Environ Manage (2006) 38:597–617
DOI 10.1007/s00267-005-0265-4

Identifying Potential Conflict Associated with Oil and Gas Exploration in Texas State Coastal Waters: A Multicriteria Spatial Analysis

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Received: 23 August 2005 / Accepted: 28 April 2006

Abstract Recent interest in expanding offshore oil production within waters of the United States has been met with opposition by groups concerned with recreational, environmental, and aesthetic values associated with the coastal zone. Although the proposition of new oil platforms off the coast has generated conflict over how coastal resources should be utilized, little research has been conducted on where these user conflicts might be most intense and which sites might be most suitable for locating oil production facilities in light of the multiple, and often times, competing interests. In this article, we develop a multiple-criteria spatial decision support tool that identifies the potential degree of conflict associated with oil and gas production activities for existing lease tracts in the coastal margin of Texas. We use geographic information systems to measure and map a range of potentially competing representative values impacted by establishing energy extraction infrastructure and then spatially identify which leased tracts are the least contentious sites for oil and gas production in Texas state waters. Visual and statistical results indicate that oil and gas lease blocks within the study area vary in their potential to generate conflict among multiple stakeholders.

Keywords Site suitability · Oil and gas · Texas, coastal · Geographic information systems

Oil and gas reserves within the coastal margin have long been considered important sources of petroleum energy worldwide. However, increasing interest in offshore oil production in the United States has generated conflicts over the sustainable management of coastal and marine resources. In recent years, multiple interest groups have opposed industry efforts to lease submerged lands for drilling and extracting petroleum products, particularly those concerned with recreation, commercial fishing, biodiversity, and aesthetic value of the coast. Public officials in Florida and California, for example, have resisted efforts to renew offshore oil drilling on the grounds that environmental, tourism, and aesthetics values will be negatively impacted.

Although the suggestion of new oil rigs and related facilities in coastal waters has spawned intractable conflict over how coastal resources should be utilized, little research has been conducted on where these user conflicts might be most intense and which sites might be most suitable for locating oil production facilities in light of the multiple, and often times, competing values associated with the coastal zone. Although there are numerous laws and permitting processes that regulate the coastal petroleum industry

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in the United States, there exists scant literature on using multiple criteria to determine suitable sites for offshore oil and gas production, particularly from a spatial perspective. Furthermore, there is no framework for systematically considering multiple criteria (i.e., multiple values and uses of stakeholders) when determining locations for oil and gas extraction infrastructure in coastal waters, particularly in Texas state-owned waters.

Our study addresses this research gap by spatially evaluating multiple value-based criteria for establishing oil production facilities off the coast of Texas. We combine methods for multiple-criteria decision-making (MCDM) and spatial decision support systems (SDSSs) to develop an evaluation approach that identifies the least contentious locations for oil and gas production activities among existing lease tracts in the coastal margin of Texas. Specifically, we (1) use geographic information systems (GISs) to measure and map a range of potentially competing spatially approximated values impacted by establishing oil and gas extraction infrastructure for all leased tracts in Texas state waters and (2) spatially and statistically analyze site-suitability scores based on overlapping proxy values to identify existing tracts in which locating oil and gas extraction infrastructure migh generate the least degree of conflict. Results provide insights on how policy makers and industry leaders can use SDSSs to consider multiple user values (in addition to the location of petroleum reserves) when locating offshore oil and gas production facilities.

The following section examines three interrelated literatures supporting this study: (1) environmental conflict management and dispute resolution; (2) the use of MCDM systems to resolve environmental conflicts; and (3) SDSS analysis. The next section describes the selection of the study area, concept measurement, and the GIS calculation and mapping techniques used to analyze each lease tract. Results are then reported in three phases. First, we describe overall statistical patterns for cumulative and individual value proxy scores. Second, we interpret a series of site-suitability maps based on the combined distribution of eight resource use value proxies. Third, we use descriptive statistics (*e.g.,* two sample *t*-tests) to develop a profile for the most suitable locations among existing tracts for oil and gas production infrastructure off the coast of Texas. Finally, we discuss how the results can inform coastal planners, policy makers, and industry officials on establishing operations in the least contentious and most suitable locations given the range of potentially conflicting stakeholder values attached to the coast.

