecological impacts of oil and gas activities. The expanded analysis looks at marine habitats, productivity, fauna, and the sensitivity of the planning area to effects of certain factors like climate change and oil spills, but it does not incorporate data on other human uses, such as how an oil spill might affect commercial and recreational fishermen (MMS, 2010).

Offshore Renewable Energy

Offshore renewable energy projects are the driving force behind CMSP efforts in Oregon, Massachusetts, and Rhode Island; states in the Mid-Atlantic and Great Lakes are also starting to invest in more sustainable sources of energy. Initial siting for offshore wind, tidal, and wave energy projects is dependent on conditions of the energy resource (wind speed, tidal ebb and flow rates, wave height, etc.). GIS is the most common tool used to identify appropriate sites for energy projects in CMS plans. The results of these siting analyses are incorporated into state plans or for states without plans, used to guide renewable offshore energy development (e.g. Ohio's Wind Turbine Placement Favorability Analysis[5], Michigan's Lakebed Alteration Decision Tool[6]). Potential locations of transmission lines for offshore renewable energy projects are an important consideration during siting. Existing substation locations were included by the Massachusetts Renewable Energy Working Group in their Draft Report (Renewable Energy Working Group, 2008), but could not be mapped in any detail due to security concerns. Data were collected by the Department of Public Utilities through personal communication with private utility companies in the area.

Commerce and Transportation

Traffic separation schemes (TSS) were developed in the 1970s by the International Maritime Organization as a measure of safety to help commercial ships entering and exiting ports. TSS include traffic lanes, separation zones, precautionary areas, and inshore traffic zones. TSS are used by ports all over the world and are for the most part areas given priority in CMS plans. All U.S. TSS are described in the U.S. Coast Pilot. Participation in a TSS is voluntary. Although viewed as hard constraints in European and U.S. CMS plans, TSS can be amended. The Boston TSS has been amended three times (most recently in 2009) to reduce the risk of collisions with North Atlantic right whales (NOAA, 2008).

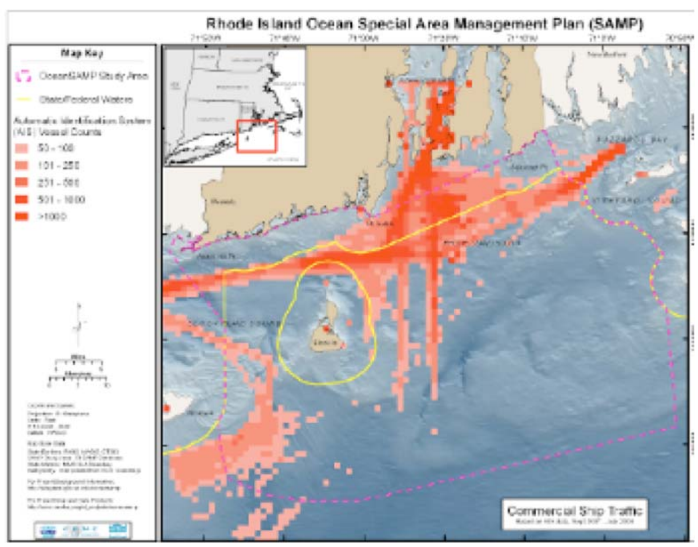

Figure 4.3 AIS-Generated Shipping Density Map Included in RI SAMP (RI CRC, 2010).

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[5] Wind Turbine Placement Favorability Analysis Map: http://www.ohiodnr.com/LinkClick.aspx?fileticket=bTQIu4JOV%2F8%3D&tabid=21234

[6] Michigan Lakebed Alteration Decision Support Tool: http://wiki.glin.net/download/attachments/950464/LADST_Webinar_PPT7.pdf

In the Rhode Island SAMP, a shipping density map was created using AIS data. The Massachusetts OMP also included commercial shipping polygons based on shipping density derived from AIS data. Passenger ferries are not required to carry AIS and data used in the Massachusetts OMP (2009) and by Halpern (2009) were collected from state departments of transportation and through information provided by ferry operators.

Military

General military use footprints are well established in marine and coastal zones and rarely change (M. Huber, personal communication). Over the last few years the Navy has focused efforts on mapping smaller, unique training areas that have been in use for decades, but have traditionally not been mapped (C. Destafney, personal communication). Military range coordinates are available in the Federal Register and the U.S. Coast Pilot. If a specific request is made, for example by the MPA Center, coordinates and maps will be provided directly by military personnel. This information usually already exists in house as it is often required for National Environmental Policy Act environmental analyses. Offshore range complexes contain activities in the subsurface, surface, and air space but are generally not restricted from other uses unless live ordinances are being deployed. These military zones can still provide conservation benefits as "de facto Marine Protected Areas" (Grober-Dunsmore et al., 2008).

Aquaculture

Aquaculture facilities are currently not permitted in federal waters. The majority of the small U.S. marine aquaculture industry is located within state waters (NOAA Aquaculture website[7]). Similar to other industrial uses, aquaculture requires particular environmental conditions and must be sited in ways to reduce impacts to the environment. Siting criteria may include water depth, water current, water quality, and bottom type (Rester, 2009). In the Massachusetts OMP cumulative mapping study (N. Napoli, personal communication) and Halpern's cumulative mapping study (2009), Google Earth was used to locate aquaculture pens in state waters, which were then digitized into a GIS.

Telecommunications Cables

NOAA nautical charts display cable areas but may not contain up-to-date information. For CMS plan development, Rhode Island and Massachusetts relied on personal communication with utility providers to obtain telecommunication cable locations. Some utilities have realized the value of working with fishermen to prevent damage to cables by fishing gear by providing them with spatial information on cable locations (e.g., the Oregon Fishermen's Cable Committee[8]).

Sand and Gravel

Mapping of sand and gravel resources has become increasingly important as the demand for beach nourishment projects continues to increase. Several states and U.S. Army Corps districts have created publically accessible sediment management databases and analysis tools to store and examine environmental variables related to borrow sites. Florida's Reconnaissance Offshore Sand Search (ROSS)[9] and California's Coastal Sediment Benefit Analysis Tool (CSBAT)[10] are a few examples of databases with spatial components that allow managers to complete general screenings of potential borrow sites.

[7] NOAA Aquaculture: http://aquaculture.noaa.gov/us/welcome.html#us.
[8] Oregon Fishermen's Cable Committee: http://www.ofcc.com/cable_locations.htm
[9] Florida's Reconnaissance Offshore Sand Search: http://ross.urs-tally.com/mapviewer/index.html
[10] California's Coastal Sediment Benefit Analysis Tool: http://www.dbw.ca.gov/csmw/csbat.aspx

4.2. Consumptive Uses: Commercial Fishing and Recreational Fishing

While there are a number of different ways to collect human use data on commercial fishing and recreational fishing, a review of recent literature and interviews with experts in the field shows that there are trends or preferred approaches for collecting data on each of these uses.

Marine fisheries in federal waters are managed under the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §§ 1801–1884). As mentioned in the previous section's discussion on military and industrial uses, regulated human uses tend to be more advanced than non-regulated uses in terms of data collection and mapping. The Magnuson-Stevens Act (1976) mandates collection of both commercial and recreational fisheries data. Due to these requirements there have been continued efforts to improve and enhance fishing data collection methods. For example, as mandated by the Magnuson-Stevens Reauthorization Act (2006), the National Marine Fisheries Service was required via its Marine Recreational Fisheries Statistics Survey (MRFSS) to improve quality and accuracy of recreational fishing data. Although consumptive uses are often regulated, commercial and recreational fishing mapping efforts must contend with the fact that fishery participants are moving targets – making these uses more challenging to portray spatially.

Commercial fishing is well-studied and there are several existing datasets that can be mined for spatial and socioeconomic data. To obtain any additional information on the industry, most researchers prefer one-on-one or small group interviews (Close and Hall, 2005; St. Martin, 2005, 2008; Scholz et al., 2006; RI CRC, 2010). Since there are few reporting requirements and regulations for recreational fishing, there are few existing datasets that can be used to map their occurrence. Many methods have been employed to acquire new data, ranging from workshops where qualitative information is gathered from industry representatives to quantitative studies that use scientifically sound surveying methods or advanced technology to obtain information or observe current levels of activity.

Common Approaches

Six general approaches have been identified for collecting human use data for commercial and recreational fishing. While a review of the literature suggests many variations to these approaches based on the details of the study and size of study area, the following six categories generally represent the majority of the approaches currently and recently being used.

Mapping and analysis of existing data: See the "Military and Industrial Uses" section. Some existing fisheries data collected through state or federal log books or forms (e.g., vessel trip reports, or VTRs) (St. Martin, 2005; St. Martin and Hall-Arber, 2008), the MRFSS (St. Martin, 2005), and the Vessel Monitoring System (VMS) (Fock, 2008) can be mapped and analyzed (Halpern et al., 2009; MA EOEEA, 2009).

Participatory GIS in a workshop setting: Selected stakeholders, fishing representatives, or fishing experts attend a workshop and assist in the development of representative mapping layers (Wahle et al., 2010a). Within these settings, fishing categories are often broken down into more specific categories relevant to the study area (e.g., California Ocean Uses Atlas uses 12 categories of commercial and recreational fishing including commercial dive fishing, kayak fishing, and commercial kelp and algae harvesting).

Interviews: Interviews are used to obtain information directly from stakeholders (Ecotrust, 2010; St. Martin, 2008; RI CRC, 2010; M. Hall-Arber, C. Steinback, personal communications). To alleviate concerns over sharing information in a group setting or through a survey, interviews are normally conducted one-on-one or with a small group.

Intercept or fixed point surveys: Surveys that are conducted in the field by researchers. For intercept surveys, researchers stop users and ask questions, usually when stationed in popular use areas (boat landings, beaches). For fixed point and fixed area surveys, researchers observe activity (i.e., count people or vessels) from a single location. Sometimes researchers are responsible for covering a geographic area on foot or in a vehicle or vessel. These surveys have been used for boaters, which may or may not include recreational fishing (Scholz et al., 2004; Lynch, 2006; Gray, 2008; Ambastha et al., 2010).

State to Watch: New York

Group participatory GIS has emerged as an effective method for collecting human use information and stakeholder input. There are many variations of this method, but one interesting development has been the work conducted by the state of New York and NOAA CSC in support of New York's offshore planning activities. In New York, researchers trained stakeholder representatives at three locations to conduct participatory GIS workshops within their own constituency, and then to provide the data to the state for consideration during its planning effort. It was a process developed out of necessity: a tight state budget meant funds were only available for one round of workshops. These workshops were used to train stakeholder representatives to hold their own workshops. One of the benefits of this method is that stakeholders are likely to be more comfortable providing use information to one of their own, instead of to government officials.

Mail, phone, or online surveys: Typical questionnaire-based surveys that often use a random representative sample to characterize the activity of the general population (Mahoney, forthcoming; Cudney-Bueno and Shaw, 2010).

Aerial surveys: Surveys that are conducted remotely using aerial photography or video to capture human use activity for a specified period of time (Tinsman and Whitmore, 2006).

Common Technology Used

The type of technology used to characterize these two human uses varies greatly. While there are no obvious technology requirements to conduct a human use study, a researcher should at least have access to a moderate level of GIS expertise in order to process and analyze the data. A brief overview of the type of technology used in human use studies is below:

Paper maps: Paper maps (often nautical charts, aerial photographs, or hand-drawn illustrations) are used as a simple way to obtain human use data from stakeholders. For this method, stakeholders indicate areas of fishing activity on the map, and the information is often digitized into GIS at a later date (St. Martin, 2008). This can be an effective way to capture human use information in an informal setting.

Desktop GIS: Users can input their information directly into a GIS (Scholz et al., 2006) or it can be digitized from survey/interview responses (St. Martin, 2008; RI CRC, 2010).

Custom mapping applications: Several custom mapping applications have been developed and used to acquire human use information, most notably Ecotrust's Open OceanMap (Scholz et al., 2006). Stakeholders use the mapping application to indicate areas of human use activity.

GPS: GPS technology is often used and sometimes coupled with on-board vessel monitoring systems. Information from GPS and other on-board vessel monitoring systems can then be brought into a GIS and analyzed.

Aerial surveying technology: Aerial surveys require certain types of aircraft and often include the use of photo or video technology. Aerial surveys also often require the use of GPS and GIS technology to understand location and to digitize raw data. Sometimes aerial surveys are conducted without a recording device and a researcher qualitatively indicates the level of use in an area.

Statistical analyses and modeling: There are a range of statistical analyses and models that are usually conducted after data have been collected and mapped. These analyses often require specific expertise, but they can identify favorite locations, associate activities with environmental features, provide researchers with the capacity for running "what if" scenarios, and articulate the linkage between specific use areas and coastal communities. These analyses are often conducted to understand the socioeconomic values associated with a particular use or use area.

Common Data Collection, Analysis, and Presentation Challenges

Some common challenges when mapping consumptive uses are listed below:

Working with people: Human use data collection usually requires a lot of interaction with individuals or stakeholder representatives. It can be difficult to work with different stakeholders because of varying levels of education, cultural differences, lack of interest in participating, and concerns over confidentiality.

Commercial Fishing Data

There are good existing datasets that are used frequently to characterize commercial fishing activity. Trip reports and log books (NMFS VTR, state trip reports) and vessel monitoring systems also provide data (either data reported to NMFS via VMS or each vessel's private GPS-based tracking system). Existing fisheries datasets sometimes do not provide data of high enough resolution for CMSP purposes (especially NMFS VTR). Individual interviews are a common approach applied to improving data on key commercial fishing areas.

Proprietary data: A number of stakeholders are hesitant to provide data for human use studies because of concerns over confidentiality (e.g., fishermen are reluctant to share their favorite fishing grounds). Therefore, the collection, management, and display of proprietary data can be a challenge.

Accuracy issues: There are often accuracy issues associated with each of the different data collection methods and human use datasets. Survey bias, stakeholder cooperation, scale and resolution, and the use of technology are just a few factors that contribute to accuracy issues. Rigorous data reviews or groundtruthing are not always feasible due to funding constraints.

Generalization of use: To conduct a manageable and affordable study, human uses often need to be generalized. A number of challenges arise when generalizing human uses, but it is also difficult and expensive to be comprehensive when collecting human use data.

Uncommon activity (Pendleton and LaFranchi, 2009): Random sampling may not be capable of capturing unique uses practiced by only a small segment of the population, such as spearfishing (L. Pendleton, personal communication). Participatory GIS workshops, even when targeting experts for participation, may have difficulty getting representation for all uses. For example, during recent workshops held in relation to developing a coral management plan along the northern Kona Coast of Hawaii (as part of the Hawaii Coastal Use Mapping Project), organizers had difficulty recruiting representatives of aquarium fishing (A. Levine, personal communication).

Commercial Fishing

There are several high-quality datasets that are frequently used to characterize commercial fishing activity. NOAA NMFS requires VTRs for fishing vessels in federally permitted fisheries. NMFS compiles these reports into a database that allows for an analysis of landings and effort by fishery using a 10-minute square grid. Databases are sometimes maintained for some state permitted fisheries, but variability in state level reporting and monitoring requirements may limit the potential for spatially analyzing these datasets. Lastly, NMFS maintains data collected from VMS. VMS is used to track vessel movement and location and is primarily used in enforcement, but the data can also be extremely helpful in understanding fishing effort and navigational trends.

While these existing datasets offer great opportunities for analyzing commercial fishing activity, there are security and privacy concerns with both datasets due to the sensitive nature of the information. These datasets do not cover all fisheries, so any characterization of the industry using these sources alone would be incomplete. Unfortunately, the data (especially NMFS VTR) are sometimes not of a high enough resolution to inform siting decisions or to be used in state CMSP exercises.

Commercial Fishing: Current Efforts

The work of Kevin St. Martin and Madeleine Hall-Arber in the Gulf of Maine and Ecotrust's work in California and Oregon are good examples of researchers mapping important commercial fishing grounds through individual or small group interviews. While there are differences in approach, both demonstrate that if time and budget are available, interviews with fishermen provide researchers with a greater understanding of the fishing community than most other methods. This improved understanding of the use is essential to map and value the activity and the resource areas appropriately.

In order to supplement these datasets, researchers use several different approaches, focusing primarily on individual or small group interviews (Scholz et al., 2004, 2006; Close and Hall, 2005; St. Martin, 2008; Ecotrust, 2010; RI CRC, 2010). Interviews allow the researcher to establish a rapport with the fishermen and facilitate a greater understanding of the "how and why" behind current fishing patterns (M. Hall-Arber, personal communication). The basic approach is to identify fishermen who frequent the area of interest, interview the fishermen to understand areas of high fishing effort or importance, and then summarize the data into maps. These maps are then reviewed with fishing industry representatives to ensure their accuracy. There are a number of challenges associated with this approach, such as scheduling conflicts and identifying the right fishermen to interview. Furthermore, the results can be viewed as biased because the researcher selects the interview subjects, whereas a random sample approach would ensure that the subjects are representative of the general fishing population.

Participatory mapping, often in a group workshop setting, is another common way to gather data on the commercial fishing industry. This method provides researchers with the opportunity to obtain information from the industry quickly and can be a less expensive alternative to individual interviews. Participatory mapping workshops can also be useful for reviewing the results and accuracy of existing data or data collected during interviews. Although less commonly used, aerial surveys can be valuable in identifying high-activity areas.

Data collected are often used to better understand the social, economic, and cultural values associated with fishing (e.g. how important a certain fishery or fishing ground is to a coastal community). Management uses of these data include fisheries management decision-making, environmental impact statements, and, more recently, marine protected area design and CMSP efforts. For example, the California Marine Life Protection Act Initiative (CA MLPAI) used these data in the design of marine protected areas, and the Massachusetts OMP and the Rhode Island SAMP used these data in their respective comprehensive planning efforts.