Background and Literature Review

Environmental Conflict Management and Dispute Resolution

Ecologically sustainable approaches to development involve dealing with human conflict as much, if not more than, managing critical natural resources (Daniels and Walker 1996). Environment conflicts among stakeholders are based on the convergence of different values related to natural resources and environmental quality (Crowfoot and Wondolleck 1990; Wondolleck and Yaffee 2000). Whereas some groups or individuals believe that the integrity of natural systems and their components should be maintained in perpetuity, others perceive the natural environment as a place to maximize ecosystems for human use (Stanley 1995). In a comprehensive survey, Milbrath (1984) was one of the first researchers to conclude that there are two major environmental perspectives: those who believe the environmental problem is small and that there are no limits to growth and those who believe the environmental problem is large and that there are limits to growth. There is in fact a broad spectrum of values associated with nature that drives people's perceptions, goals, and the manner in which they act upon critical natural resources.

Nowhere is multiple-user conflict more apparent than within the coastal zone (Charlier and Bologa 2003). Increasing human population growth, structural development, and opportunities for tourism and recreation along the coast (especially in Texas) have made conflict resolution a core component of sustainable resource management (Bruckmeier 2005; Le Tissier and others 2004; McCreary and others 2001; Westmacott 2002). Conflict ignites when these fundamentally different values represented by multiple stakeholders converge around a specific problem, issue, or place. This phenomenon is often called ‘‘interdependence,’’ where parties enter into conflict because they have interlocking values, goals, or interests (Lewicki and others 2001). One of the major goals of identifying potential conflicts and untangling the various interdependent relationships is to understand the different environmental perspectives and how they interlock to generate conflict (Crowfoot and Wondolleck 1990; Susskind and Cruikshank 1987; Susskind and others 1999; Wondolleck and Yaffee 2000). Unraveling the interplay of multiple environmental values, goals, and interests is one step in resolving a dispute and reaching an agreement that maximizes joint gains.

The decision of where to locate offshore oil and gas production operations can be framed as a dispute of spatial interdependence; that is, there can be multiple and often conflicting values associated with marine use attached to the same location. Drilling for oil or gas can be perceived as incompatible with other values attached to the same site, such as biodiversity, environmental quality, recreation, and aesthetics (although it has been argued that inactive offshore rigs can, in some instances, increase biodiversity and provide increased opportunities for recreation). The potential for intractable conflicts in part led to a drilling moratorium for most of the US outer continental shelf (excluding the Gulf of Mexico and some waters off of Alaska) in 1990 and is still in effect. The states of Florida and California have resisted recent attempts to rescind this moratorium and locate offshore oil and gas facilities along their coast based on potential adverse environmental impacts, loss of revenue from tourism and recreation, and aesthetic concerns from coastal homeowners. Environmental, tourism, and recreational nongovernmental organizations (NGOs) also oppose offshore drilling in many parts of the country. For example, an analysis of stakeholder attitudes toward offshore oil and gas production in Florida found that most stakeholder organizations do not see themselves as gaining positive effects from offshore energy development. Those interviewed were almost unanimous in their opposition to future offshore development activity (Blanchard 1999).

Multiple-Criteria Decision-Making

Resolving environmental disputes often requires selecting from among multiple proposed scenarios and generating a solution that satisfies the criteria of multiple interests. MCDM has been used to assist decision-makers in selecting the best alternative from a number of feasible choice alternatives under the presence of multiple priorities and choice criteria (Conchrane and Zelany 1973; Jankowski 1995; Voogd 1983). MCDM is, in many ways, a dispute-resolution tool because the methodology involves identifying choice alternatives satisfying the goals of multiple parties in a decision-making process and then selecting the alternative most preferred by all parties. MCDM is particularly useful when it is applied to spatial conflicts or problems involving the search for the most suitable location for a particular use, ranging from power-line (Harris 1992) and pipeline (Jankowski and Richard 1994) routes to land uses on individual parcels (Berry 1992).