There are a number of challenges associated with the collection, management, and presentation of these data. While these challenges are similar to those that arise when collecting information on other human uses, they are often heightened due to the industry's skepticism of how the data will be used (i.e., fear of further restrictions). This challenge can often be overcome through appropriate communications and by working with key industry representatives. Fishermen also have limited time to participate in these studies and it can be a challenge to schedule a workshop or an interview.

Recreational Fishing

In general, there are limited existing spatial data for recreational fishing. The MRFSS, conducted by NOAA NMFS, collects some information on recreational fishing activity, but these data are not typically spatial. Recent requirements for recreational saltwater fishing permits or registries will provide additional opportunities for gathering data from recreational fishermen, but this program is still in the initial stages of implementation in many regions. Lastly, some data on "for hire" recreational fishing activity (charters, party boats) are collected by NMFS through VTRs.

Researchers have used a range of methods to collect new data on recreational fishing activity in order to supplement these existing datasets. One common method for acquiring information on recreational fishing activity is through Web-based or mail surveys (Mahoney, forthcoming; Cudney-Bueno and Shaw, 2010). Participants are often selected at random or solicited dockside at ports or other locales where recreational fishermen congregate.

Collecting Recreational Fishing Data

The Oregon Recreational Fishing Survey (created by Ecotrust) and the Florida Saltwater Fishing Demonstration are examples of using surveys to collect human use information from recreational fishermen. The Oregon Recreational Fishing Survey uses an online mapping tool to gather information to assess the socioeconomic importance of ocean areas to recreational fishermen. The Florida Saltwater Fishing Demonstration also uses an online survey, but is slightly different in that it collects data on recreational fishing trips that involve boat trailering, and the data can be used to classify and analyze different types of trips. This demonstration gathers information on the fishing trip origin, launch location, boating routes, number of fish caught and released, and distance traveled to fishing destinations.

One-on-one or small group interviews, participatory GIS workshops, aerial surveys, and fixed point surveys have also been used to collect information on recreational fishing. As with commercial fishing, one-on-one or small group interviews give researchers an opportunity to directly engage recreational fishermen, but due to the variable nature of recreational fishing, it is difficult to generalize this information to the broader population (Scholz et al., 2004; St. Martin, 2005; RI CRC, 2010). Participatory GIS workshops provide an opportunity to collect information from recreational fishing representatives and allow for some level of consensus around high priority areas (Wahle et al., 2010a; A. Levine, personal communication).

While the data collection methods noted above can be effective in capturing new human use information, there are a number of challenges associated with each one. Recreational fishing is often difficult to generalize based on intermittent surveys and the randomness of fishing activity. Fishermen may be cautious or secretive about sharing their favorite fishing grounds due to crowding concerns, and data can be biased toward highly sampled popular areas.

4.3. Non-Consumptive Uses: Beach Access and Swimming, Surfing, Conservation, Maritime Heritage and Archeology, Diving, Tourism, Nature and Whale Watching, Recreational Boating

Non-consumptive uses are the most underrepresented out of the three human use categories examined in this report. There are no obvious preferences or trends when it comes to mapping these uses, since they are rarely mapped and are generally not included in most existing coastal and marine spatial plans in the United States and abroad. Data gathering for many non-consumptive uses poses a challenge due to the lack of regulation, the small size of user groups, and the perception that many of these uses are not as economically valuable as consumptive or military and industrial uses (conservation is an exception to this; see "Conservation" below). There are growing efforts in the United States to include non-consumptive uses in comprehensive mapping projects such as the California Ocean Uses Atlas, the New Hampshire and Southern Maine Ocean Uses Atlas, the Hawaii Coastal Use Mapping Project (Western Hawaii), and the Oregon Recreational Ocean Use Survey.

Common Approaches

The techniques employed to collect non-consumptive data are varied in technological sophistication and the amount of work involved in collecting the data.

Analysis and mapping of existing data: Many human use mapping efforts are merely a collection and analysis of existing data from known datasets. State and federal data can be used to spatially depict socioeconomic information (Allen, 2009), model recreational use (Itami et al., 2003), and complete risk and cumulative mapping (Halpern et al., 2009). Existing data often serve as base layers for participatory GIS exercises (Wahle and D'Iorio, 2010b; A. Levine, personal communication).

Aerial surveys: These surveys are conducted remotely using aerial photography or video to capture beachgoer attendance and location (Coombes et al., 2009) or marine mammal location (Buckingham, 1990; Leeney et al., 2009) for a specified period of time. In California and Australia, land-based video cameras have been used to determine environmental conditions, recreational uses, and increase safety along public beaches (C. Nelsen, L. Pendleton, personal communications). Early efforts to spatially zone the Florida Keys National Marine Sanctuary relied on data gathered from aerial surveys.

Participatory GIS in a workshop setting: Selected stakeholders or group representatives attend a workshop and assist in the development of representative human use mapping layers. This is the approach favored by the MPA Center as they developed Ocean Uses Atlases for California and New Hampshire/southern Maine (Wahle and D'Iorio, 2010b). Additionally, it is the primary method used for the Hawaii Coastal Use Mapping Project currently under completion for the North Kona and South Kohala coast of Hawaii (Wahle and D'Iorio, 2010b; A. Levine, personal communication).

Observation: Field observation can give researchers general information on recreational activities at a specific beach or help them map noncompliance with laws (Antos et al., 2007) or suggested guidelines (e.g., on whale watching – Stellwagen Bank National Marine Sanctuary, 2003; Walker, 2010). It is also a method by which existing data on beach public access points and wildlife viewing areas can be groundtruthed (Ohio Coastal Atlas and Ohio's Lake Erie Public Access Guidebook, B. George, personal communication).

Intercept or fixed point surveys: These field surveys are commonly used for gathering information from beachgoers (Shelby and Tokarczyk, 2002; Loomis et al., 2009) or recreational boaters (Gray, 2008). For intercept surveys, researchers stop users and ask questions, usually when stationed in popular use areas (e.g., boat landings, beaches). For fixed point and fixed area surveys, researchers observe activity (i.e., count people or vessels) from a single location.

State to Watch: Oregon

Oregon is an example of a state actively engaged in human use mapping. The state has had a Territorial Sea Plan (TS) in place since 1994, and recently amended it in 2009 to allow for inclusion of burgeoning ocean energy projects in state waters. The state is beginning to conduct the second phase of this amendment process, which is the actual mapping of areas suitable for renewable energy development. This phase includes surveys of non-consumptive, recreational users and gathering of other managed and regulated uses (including dredge material deposits sites, marine fiber optic cable crossing corridors, navigation corridors and tow lanes) (Oregon Coastal Management Program, 2010). The state is hoping to become a leader in wave energy development and development of this sector is being approached with careful consideration to traditional uses, most importantly fisheries, and community engagement. Unlike other CMSP efforts in the U.S. and abroad that prioritize traditionally mapped uses such as shipping, Oregon's TSP is prioritizing protection of renewable marine resources and other ocean projects will defer to this objective.

Mail, phone, or online surveys: These typical questionnaire-based surveys may use random representative samples (e.g., **Internet panels**; Pendleton and LaFranchi, 2009) in order to characterize the activity of the general population or be strategically distributed in order to capture a particular user group. For example, to target recreational boaters, mailing addresses can be obtained through vessel and boat trailer registration databases (Goldman et al., 1998; Sidman et al., 2001; Thomas and Stratis, 2002; Henry, 2005).

Voluntary website contributions: Volunteers contribute personal knowledge about use locations through website forms and maps.

Common Technology Used

Broadly, two types of data depiction prevailed. In studies that sought simply to map uses and patterns, human use data were gathered from one or more sources, digitized, and input into a GIS, such as OceanMap (e.g., Scholz et al., 2004, 2006). In cases when the researcher sought to examine a person's attitudinal response to a question (for example, "To what extent do you believe that the site you primarily use is in good ecological condition?") (Brown, 2005) as a function of activity location, then data were often coded and entered into a statistical software program for analysis and reporting (e.g., Loomis et al., 2007, 2009).

Desktop GIS: See the "Military and Industrial Use" and "Consumptive Use" sections. GIS is used during participatory GIS exercises, such as MPA Center's California, New England, and Hawaii human use mapping workshops (Wahle and D'Iorio, 2010b; A. Levine, M. D'Iorio, personal communications). GIS software in conjunction with digital whiteboards and tablets is used to capture user input.

GPS: An aggregate of GPS data gathered from whale watching vessels (Stellwagen Bank National Marine Sanctuary, 2009) can be combined with an aerial flight to take inventory of human uses like whale watching and fishing in particular area (Jacquet et al., 2005, 2006, 2007; Leeney et al., 2008, 2009; Mayo et al., 2004; Center for Coastal Studies, 2003).

Online mapping: Google Maps has become a common tool for mapping recreational "hotspots." Websites like WannaSurf and WannaDive[11] allow volunteers to input point data into Google Maps, as well as additional information on conditions.

Economic modeling and statistical analysis: Beach visitor counts can be modeled in relation to beach characteristics using Poisson regression (Coombes et al. 2009), random utility modeling of choices made by recreational boaters (Thomas and Stratis, 2002), travel cost non-market valuation of recreational beach users (King, 2001, 2002), and data analysis of recreational survey results (Pendleton and LaFranchi, 2009).

Common Data Collection, Analysis, and Presentation Challenges

A number of data collection, analysis, and presentation challenges can arise during human use studies, particularly attempts to collect non-consumptive use data. These challenges vary, depending on the data collection methods used. Some common challenges are listed below:

Uncommon activity (Pendleton and LaFranchi, 2009): Some non-consumptive uses, such as spearfishing, are completed by a very small segment of the population. A random sample of the general population may not yield anyone who engages in such uses, thus excluding them from the study.

Working with people: Collecting data from people for unpermitted or illegal uses can be challenging (A. Levine, personal communication). It can be difficult to work with different stakeholders because of varying levels of education, cultural differences, lack of interest in participating, language barriers, and concerns over confidentiality.

Non-Consumptive Uses: Current Efforts

The Surfrider Foundation, along with Ecotrust, Natural Equity and the Oregon Department of Land Conservation and Development, is conducting a non-consumptive use study in Oregon (*Oregon Recreational Ocean Use Survey)* to gather human use data on water sports (surfing, diving, kayaking), beach-going, wildlife viewing, and boating. The extent, demographics, and economic impact of the activity will be collected from recreational users (random sample and volunteers) using an online mapping tool. Additional information on recreational uses will be gathered through in-person interviews of coastal users at meetings, harbors, for-hire charter operations, and at key coastal intercept sites on the Oregon coast. This information will have various policy applications, including use during the TSP update process.

Trust: As with consumptive uses, non-consumptive stakeholders may be hesitant to provide data for mapping projects because they fear results will lead to restrictions of their use or stricter management.

Accuracy issues: There are often accuracy issues associated with each of the data collection methods and human use datasets. Survey bias, stakeholder cooperation, scale and resolution, and the use of technology are just a few factors that contribute to accuracy issues. Many methods use base maps to give the user a sense of the area being studied, so it is important that these maps be highly accurate. For example, in the Maryland Coastal Atlas project, the Ohio Coastal Atlas, and the ongoing Hawaii Coastal Use Mapping Project, existing data layers that were either being included in the atlases or serving as base layers were verified for accuracy through field work and stakeholder input during workshops (Cortina, 2010; A. Levine, B. George, personal communications).

[11] WannaDive, WannaSurf, WannaKitesurf: http://www.wannadive.net/, http://www.wannasurf.com/, http://www.wannakitesurf.com/

Consideration of multiple user and interest groups: It is important, and often challenging, to consider the varying user and interest groups when both collecting and presenting data for human use studies. Certain user group interests may affect the data collection and presentation process. The final presentation of human use data should balance the needs of managers with the sensitivities of the user group (i.e., security, privacy, proprietary info).

Cultural sensitivity: In some regions of the United States – for example, the Pacific Northwest and Pacific Islands – culturally significant coastal and marine areas are difficult to map during workshops because the perception of what is culturally significant can vary or people may be concerned about misuse of information and confidentiality issues (A. Levine, personal communication).

Intensity and quality: Aspects of non-consumptive uses are not currently being mapped although these concepts are critical to the usefulness of the data. There are few existing tools that allow researchers to determine intensity of recreational beach uses.

Surfing

Researchers and coastal managers in California have been gathering data on recreational beach users for small segments of the coast over the last few decades. As seen in California, beach attendance records and socio-economic data help coastal managers make decisions about responses to oil spills, beach nourishment projects, and a variety of other issues affecting the coast. Within the last decade, economic information on beachgoers has permitted more insight into what recreational uses mean to the coast, including non-market benefits, estimated at approximately $5.8 billion annually for the state of California (Pendleton, 2003, 2004).

More recently, beachgoer studies and surveys have started acknowledging a distinct difference in beach use patterns of surfers as well as the difficulty in capturing these distinct users using survey methods (Shaw and Jakus, 1996; Hanemann et al., 2004; Nelsen, 2007). It is now recognized that surfers have different visitation patterns, demographics, and interests when compared to other beachgoers, which means efforts to collect data, spatial or otherwise, must be adjusted to accommodate these issues (Nelsen, 2007). Surfers and other “uncommon activities” (Pendleton and LaFranchi, 2009) are not always captured by random sampling methods and therefore data need to be supplemented with more targeted surveys. Nelsen’s ongoing work compares surveys methods for gathering data on surfers in particular (intercept surveys and online opt-in surveys).

The collection of socioeconomic data on surfers in California serves as a type of foundation for mapping of the same users in the future, given that surveys often include a mapping component or questions regarding location of use. In future studies, data on the intensity of surfer visits and quality of the surf location will be necessary for a full understanding of surfer activity. The California Ocean Uses Atlas attempted capturing some intensity of use data by having participants select “dominant” use areas as opposed to the “general use” footprint (M. D’Iorio, personal communication). This data is admittedly more qualitative when compared to other intensity mapping. For example, AIS data for ships can be aggregated to create density maps (Figure 4.3). Additionally, the “dominant” use designation in the California Ocean Uses Atlas does not capture information on the quality of the surf spot. Along the Oregon coast, there are only a few high-quality surf spots that surfers consider to be iconic, yet the skill level required to surf these spots means they are accessible to a very small number of surfers (C. Nelsen, personal communication). Simply mapping density of use in this instance would not reveal anything significant for coastal planning purposes.

Whale Watching

The few studies that explore whale watch data gathering and mapping are focused on enforcement of voluntary guidelines and whale conservation. Whale watching vessels can similarly be tracked using GPS (Stellwagen Bank National Marine Sanctuary, 2009) as well as aerial surveys (Jacquet et al., 2005, 2006, 2007; Leeney et al., 2008, 2009; Mayo et al., 2004; Center for Coastal Studies, 2003). But, like recreational boating and fishing activities, whale watching is to a certain extent random and dependent on a variety of factors – most importantly, where whales are located. It is also important to note that whale watching does not necessarily only occur via commercial motorized boats (Walker, 2010). Recreational boaters and kayakers also participate in whale watching, but there is little data on these uses available.

Bird Watching and Wildlife Viewing

Similar to whale watching, bird and other wildlife viewing depends on the locations of birds and wildlife, which in turn depend on environmental conditions. Therefore, data identifying bird locations may be helpful in providing a proxy for bird watching user locations. Programs like the Great Backyard Bird Count and eBird[12] (National Audubon Society and Cornell Lab of Ornithology) are citizen-science efforts where users are given an opportunity to gather bird sighting data which is screened and verified before being used by the scientific community to increases understanding of bird distribution, richness, and biodiversity (eBird website, Figure 4.4). In many states, wildlife viewing platforms exist along the coast and are already mapped. Field visits by state managers in Ohio connected with development of the Coastal Atlas were an exercise in groundtruthing the locations of these platforms (B. George, personal communication).

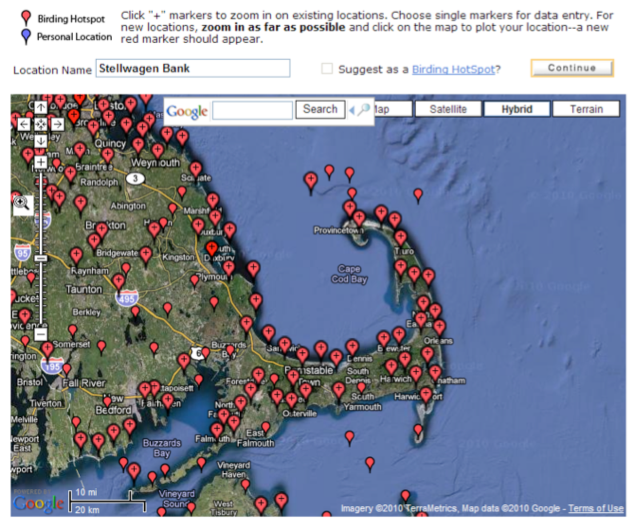

Figure 4.4 To address issues of data quality in Citizen-Science, eBird uses a combination of automated data filters and a network of local experts (http://ebird.org/content/ebird/about/ebird-data-quality).

Diving and Other Site-Specific Uses

As with bird watching and wildlife viewing, the locations of activities like snorkeling and scuba diving can to a certain extent be inferred from the resources attracting the use (reefs, shipwrecks, culturally significant sites and infrastructure e.g. moorings, rigs). There is little information, however, on mapping travel to and from these resources, as well as temporal and seasonality characteristics.