Recently, Hämäläinen and others (2001) applied MCDM techniques to finding Pareto-optimal alternatives among multiple stakeholders for water resource management in Finland. The authors present a framework for applying MCDM to a group decision-making context that is useful for developing a conceptual and methodological basis for our study. The framework begins by screening value dimensions of various interest groups, selecting decision criteria, and defining operational, measurable attributes. Next, Pareto-optimal alternatives that best meet the interests of all parties are searched for and identified. This study is just one example of a growing literature on multicriteria approaches to environmental problem solving (Agrell and others 1998; Hämäläinen and others 2000; Hipel and others 1997; Ridgley and others 1997; Tecle and others 1998).

Although MCDM has traditionally been used for land-based applications, this analytical approach has recently been applied to coastal and marine areas. For example, studies have been done on coastal development and marine protection (Moriki and others 1996), coral reefs to evaluate management options in terms of economic, ecological, and social criteria (Fernandes and others 1999), planning for marine reserves (Airamé and others 2003), and evaluating coastal areas for future land development (Kitsiou and others 2002). Although all of these studies apply MCDM to coastal and marine issues, little scholarly work has been done to date that addresses how this tool can be used to evaluate the suitability of certain sites for oil and gas development. Most research regarding oil and gas development instead focuses on examining ecological or socioeconomic impacts caused by a specific facility. Also, although numerous agencies have overlapping jurisdictions and a variety of regulations and permitting requirements in Texas state waters (GLO 2004), it appears that most of the site-suitability analyses in coastal leasing is done ad hoc by both the companies desiring a lease and by the agencies reviewing the lease applications (Daryl Morgan; personal communication; GLO 2002). Despite the absence of a formalized process for multiple-criteria site selection, various public and private initiatives have been undertaken that indicate an increasing awareness of the multiple values affected by offshore energy production facilities. For example, the Mineral Management Service (MMS) commissioned an evaluation of the socioeconomic impacts of oil and gas development in the Gulf of Mexico (Aratame and Singlemann 2002). Also, the oil and gas industry published guidelines for evaluating social impacts of oil and gas activities before projects are implemented (OGP 2002).

Geographic Information Systems and Spatial Decision Support Systems

Beginning mostly in the 1990s, scholars began to recognize that conflict is associated with location. Locational conflict arises due to differences or disagreements in values and locational perspectives with respect to how resources are to be utilized (Susskind and Cruikshank 1987). To address this issue, researchers began integrating MCDM techniques with the emerging geographic information systems (GIS) technology to develop SDSS (Jankowski 1995). SDSSs are defined as an information storage and manipulation system supported by spatially referenced data that are connected to specific thematic points or polygons in a problem-solving environment (Cooke 1992; Cowen 1988; Padgett 1994). The approach has been suggested as an information technology aid to facilitate geographical problem understanding for groups engaged in a location-based conflict (Armstrong 1993; Carver 1991; Faber and others 1995; Godschalk and others 1992; Jankowski and Nyerges 2001; Jankowski and others 1997; Malczewski 1999; Thill 1999).

Spatial decision support systems and associated technology is considered helpful in resolving site-suitability issues because it allows decision-makers to (1) integrate information representing multiple perspectives and disciplines (MacEachren 2000), (2) geographically represent value differences (Jankowski and Nyerges 2001), (3) consider the multiple and conflicting viewpoints as they are situated in space; and (4) visualize the results of a multiple-criteria analysis (Jankowski 1995). For example, Villa and others (1996) combined MCDM approaches with GIS to conduct a multiobjective evaluation of park vegetation. The authors produced conflict maps showing the agreement between priorities specified and the features of the landscape under consideration. Villa and others (2002) argue that systematic objective approaches to site selection can help reconcile conflicting interests, represent stakeholder viewpoints fairly and evenly, and extend the scope of planning studies. The authors used spatial multiple-criteria analysis to integrate objective data with the contrasting priorities of different stakeholder values in the planning of a marine protected area (MPA) in Italy. The results of the analysis were used to locate optimal spatial arrangements for marine protection under different scenarios. Available spatial data were aggregated into five higher-level variables representing values related to environmental, economic, and social influences in the study area. Spatial analysis of value-based variables produced stakeholder conflict maps that formed the basis of a MPAs zoning plan.

Using similar methods, Brody and others (2004) used GIS to map potentially competing stakeholder values associated with establishing protected areas in Matagorda Bay, Texas. By overlaying multiple values associated with a range of stakeholders across a geographic region, they were able to identify hot spots of potential conflict as well as areas of opportunity for maximizing joint gains. In this study, mapping stakeholder conflict was used as an approach to proactively locate potential controversy in response to a specific environmental management proposal and guide decision-makers in crafting planning processes that mitigate the possibility of intractable disputes while facilitating the implementation of sustainable coastal policies. Results indicated that under different management scenarios, protected area proposals generate more conflict in specific areas. Most notably, regulated uses produce the greatest degree of conflict on or near shore, particularly at the mouth of the Colorado River. Additionally, of all the management scenarios evaluated, the prohibition of coastal structural development generates the overall highest level of conflict within the Bay.

Research Methods

Study Area

We selected the Texas coast (Fig. 1) as the study area in which to conduct a multiple-criteria site-suitability analysis for the following reasons: (1) The oil and gas industry has an active and internationally significant presence in the Gulf of Mexico region and in Texas state waters. In October 2004, 105 exploration wells were being drilled in Gulf waters and 33 of these were in water depths of 1000 ft or greater. Currently, there are approximately 4000 producing platforms, of which about 1962 are major platforms (954 of these are manned by personnel) and some 152 companies are active in the Gulf of Mexico (MMS 2004). There are approximately 10,843 tracts available for leasing for oil and gas exploration within Texas coastal waters (GLO 2004), making the petroleum industry one of the top sources of revenue for the state. (2) The Texas coast contains ecologically sensitive areas with high marine biodiversity and critical habitats, particularly for migratory birds. (3) The Texas coast is an area valued and used by multiple overlapping interests, including commercial