Conservation

Many projects have been undertaken to further general and specific conservation objectives. Indeed, because agencies and NGOs tend to first evaluate human uses of the coastal marine environment for their negative impacts, conservation and preservation programs tend to be primary drivers and beneficiaries of human use mapping studies (Ban et al., 2010; see spreadsheet

[12] eBird: http://ebird.org/content/ebird/

for additional references). However, there is some debate in the literature as to whether conservation itself is a “use” of the marine environment, with some arguing that it is a policy goal and others asserting that it is in fact a use with temporal and spatial dimensions. The August–September 2009 issue of *Marine Ecosystems and Management* contains a good synopsis of this debate (Davis, 2009).

Conservation: Activities and Impacts

Conservation studies often focus on the spatial dimensions of human uses as a way to determine negative impacts to the environment. In one such example, Ban et al. (2010) examined the exclusive economic zone of Canada’s Pacific coast. The researchers combined four categories of information to evaluate the connections between human uses and ecological outcomes: (1) spatial data on human activity location and intensity, (2) the kinds of stressors that result from these uses, (3) the relative impact of activities on habitats, and (4) the likely distance to which the effect of activities extends.

Conservation studies tend to fall first into two broad categories: those that are resource-intensive (i.e., that rely on technology and equipment) and those that are resource-light. The latter projects were more often associated with remote field sites, where the use of participant interviews, paper maps, and aerial photographs were common. However, several studies were a mix of methods. For example, to better understand the nature of regional resource use, Aswani and Lauer (2006) observed villagers’ behavior, used GPS devices to mark the locations of indigenously defined sites, and conducted open-ended and structured interviews. Across studies, data collection approaches included the use of aerial photographs in participant interviews, analysis of satellite photography, mining government databases and permit reports, the use of vessel logbooks, quantitative mail surveys with attendant maps, stand-off observation of an individual or group behaviors, and real-time data collection using ultra-portable GPS devices which can be easily carried on a person or watercraft. Because such devices record temporal and spatial data, the information being transmitted includes popular routes and residence time at specific locations, such as reefs.

A number of conservation studies particular to human use mapping were related to marine protected area (MPA) planning. Participatory GIS has been used in a number of locales as a mechanism to provide for stakeholder input and to understand important areas of traditional and recreational fishing (as well as other marine uses) for the purpose of MPA planning. For example, Aswani and Lauer (2006) encourage the use of traditional spatial knowledge to inform MPA development in Oceania and Moreno-Báez et al. (2010) apply spatial mapping techniques to aid fishery management in the Gulf of California (Figure 4.5). A multi-faceted project to obtain spatial data across a variety of marine uses resulted in a complex and comprehensive rezoning of the Great Barrier Reef Marine Park early this decade (Lewis et al., 2003).

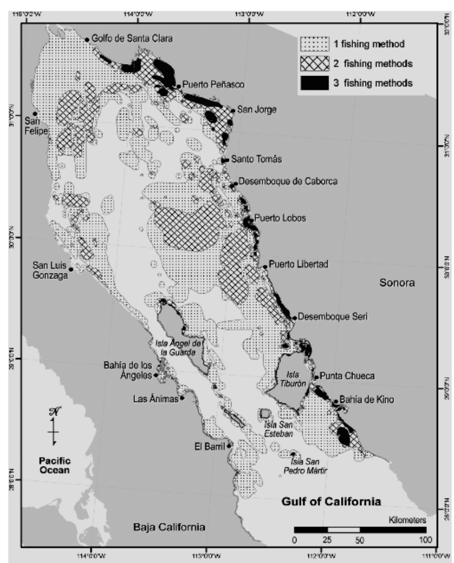

Figure 4.5 Mapping in the Gulf of California to aid fishery management (Moreno-Báez et al., 2010).

Spatial data has the ability to aid management in a number of generic ways. For example, conservation of coastal mangrove forests in India was given a boost by an assessment of the spatial nature of mangrove cutting (Ambastha et al., 2010), while linking survey-derived data to general and specific locations (Brown, 2005; Loomis et al., 2007) can inform carrying-capacity decisions, provide social validation of expert assessments, and develop marine patrol schedules. Linking data to locations has seen increasing attention in the past several years, with researchers asking respondents to indicate locations of their activities on enclosed maps and then linking that data to the person's responses to survey questions about, for example, perceptions of ecological health (Brown, 2005; Loomis et al., 2007).

Challenges in the conservation arena are broadly similar to those in other non-consumptive categories. One important challenge is fostering stakeholder trust. This is because conservation activities are often viewed with some skepticism by those who use and depend on the local resource. Conservation activities tend also to be policy-oriented. Other challenges include the number of uses that must often be incorporated for conservation purposes, the size of some sites (e.g., the Great Barrier Reef Marine Park stretches more than 2,300 kilometers along Australia's northeast coast), and the lack of data about many of the uses that are of conservation importance – about both the uses themselves and the habitat and ecology in the areas where those uses occur.

Beach Access and Swimming

As mentioned above in the discussion on surfing, beach access and swimming data have often been gathered together. Aerial, onsite, and mail surveys are the most common approaches to collecting data on these uses. Aerial surveys face challenges in capturing the temporal aspect of beach access since they are a snapshot in time (Jones, 2009). This type of data supports coastal management activities by allowing review of whether there is a need for more facilities to support the use (more beaches, more facilities); an understanding of how climate change may affect coastal recreation; inclusion in shoreline and beach management plans or conservation plans; and determination of beach nourishment project funding. Currently, there is no evidence of incorporation specific beach activities into CMSP, but as mentioned previously, few non-consumptive uses have been included in CMSP efforts to date.

Recreational Boating

As with recreational fishing, there are few existing datasets that can be used to characterize recreational boating activity. This is largely because there are few regulations that limit recreational activity or require reporting. Since recreational boaters are such a significant user group, there are many different studies that attempt to acquire new data for a variety of purposes.

One common way to obtain new data on recreational boating activity is through a survey. Surveys can be implemented through the mail (Stynes et al., 1994; Sidman et al., 2001; Thomas and Stratis, 2002; Henry, 2005), in-person, or on the Web. Recent technological advances have facilitated the development of mapping applications that are increasingly being used to collect data on human activity through Internet-based surveys (Napoli et al., study underway). Survey participants are often selected from the state boat registration database at random, allowing the information obtained from the study to be

Collecting Recreational Boating Data

Online, paper, and in-person surveys are often used to obtain recreational boating human use data. The Massachusetts Recreational Boater Survey is an example of a Web-based survey that contains an online questionnaire and mapping application where boaters provide information on their boating routes and activities. The Boating in Oregon study used the paper survey approach, where questionnaires were mailed to a random sample of boaters to obtain information on the types, locations, and amount of recreational boating in Oregon. Finally, *A Case Study of Recreational Boating in the Southern Gulf Islands, British Columbia,* is a prime example of gathering information through an in-person survey. In this study, boaters were approached on the water and asked to report on their current trip, specifically including details on their route, destination, and general boating activity.

generalized to the population. In the case of in-person surveys, researchers approach boaters and ask for information on their current trip (route, destination, etc.) (Gray, 2008). Information from these methods is then digitized into GIS for mapping and analysis.

In aerial surveys, an observer on a plane either records on video or takes photographs of recreational boating activity, and the information collected is then digitized into GIS maps (Jacquet et al., 2005, 2006, 2007; Leeney et al., 2008, 2009; Mayo et al., 2004; Center for Coastal Studies, 2003). Aerial surveys can be used to determine popular boating routes, destinations, or anchorage sites.

The information collected on recreational boating can have a number of different management applications, such as law enforcement and safety (Thomas and Stratis, 2002; Henry, 2005), recreational facility management (Stynes et al., 1994; Resources Studies Center, 2001; Henry, 2005), anchorage management (Sidman, 2000), and environmental risk analyses (Gray, 2008). Recreational boating data can also be used in development of developing plans geared toward conservation (habitat protection) (Thomas and Stratis, 2002) or multiple uses (Napoli et al., study underway). Furthermore, with the new movement towards CMSP, any data collected on recreational boating will be critical to developing a comprehensive plan that accounts for the varying uses of the ocean.

The challenges that exist for collecting data on recreational boating activity are similar to those for recreational fishing mentioned above (i.e., surveying bias, randomness of user activity, intermittent surveys, and caution about sharing favorite boating routes/destinations). In addition, some studies require state boat registration data, which may be challenging to obtain due to confidentiality concerns.

Maritime Heritage and Archeology

Marine archeologists use a variety of methods to locate and identify inundated sites. A survey starts out in the archives/library and the State Historic Preservation Office (SHPO), where maps and historical documents are examined to determine the location of shipwrecks and other types of underwater sites and to provide a context for understanding the different types of resources that may be encountered. Often the scope of the project will determine the boundaries of the area to be examined, but not always. Archeologists determine the extent of the physical resource through archeological survey and draw boundaries around the resources that meet the National Register Criteria or applicable state historic preservation criteria.

State to Watch: Virginia

The Virginia Historic Resources Data Sharing System (DSS) is a joint venture between the Department of Historic Resources (DHR) and the Virginia Department of Transportation. The two agencies collaborate to provide a platform for dissemination of and enhancements to survey records in the DHR inventory. This online system merges a database of historic and prehistoric sites throughout Virginia with a GIS for efficient querying. There are over 110,000 historic (archaeological and architectural) resources recorded in the DSS. The locations of these resources are also mapped and can be viewed in the GIS portion of the DSS. This number includes historic resources listed in the Virginia Landmarks Register, resources listed in the National Register of Historic Places, and resources that have been evaluated for potential listing in the registers. Thousands of additional records of contributing and non-contributing properties within historic districts are also entered into the database.

SHPOs are an excellent source of information for determining the locations of maritime heritage and archeology sites. They have large inventories of historic coastal sites, which are populated via mapping themselves, accessing research, hiring out project consultants, or obtaining information from state environmental review processes. Depending on whether the site is prehistoric or historic, their “mappers” use topographical visual studies based on literature, local lore from divers and fishermen (including "hang charts") historic shipping records, NOAA surveys, Lloyds' Registers, and U.S. Coast Guard inventories.

Valuable mapping information becomes available every time a project proponent triggers an environmental review requirement. While the process varies by state, the SHPO often receives funding from the potential developer to launch a survey, which will result in mapping. Alternately, the project proponent can hire a consultant to do the mapping. The SHPO can play an important role in pointing out potential sites for investigation, the form the study should take, and what mapping method should be used. The SHPO determines the site's potential for being significant and possibly eligible for protection under state and federal historic preservation regulations (K. Abbas, personal communication).

In Massachusetts, cultural or historic sites are often mapped at the municipal level, through a GIS, and then integrated at the state level into a databank of heritage resources called MACRIS[13]. Research is usually carried out by study of historic maps, local written histories, and analysis of period photographs (C. Dempsey, personal communication). Virginia's DHR collects most of this information through consultants that submit surveys on behalf of developers to comply with environmental and historic preservation laws (although reporting is not consistent) (Figure 4.6). Since archaeological sites may easily fall victim to looting or destruction, specific information is generally not accessible to the public. This is especially true for maritime resources (J. Smith, personal communication).

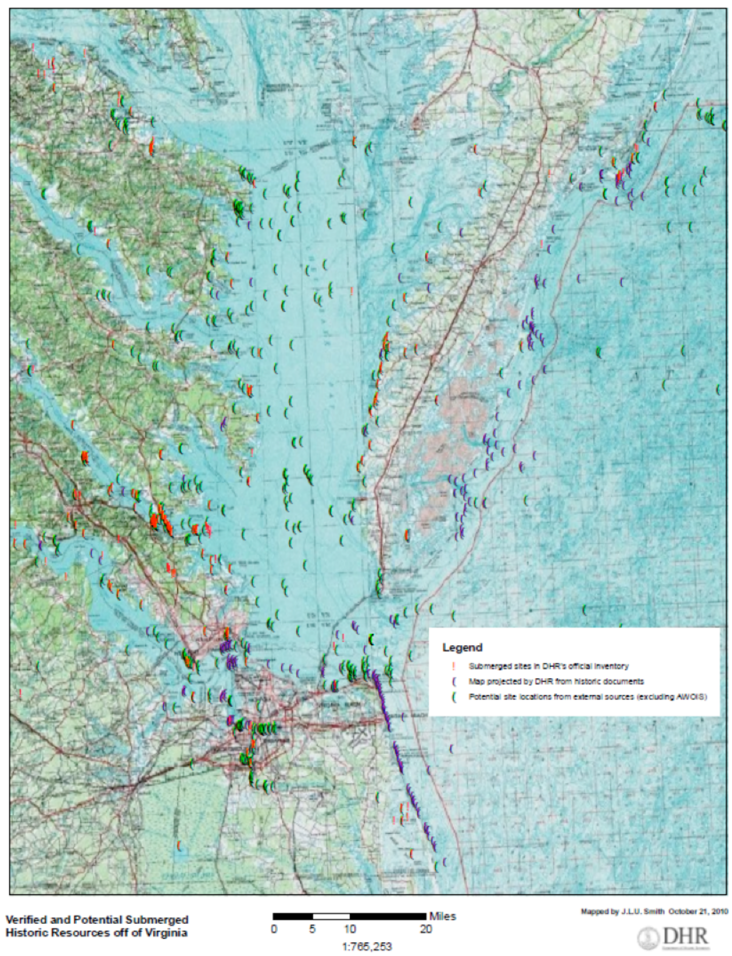

Figure 4.6 **MAP of submerged DHR sites (courtesy of J. Smith).**

Looking Beyond Use-Specific Applications

The tools that enable human use mapping (i.e., remote sensing, GIS, and their related data foundations) evolved to deal with problems on dry land, and a great deal has been learned about how to apply the principles and practices of GIS to the terrestrial surface. However, the use of GIS has grown much more slowly in the marine and coastal environment than in the terrestrial sector. This reflects the complexities of working in the coastal marine domain (Meaden, 2000), which, unlike the terrestrial surface, does not provide for a rigid coordinate

[13] MACRIS: http://mhc-macris.net/index.htm

system that can be used to position any feature. Practitioners have had to adjust their methodologies and develop different ways of presenting spatial information that account for the absence of an absolute coordinate system (Wright and Bartlett, 2000).

For this reason, marine application has generally lagged behind. For example, little growth occurred in GIS applications in fisheries until the 1990s (Meaden, 2000), and those applications tended to be focused on aquaculture site location, since this is akin to a terrestrial operation: sites are static and data are easily acquired. While it is telling for human use mapping that GIS was slow to develop for use in commercial fishing management, where logbooks record catch and latitude/longitude data typically exist, it is also the case that coastal marine GIS practitioners have largely focused their efforts on environmental features, such as reefs, mangroves, and sea grass areas, rather than human activities. This focus has stunted human use mapping efforts.

Nevertheless, increased interest in the oceans has furthered improvements in GIS applications and methods in this domain (Wright and Bartlett, 2000). Perhaps nowhere has the knowledge gained in terrestrial applications been more useful than with the recent paradigm shift to place-based management of fisheries and other marine resources (Pauly, 1997). Place-based (or site-based) management provides at least two benefits to GIS application: (1) it allows managers to focus on questions about what people are doing and where within given boundaries and (2) it is often linked to more consistent funding streams. Examples include the comprehensive rezoning of the Great Barrier Reef Marine Park Authority and the spatial zoning scheme of the Florida Keys National Marine Sanctuary.

More recently, as data and tools have become increasingly available, resource managers and GIS analysts are turning their attention to the use of terrestrial tools, such as specific-purpose GPS devices, to map transit routes and activity locations in the marine environment. For example, a new marine study for the U.S. National Park Service in Biscayne National Park will be based on technology and methods used in a terrestrial Parks Canada project that tracked hikers (Loomis et al., study underway).

One fairly new, and promising, area of inquiry is cumulative impact mapping (Halpern et al., 2009; Selkoe et al., 2009). Here, information regarding a number of anthropogenic drivers is entered into a database and then exported to a GIS in order to understand the magnitude of these drivers' combined impact on coastal marine environments. While the current literature includes more general variables, such as marine pollution and climate data, a researcher could use this approach to isolate more direct human use information and map hotspots of activity.

5. Data Gaps

Several gaps in data, methods, and technology were identified during this study's literature review and interviews with experts and practitioners. However, there may be tools and approaches to aid in addressing some of these gaps going forward. The following are a few noticeable gaps in human use mapping methods and some corresponding potential tools and/or strategies:

5.1. Military and Industrial Uses Key Gaps

Impact data: While regulated uses have established footprints, the impacts from their operation are not mapped, including construction impacts and day-to-day impacts (e.g., vessel traffic to and from oil platforms).

Mapping standards: Spatial data on resources, like sand and gravel, are often gathered to meet internal needs of a state or federal agency and are not available for the public's use (G. Wikel, personal communication). This means mapping is not always completed with established standards and may not include accurate **metadata** (M. Huber, personal communication).

Smaller industrial uses: Existing data may underrepresent smaller industrial uses. For example, AIS only cover vessels over 300 tons, resulting in a lack of information on a number of smaller vessels that may be conducting significant commercial non-fishing activity.

Current limits of Google Earth: Higher-resolution satellite imagery has been made available sporadically on Google Earth, but imagery for federal waters is for the most part unavailable.

Potential Solutions

Mapping standards: Data sharing capabilities might be improved if standards could be adopted across state and federal agencies and the same versions of software could be made available. The continued development of regional data portals to support regional CMSP efforts (see the introduction) will help organize and screen data, including verification of attached metadata.

Cumulative mapping: Managers seeking to implement ecosystem-based management will need an understanding of the multiple, simultaneous impacts occurring in the coastal and marine zone (Halpern et al., 2009). There already some studies and CMSP efforts in existence that are investigating cumulative impacts of human uses (Halpern et al., 2009; EOEEA, 2009; RI CRC, 2010).