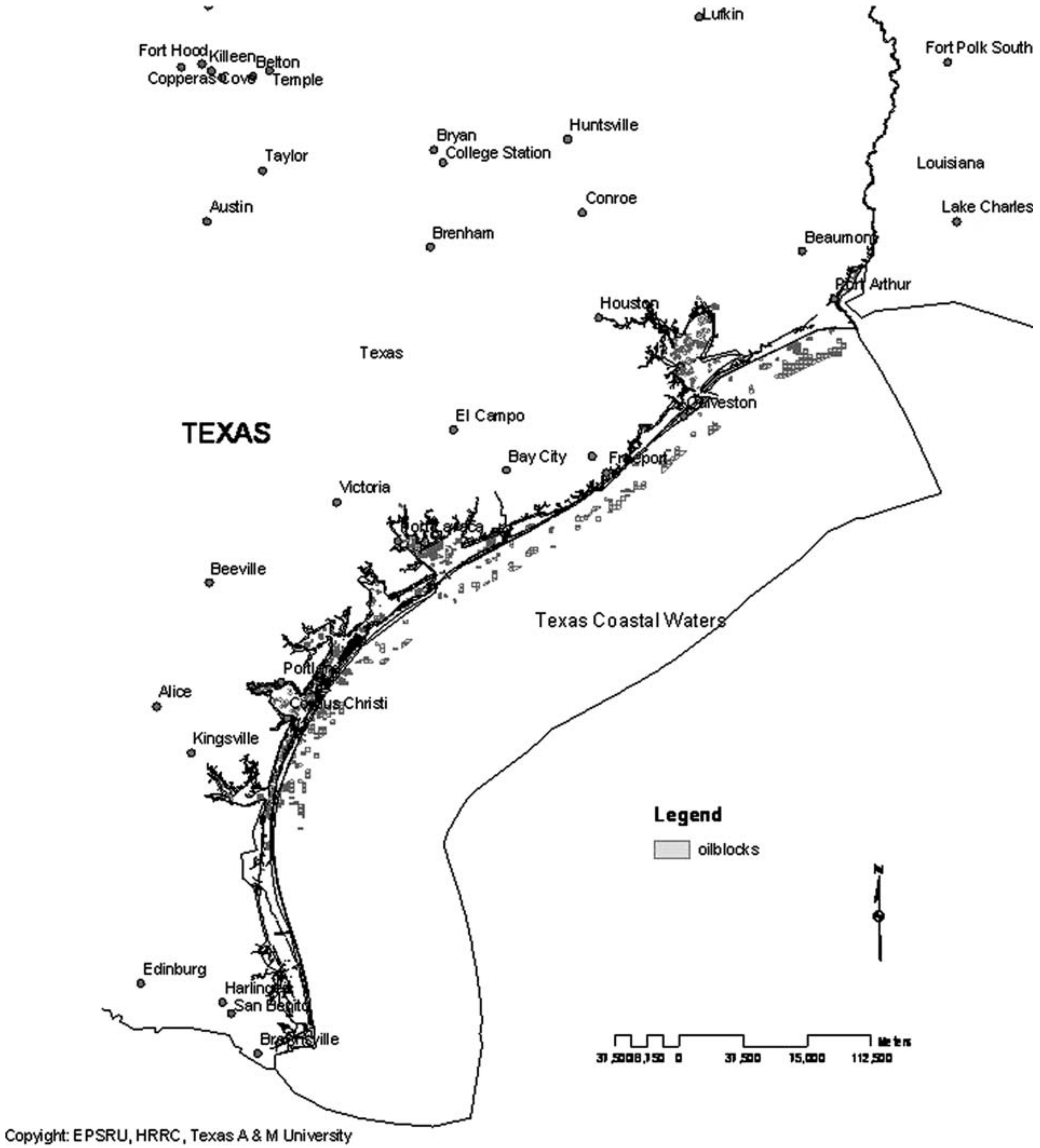

Fig. 1 Selected oil lease blocks along the Texas shore, Gulf of Mexico

fishing, recreational fishing and boating, tourism, bird watching, marine transportation, research, and structural development. These multiple and often times competing interests can result in spatially defined conflict. (4) Although the Texas coastline is one of the least developed coastlines in the United States, it is expected to undergo significant future population growth where nearly six million people will be living along the Texas coast by 2010, possibly exacerbating stakeholder conflicts related to offshore oil and gas production (GLO 2002). These conditions are ideal for developing a SDSS to identify the most suitable location for oil and gas development based on a range of coastal values.

Sample Selection

We selected for analysis the currently leased oil and natural gas tracts from a sampling frame of 10,843 blocks available for leasing in Texas submerged coastal lands. These state coastal lease tracts are defined as beginning at the high-tide mark and extending out to the Three Marine League line, which indicates the end of state jurisdiction and the beginning of federal jurisdiction. Based on the information published on the Texas General Land Office website as of October 6, 2004, we generated a sample size of 1385 leased tracts. Selecting currently leased tracts for analysis had several advantages. First, it reduced the sample size, the extent of data needed, and the computational burden of spatially analyzing almost 11,000 polygons. Second, and most importantly, we could assume currently leased tracts either contain petroleum reserves or have a strong possibility of producing petroleum-based energy by virtue of the fact that industry has already chosen the sites. Because we cannot determine the precise location of oil and gas deposits, our research design effectively controls for the key industry value of petroleum reserves, which drives the decision to establish offshore production facilities. By assuming that each lease tract in our sample has already been selected based on values associated with oil and gas exploration, we could focus our analysis on evaluating each existing tract against a range of other spatially represented marine values not traditionally incorporated in the offshore drilling site-selection process.

Selection of Spatially Representative Marine Values

As done by Villa and others (2002) and Brody and others (2004), we aggregated spatial data to derive the following eight spatially representative values most likely associated with various stakeholders present along the coast of Texas: (1) biodiversity/critical habitat, (2) recreation and tourism, (3) aesthetics, (4) commercial fishing and bioproductivity, (5) marine transportation, (6) coastal development, (7) historic/cultural, and (8) research and education. Each proxy value comprises multiple spatial data layers collected primarily from public agencies such as the Texas General Land Office, the National Marine Fisheries Service (NMFS), and the National Oceanic and Atmospheric Administration (NOAA 2004). For example, habitat and biodiversity data were used to delineate areas critical to ecosystem function in coastal and marine areas. Recreational and coastal land development data, such as point locations of beach access, boat ramps, and marinas, were collected to assess areas for recreation and aesthetic enjoyment. Spatial data delineating shipping channels and anchorage areas were used to assess offshore transportation and development values in the study area. In some cases, the same spatial data layer was used to measure more than one value proxy. The eight representative values and their corresponding spatial data layers are listed and described in Table 1.

The environmental value proxies and associated spatial data layers are not intended to be an exhaustive list; instead, they represent the potential major values of stakeholders along the Texas coast as measured by the best available existing spatial data. Along these lines, our study spatially identified a range of approximated values most likely representing the interests of those relying on coastal and marine resources, but it did not rely on the input from actual stakeholders. Thus, the focus was on representing and mapping a set of commonly held marine values or interests, not the positions of specific stakeholders. The rationale for selecting each spatial data layer and its measurement is described in Appendix A. It is important to note that several of the data layers have influence beyond their represented point or polygon. In these cases, we calculated buffers or influence zones to better spatially account for their impact on users within the study area. The justification for converting each of these layers is described in Appendix B.

All spatial data were assembled into a GIS and then aggregated by associated stakeholder value proxy. Data layers were projected and rectified to Lambert Conformal Conic coordinate systems with datum North American 1983. Values (*i.e.,* environmental parameters) were measured by assigning a binary numeric field indicating the occurrence of data associated with a value layer for each lease block in the sample. If spatial data associated with a value proxy were present, the cell was coded as 1; if there was an absence of spatial data, the cell was assigned a 0. The occurrences of the spatial data (X_n) in the lease block were summed to derive a cumulative score (ΣX_n) for the resulting value. Because the number of spatial data layers comprising a representative value varied, we normalized the final score by dividing it by the total number of spatial layers for the respective value proxy. The occurrence score (O) for each of the layers was thus calculated as:

$$O_{\text{value layer}} = \Sigma X_n / n \quad (1)$$

where X is the binary value proxy of the attribute and n is the number of spatial data layers in the value layer.

Table 1 Environmental values and the corresponding spatial data layers for Texas coastal lease tracts

Value proxy	Spatial data layer	Description
Biodiversity/ critical habitat		Areas that contain or provide the habitat for the species that live in the coastal waters of Texas and the species that live in those areas
	Audubon Sanctuaries	Coastal tracts containing waterbird colonies leased to the National Audubon Society.
	Colonial Waterbird Rookery Areas	Locations of waterbird rookery sites in the coastal counties of Texas. Information compiled by the Texas Colonial Waterbird Society.
	State Coastal Preserves	GLO/TPWD coastal preserve areas; digitized from state tract maps
	Seagrass Areas	Seagrass beds compiled from TPWD sample data (Redfish, Aransas, and Corpus Christi bays) and areas of submerged vegetation.
	National Wildlife Refuges	Approximate boundaries of national wildlife refuge lands.
	Priority Protection Habitat Areas	Priority coastal habitat areas to be protected during oil or hazardous material spills on the Texas coast.
Recreation and tourism		Activities that provide an opportunity for people to interact in a nonconsumptive manner with the environment, including recreational fishing, birding, wildlife watching, diving, boating, and other water sports
	City and County Parks	Selected city and county parks on the coast. Compiled from TxDOT digital county map files.
	Beach Access Points	Public beach access points. Mapped by the GLO in cooperation with coastal towns and counties.
	Audubon Sanctuaries	Coastal tracts containing water bird colonies leased to the National Audubon Society.
	Texas Artificial Reefs	This layer gives locations of artificial reefs in the state and federal waters of the Gulf of Mexico off the Texas coast.
	Boat Ramps	Locations of public boat ramps on the Texas coast. Information compiled by the TPWD Coastal Fisheries Division.
	State Parks/Wildlife Management Areas (TPWD)	Boundaries of state parks and wildlife management areas owned or managed by the TPWD. Data provided by TPWD.
Aesthetic		Unobstructed coastal view shed, as seen from public access points on land
	Audubon Sanctuaries	Coastal tracts containing water bird colonies leased to the National Audubon Society.
	Boat Ramps	Locations of public boat ramps on the Texas coast. Information compiled by the TPWD Coastal Fisheries Division.
	State Parks/Wildlife Management Areas (TPWD)	Boundaries of state parks and wildlife management areas owned or managed by the TPWD. Data provided by TPWD.
	City and County Parks	Selected city and county parks on the coast. Compiled from TxDOT digital county map files.
	Marinas	Public (and some private) marinas on the Texas coast.
	Beach Access Points	Public beach access points. Mapped by the GLO in cooperation with coastal towns and counties.
Commercial fishing & bioproductivity		Locations of species of commercial interest for harvest
	Private Oyster Leases	Submerged tracts leased for oyster harvesting by private operators
	SEAMAP data live bottom 1982–1999	Live bottom organisms included sponges, corals, sea fans, sea pansies, gorgonians, sea pens, bryozoans, endoprocts, and crinoids based on commercial fishing catches.
	SEAMAP data fishery species 1982–1990	The fishery species database represents the subset of start locations where fishes and invertebrates managed by the Gulf of Mexico Fishery Management Council were recorded. Managed fisheries include 37 fish species and 2 invertebrate species as determined by commercial fishing catches.
Marine transportation		The movement of goods and services across coastal waters
	Gulf Intracoastal Waterway/ Ship Channels	Dredged shipping channels in coastal waters.
	Shipping Safety Fairways	Shipping safety fairways in the western Gulf of Mexico. Digitized from NOAA maps.
	Anchorage Areas	Offshore anchorage areas. Digitized from NOAA maps.
Coastal development		Development occurring in both Texas coastal waters and in the lands adjacent to coastal waters