Updating online mapping application: Google Earth and Google Maps were frequently mentioned in the literature and interviews as tools used to map and gather data on human uses. Human use mapping efforts would benefit greatly from the addition of high-resolution satellite imagery beyond the nearshore environment.

5.2. Consumptive Uses Key Gaps

Lower-value fisheries: Smaller fisheries (in terms of overall landings and value) can be overlooked or underrepresented in commercial fishing studies. Whether through an analysis of existing data or through the collection of new information from the industry, researchers often focus on the higher-value fisheries. While this may be appropriate considering budget and management requirements, it can often lead researchers to overlook the importance of these smaller fisheries to specific operations and communities.

Illegal fishing activities: Fishing with poisons or unregulated gear is illegal and can damage to marine habitats. People who participate in these activities are unlikely to be forthcoming about where these uses occur for fear of repercussions.

Potential Solutions

Smaller-scale studies: To account for smaller fisheries and regional differences in fisheries, mapping at a smaller scale may improve coverage. As seen in participatory GIS efforts, the smaller the geographic area of the study, the more specific the desired mapped uses can become.

Online surveys: There is the potential for online surveys to fill the gap of mapping illegal fishing activities. If participants may remain anonymous, they may be more likely to divulge where these activities are known to occur.

5.3. Non-consumptive Uses Key Gaps

Not regulated: Recreational uses or other uses that are not regulated have limited existing data. These uses can be challenging to characterize because they are often random (influenced by the weather, economy, and time of year).

Quality and intensity data: When a use cannot be tracked with GPS, intensity mapping becomes more difficult. Additionally, gathering data on quality of a use experience – such as a scenic kayaking route or challenging surf spot – through workshops or individual interviews is often resource-consuming.

Larger-scale data gathering and mapping: Data gathering on non-consumptive uses through participatory GIS has occurred at a large scale (the entire California coast) for the California Ocean Use Atlas and smaller scales (the North Kona coast, Hawaii; New Hampshire/southern Maine) for the Hawaii Coastal Use Mapping Project. Other methods cannot be as easily adjusted from one scale to another. For example, recreational beach intercept surveys become particularly difficult at larger scales when there are numerous public access points across multiple beaches (L. Pendleton, C. Nelsen, personal communications).

Data standardization: Currently, multiple methods are being suggested to gather and map non-consumptive use data. Unfortunately, this means that using these studies to inform parallel and future projects, as well as make regional and national policy decisions, is not possible if they are too disparate in methods and technology.

Organized constituency: Many of these uses do not have a centralized stakeholder group to partner with, making it difficult to conduct a human use study. As mentioned above, there are also considerable challenges in collecting data on illegal practices, even though these are activities that do occur and have significant impacts on the surrounding environment.

Beach uses and other uncommon activities: Surfing and similar surface water sports are popular in many coastal states, but people who partake in these activities still represent a small portion of the general population.

Mapping culturally significant areas: This remains a challenge to human use mapping efforts due to the sensitive nature of the topic. Native American and indigenous groups may vary in their knowledge or opinion of which areas are culturally significant and may not feel comfortable sharing where significant areas are located, or why an area is considered culturally significant. While it is important to acknowledge the significance of these areas, native/indigenous representatives should be consulted to determine how (and if) these areas should be mapped, as well as what information is deemed to be confidential. It may be necessary to map these areas as broader regions, or to refrain from publishing certain mapping outcomes, in order avoid conflict or a breech of confidentiality (A. Levine, personal communication).

The MPA Center's Ocean Uses Atlas Project

NOAA's MPA Center, in partnership with the Marine Conservation Biology Institute, completed a statewide participatory mapping effort in California in 2009. The Ocean Uses Atlas brought together selected individuals to map nearly 30 military/industrial, fishing, and non-consumptive uses of state and federal waters. Data has been processed and can now be accessed and viewed online at: http://www.mpa.gov/dataanalysis/mpainventory/mpaviewer/mpaOceanUseAtlas.swf.

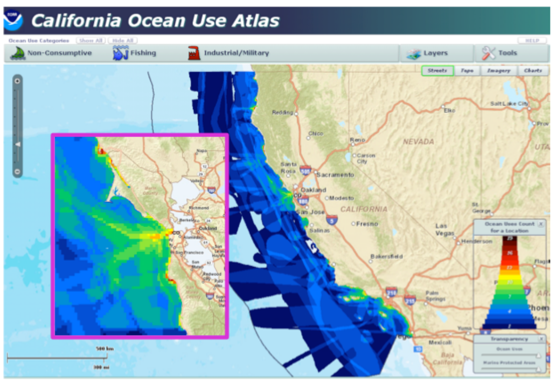

Figure 5.1 Interactive California Ocean Uses Atlas Mapping Tool displaying aggregated uses.

In early 2010, the MPA Center partnered with the University of New Hampshire Coastal Response Research Center to conduct a similar human use mapping exercise as part of a Spill of National Significance (SONS) drill to fill in critical gaps in ocean use data in New Hampshire and southern Maine. The data will be used to increase accuracy and efficiency of agency responses during an actual spill. With the new maps, agencies will be able to quickly answer important questions such as which resources and uses are being affected; how users, if possible, can be diverted elsewhere; and how to prioritize response actions.

Other ocean use mapping efforts are underway in the Pacific, where the MPA Center has teamed with various state and federal agencies to assist in mapping ocean uses along the Northwest coast of Hawaii. In September 2010, the Hawaii Coastal Use Mapping Project led participatory mapping workshops with local ocean experts that will yield detailed use data, maps and tools needed to support conservation planning and resource management objectives.

Potential Solutions

Beach cameras: Watch the Water and other coastal monitoring networks currently use land-based cameras to record beach activity. The cameras can provide information on environmental conditions and recreation, improve beach safety, and lead to better coastal zone management. They would not allow for exact mapping of uses, but could contribute data on non-consumptive use intensity and quality.

Portable GPS devices: Used in terrestrial studies, portable GPS devices would give researchers and managers the ability to aggregate recreational user data to get a better sense of intensity of use which can be easily carried on a

Collecting Non-Consumptive Data: Surfing

Data on surfing and increasingly popular surface-water sports like paddle boarding is hard to come by. Methods to collect data often rely on in-person or online surveys. There are tradeoffs between methods: random surveys often cannot capture surfers due to the small subset of the population that surfs while non-random surveys like opt-in online surveys are more difficult to replicate. The state of Oregon is currently collecting data to support mapping of recreational uses in their TSP, and will include both a random sampling of recreational users (via Internet panel) as well as an opt-in online mapping survey to capture uses that may be overlooked by the panel. In addition to trade-offs between methods, data on non-consumptive uses must document more than presence/absence of the use. To be valuable to coastal and marine planning, the quality and intensity of the use must be mapped as well.

person or watercraft. Because such devices record temporal and spatial data, the information being transmitted includes popular routes and residence time at specific locations, such as reefs.

Opt-in surveys: Surveys where people agree to be part of the panel based on their interests are able to capture uncommon uses that otherwise may not be represented if a random sample of the public was used (see the highlight box above).

Additional Recommendations Going Forward

Qualitative and quantitative non-consumptive data: Several experts interviewed suggested the importance of both quantitative and qualitative information when mapping non-consumptive uses. Surveys that can address both quality and intensity of a recreational use at a particular location could be combined with participatory GIS mapping exercises to develop extremely robust non-consumptive use datasets.

Improving trust: Stakeholders will be more willing to provide spatial data on their uses if they have a better understanding of the end goals, i.e., mapping compatible uses. From a participatory standpoint, managers must overcome a management environment in which spatial data have sometimes been used in ways that the providers of the data perceive to be to their detriment – equated with closures and a loss of freedom (M. D'Iorio, personal communication).

Input from key stakeholders: An advisory group of key stakeholders from the industry can provide useful input during the development and implementation of a human use study. Advisory group members can help design studies that are appropriate for their use, communicate the details of the study to their constituents to enhance understanding and encourage participation, as well as relay any stakeholder concerns about the study to the researchers. Advice from key stakeholders throughout the process will ultimately result in greater support from the industry and greater participation in future studies.

Incentives: Incentives (both cash and prizes) have been used as a means to encourage input on human use activity from stakeholders (e.g., in the Massachusetts Recreational Boaters Survey). Incentives can be especially useful in reducing attrition in studies that ask respondents to participate over a period of time.

Cross-agency collaboration and education: With the recent focus on CMSP, existing state and federal agency datasets are increasingly being used in ways in which they were not originally intended. Increased cross-agency collaboration and education about these datasets and their potential uses would help clarify the opportunities and constraints to characterizing human uses when using these data sources. This would in turn help to clarify human use data gaps and the potential for addressing these gaps using existing reporting mechanisms and authorities.

Best practices: In the future, regional CMSP efforts could greatly benefit from lessons learned from completed or planned human use data collection and mapping studies. Based on their experiences with the California and New Hampshire/Southern Maine Ocean Use Atlases, the MPA Center has compiled a best practices manual to help guide participatory GIS efforts (Wahle and D'Iorio, 2010b).

Accuracy: Redundancy can be built into the participatory GIS mapping procedure (A. Levine, M. D'Iorio, personal communications). If each small group within the larger workshop is mapping the same uses, areas of overlap usually occur. Stakeholders are reconvened to review preliminary results and share feedback as well as verify accuracy of existing data layers (Cortina, 2010; A. Levine, personal communication).

6. Conclusion

Data on human uses of the ocean are being collected and mapped by a variety of methods which are certainly not one-size-fits-all. Availability of data, the scale of the study area, and overall project goals will all affect the type of method and technology selected. There are some broad conclusions that can be drawn from this overview of human use mapping methods:

- *Regulation:* Human uses that are more heavily regulated tend to have more data available and mapped. Despite the growing amount of literature supporting the economic benefits of non-consumptive uses, for the most part they remain (with the exception of conservation) unmapped.
- *Scale:* The literature and interviews revealed that the geographic scale of a study area will affect the type of mapping methods used. For example, smaller-scale management plans require highly detailed human use data and this in turn lends itself to participatory GIS as an appropriate method; for development of state CMS plans or other larger scale efforts, Internet surveys may be an affordable and useful option. However, developing robust human use datasets may mean combining survey-based methods with participatory GIS methods for any scale project (funding permitting).
- *Data access:* The methodology chosen to map human use data is often affected by the availability of and access to other data about the use. For example, several recreational boating surveys relied on access to an existing boat registration database. Boaters were chosen from the database at random and invited to participate in a survey. If a boat registration database had not been available, researchers might have decided to use a volunteer or intercept survey instead of a random sample.
- *Applications:* The policy and management context for the human use study is one of the biggest factors influencing the chosen method and the results. For example, if the goal is to use the information for facility management or to ensure that there are adequate services to support a use, then the study tends to focus on overall visitation and use and may not produce high-resolution spatial information. Alternatively, studies conducted to support CMSP will usually produce higher-resolution spatial information for high-priority sites or densely traveled routes. It is important to understand the policy and management context when researching or using data from previous studies and when designing new human use studies.

The deficiency of human use data in several categories creates a challenge for the United States as it embarks on implementing a National Ocean Policy with ecosystem-based management and CMSP as two key objectives. It is the hope of NOAA CSC that this preliminary review of human use mapping methods will illuminate human use mapping progress as well as gaps, in order to improve human use mapping in the future.

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8. Appendices

APPENDIX A: Glossary

Bathymetry: The measurement of depths of water in oceans, seas, and lakes; also the information derived from such measurements. (See www.csc.noaa.gov/text/glossary.html.)

Coastal and Marine Spatial Planning (CMSP): A comprehensive, adaptive, integrated, ecosystem-based, and transparent spatial planning process, based on sound science, for analyzing current and anticipated uses of ocean, coastal, and Great Lakes areas. CMSP identifies areas most suitable for various types or classes of activities in order to reduce conflicts among uses, reduce environmental impacts, facilitate compatible uses, and preserve critical ecosystem services to meet economic, environmental, security, and social objectives. (See http://www.whitehouse.gov/files/documents/OPTF_FinalRecs.pdf, Final Recommendations of the Interagency Ocean Policy Task Force, 2010).

Digital/interactive whiteboard: A large interactive display that connects to a computer and projector. A projector projects the computer's desktop onto the board's surface where users control the computer using a pen, finger or other device. The board is typically mounted to a wall or floor stand. (See http://en.wikipedia.org/wiki/Interactive_whiteboard),

Digital tablet: A computer input device that allows one to hand-draw images and graphics, similar to the way one draws images with a pencil and paper. (See http://en.wikipedia.org/wiki/Graphics_tablet).

Digitize: The process of converting the geographic features on an analog map into digital format using a digitizing tablet, or digitizer, which is connected to a computer. Features on a paper map are traced with a digitizer puck, a device similar to a mouse, and the x,y coordinates of these features are automatically recorded and stored as spatial data. (See http://resources.arcgis.com/glossary).

Federal Register: The official daily publication for rules, proposed rules, and notices of Federal agencies and organizations, as well as executive orders and other Presidential documents. (See http://www.federalregister.com/).

Geographic information system (GIS): A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. (See www.gis.com/whatisgis/index.html).

Global Positioning System (GPS): A system of radio-emitting and -receiving satellites used for determining positions on the earth. The orbiting satellites transmit signals that allow a GPS receiver anywhere on earth to calculate its own location through trilateration. Developed and operated by the U.S. Department of Defense, the system is used in navigation, mapping, surveying, and other applications in which precise positioning is necessary. (See http://resources.arcgis.com/glossary).

Internet panel survey: Survey that uses random samples of a large, pre-selected group of volunteer respondents who have agreed to participate in surveys (Pendleton and LaFranchi, 2009).

Lease blocks: In accordance with the Code of Federal Regulations, Outer Continental Shelf (OCS) lease blocks and administrative boundaries are generated to define small geographic areas that identify federal land ownership and support offshore resource management. (See http://www.csc.noaa.gov/digitalcoast/data/ocsleaseblocks/index.html).

Metadata: A metadata record is a file of information, usually presented as an XML document, that captures the basic characteristics of a data or information resource. It provides the who, what, when, where, why, and how of the resource. (See www.fgdc.gov/metadata.)

Participatory GIS: A technique that offers a unique, interactive means of collecting spatial information on ocean uses that capitalizes on expert knowledge from local individuals through the application of specialized GIS mapping tools (Wahle and D'Iorio, 2010b).

Point: A geometric element defined by a pair of x,y coordinates. (See http://resources.arcgis.com/glossary).

Polyline: A shape defined by one or more paths, in which a path is a series of connected segments. If a polyline has more than one path (a multipart polyline), the paths may either branch or be discontinuous. (See http://resources.arcgis.com/glossary).

Shapefile: A vector data storage format for storing the location, shape, and attributes of geographic features. A shapefile is stored in a set of related files and contains one feature class. (See http://resources.arcgis.com/glossary).

Use footprint: Area (represented as a polygon in GIS) where a human activity is know to occur. Three categories of use footprints were use during the California Ocean Uses Atlas project (see http://www.mpa.gov/pdf/helpful-resources/factsheet_atlasmar10.pdf):

General Use Footprint: Areas where the use is known to occur with some regularity, regardless of frequency or intensity.

Dominant Use Areas: Areas within the general use footprint where the use is pursued by most of the users, most of the time.

Future Use Areas: Areas where the patterns of use may either expand or increase in intensity in the foreseeable future.

APPENDIX B: Personal Communications

List of people interviewed by phone or email:

Kathy Abbas, Rhode Island Marine Archaeology Project
Claire Dempsey, Massachusetts Program in Historic Preservation, Boston University
Camille Destafney, Naval Facilities Engineering Command (NAVFAC), Southeast
Mimi D'Iorio, NOAA
Brian George, Ohio Department of Natural Resources, Office of Coastal Management
Madeleine Hall-Arber, Massachusetts Institute of Technology (MIT) Sea Grant
Jeff Herter, New York Department of State, Division of Coastal Resources
Michael Huber, Department of Defense Regional Environmental Coordination (DoDREC 9)
Phillip King, San Francisco State University
Arielle Levine, NOAA, Pacific Islands Regional Office
Nick Napoli, Massachusetts Ocean Partnership
Chad Nelsen, Surfrider Foundation
Harry Norris, Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission
Linwood Pendleton, Duke University
Joe Perryman, Bureau of Ocean Energy Management, Regulation and Enforcement
Sue Senecah, New York Department of State, Office of Coastal, Local Government, and Community Sustainability
Jolene Smith, Virginia Department of Historic Resources
Charles Steinback, Ecotrust
Geoffrey Wikel, Bureau of Ocean Energy Management, Regulation and Enforcement

APPENDIX C: List of Personal Communication Questions

Which human uses do you map?

What step-by-step processes have been used to derive usable human use data? (Maybe more than one process…)

- How is the use data acquired?
- What are human use mapping approaches to engage specific groups and individuals when collecting spatial human use data?
- Is the data accuracy verified through a review or groundtruthing?
- What are some of the tools and technology used to collect and map human use data?
- Mapping standards?

What are some applications of the data gathered?

What is the general degree of technical and content knowledge required to map this human use?

What are some of the challenges and limitations of data collection, analysis, and presentation?

Other organizations/projects/individuals collecting the same type of use data that you're aware of?

Any methods for collecting other types of data that may be transferable to collecting human use data in coastal and marine environments?

How, and to what degree, are human use data being used to make coastal management decisions?

Future of human use mapping? How will human use data be used?

Why do you believe there are gaps in mapping methods for particular human uses? How do you believe this could be remedied?

How comfortable would you feel using mapped human uses in developing CMS Plans, management decisions, etc.?

Any studies or reports you could recommend that are good examples of their use or set of uses?