Table 1 Continued

Value proxy	Spatial data layer	Description
	Boat Ramps	Locations of public boat ramps on the Texas coast. Information compiled by the TPWD Coastal Fisheries Division.
	Marinas	Public (and some private) marinas on the Texas coast.
	Coastal Leases (Point Locations)	Locations of structures and activities permitted by the GLO within state-owned land and waters. Includes features represented by a single point location, such as piers, docks, breakwaters, and shoreline protection projects.
	Aquaculture Facilities	Locations of aquaculture operations on the Texas coast (incomplete).
Historical/cultural sites		Shipwrecks, battle locations, closed military locations
	Archeological Sites	Density of archeological sites in each USGS 1:24,000 quad in the coastal zone.
Research and education		Encouraging the acquisition and sharing of knowledge
	Audubon Sanctuaries	Coastal tracts containing waterbird colonies leased to the National Audubon Society.
	National Wildlife Refuges	Approximate boundaries of national wildlife refuge lands.
	State Parks/Wildlife Management Areas (TPWD)	Boundaries of state parks and wildlife management areas owned or managed by the TPWD. Data provided by TPWD.

To further qualify the data analysis, the occurrence score for each block was weighted against the proportional cumulative geographical coverage by the spatial value layer. This coverage value (C) was calculated as

$$C_{\text{value layer}} = \{(\text{Area}_{\text{A1}} \cup \text{Area}_{\text{A2}} ... \cup \text{Area}_{\text{An}}) - (\text{Area}_{\text{A1}} \cap \text{Area}_{\text{A2}} ... \cap \text{Area}_{\text{An}})\}/\text{Area}_{\text{oil lease block}} \quad (2)$$

where C is the proportional coverage of the value layer and A_1 to A_n are the various spatial layers that comprise the value layer.

A final value score for each block was calculated as

$$V_i = (O_{\text{value layer}})(C_{\text{value layer}}) \quad (3)$$

Finally, the numeric scores for each of the eight representative marine user values were summed to derive a Cumulative Value Proxy Score (CVPS) for each lease block, ranging from 0 to 8:

$$\text{CVPS} = V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7 + V_8 \quad (4)$$

A higher CVPS indicates greater overlap or spatial intersection of spatially representative user values and the potential for conflict among multiple users. Thus, for the purposes of this study, a block with a high CVPS is considered less suitable for locating oil and gas production facilities. We did not weight spatial data layers by their relative importance because this approach would introduce an additional level of subjectivity into the analyses. Such weighting assignments should, instead, be conducted in a group setting with input from multiple stakeholders.

Data Analysis

The data were analyzed in several descriptive phases. First, we calculated descriptive statistics for each value score and CVPSs across the entire study area. Second, we mapped and graphically analyzed these scores along high, medium, and low natural breaks to make conclusions about the variation of site suitability along the Texas coast. Third, we performed independent two-sample t-tests for CVPSs and individual value scores for the following variables: inshore/offshore, northern most coastal bay/southern most coastal bay, producing lease tracts/nonproducing lease tracts, and year of lease (on or before 1990/after 1990). The year 1990 was chosen as a critical analytical period because this was the year that the US government imposed a moratorium on offshore oil/gas drilling in US waters. This date thus represented an increasing level of concern over the adverse environmental, economic, and aesthetic impacts of offshore energy production facilities in the United States. Even though Texas was not part of the moratorium, we believe that site selection for oil/gas drilling platforms were affected by the federal government's decision and an overall heightened public sensitivity to the construction of offshore production facilities.

Table 2 Presence, coverage, and value proxy scores for all leases

Value	Presence, ΣX_n (No. of lease blocks with this value)	Mean coverage, $C_{\text{value layer}}$ (Average proportion of area covered by the value in the occurrence blocks)	Average value score, V_i (all leases)
Aesthetics	963 (69.50%)	0.667	0.264
Std. dev.		0.464	0.211
Biodiversity/critical habitat	431 (31.00%)	0.164	0.049
Std. dev.		0.332	0.110
Coastal development	1005 (72.6%)	0.675	0.283
Std. dev.		0.456	0.226
Commercial Fishing/Bio-productivity	108 (7.80%)	0.061	0.023
Std. Dev.		0.240	0.092
Historical/cultural sites	1066 (77.00%)	0.051	0.051
Std. Dev.		0.089	0.089
Marine transportation	182 (13.10%)	0.131	0.045
Std. Dev.		0.338	0.0116
Recreation and tourism	964 (69.60%)	0.667	0.179
Std. Dev.		0.464	0.145
Research and education	38 (2.70%)	0.003	0.001
Std. Dev.		0.037	0.013
CVPS	1227 (88.60%)	0.44	0.895

Total lease blocks evaluated = 1385 (year 2004)

The first column represents the number of blocks in which the respective use value was found to be present. The second column represents the average proportion of the area covered by the respective value in a lease block (occurrence). The final column is the average value score for the respective value layers across all of the study blocks (including blocks with zero presence). The calculation of value and CVPS scores is based on occurrence × coverage as explained in the Methods section

Results

As shown in Table 2, over 88% of the lease blocks in the study sample were influenced by at least one of the eight potential stakeholder value proxies. Historic/cultural (77%), coastal development (72.6%), and aesthetic (69.5%) values cover the largest number of tracts. In contrast, research and education (2.7%) and commercial fishing/bioproductivity (7.8%) values are present in the lowest number of tracts. When spatial data are present in a lease block, the degree of spatial coverage is highest for coastal development (0.675), recreation and tourism (0.667), and aesthetic (0.667) values. Spatial coverage is lowest for research/education (0.003), historical/cultural (0.051), and commercial fishing/bioproductivity (0.061) values. Comparing the frequency of scores in the first two columns of Table 2 indicates that the presence of a value as determined by corresponding spatial data layers and the degree of spatial coverage for a lease block are not identical and, thus, both should be considered when calculating the impact of an offshore facility on various marine interests.

The overall CVPSs for all 1385 leased coastal tracts in Texas are fairly low, ranging from 0.00 to 2.75, out of a possible 8.0. These scores are perhaps the most detailed measure of the degree to which an offshore oil/gas production facility will infringe upon other interests because it considers both the occurrence of a value and its spatial coverage within a lease block. As shown in Table 2, the average CVPS ($O + C$) for all leases is 0.895, with a standard deviation of 0.640. Coastal development (0.283) and aesthetic (0.264) values scored the highest. In contrast, lease tract values associated with research and education (0.001) and commercial fishing/bioproductivity (0.023) received the lowest scores.

Figures 2 through 6 illustrate the spatial distribution of cumulative and individual value proxy scores across the entire study area. Scores are mapped according to numerical natural breaks of high, medium, and low. High CVPSs occur primarily near shore and within major bays, at the mouths of tributaries. CVPSs are especially high within and directly outside of Corpus Christi Bay to the south of the study area. In contrast, offshore lease blocks, where there is comparatively less stakeholder activity and ecological value, have lower CVPSs.

Examining the spatial distribution of individual value proxy scores provides further insights into potential conflicts associated with the siting of oil/gas production facilities. For example, biodiversity scores are highest in lease blocks located to the south of the study area in and around the mouth of Corpus Christi

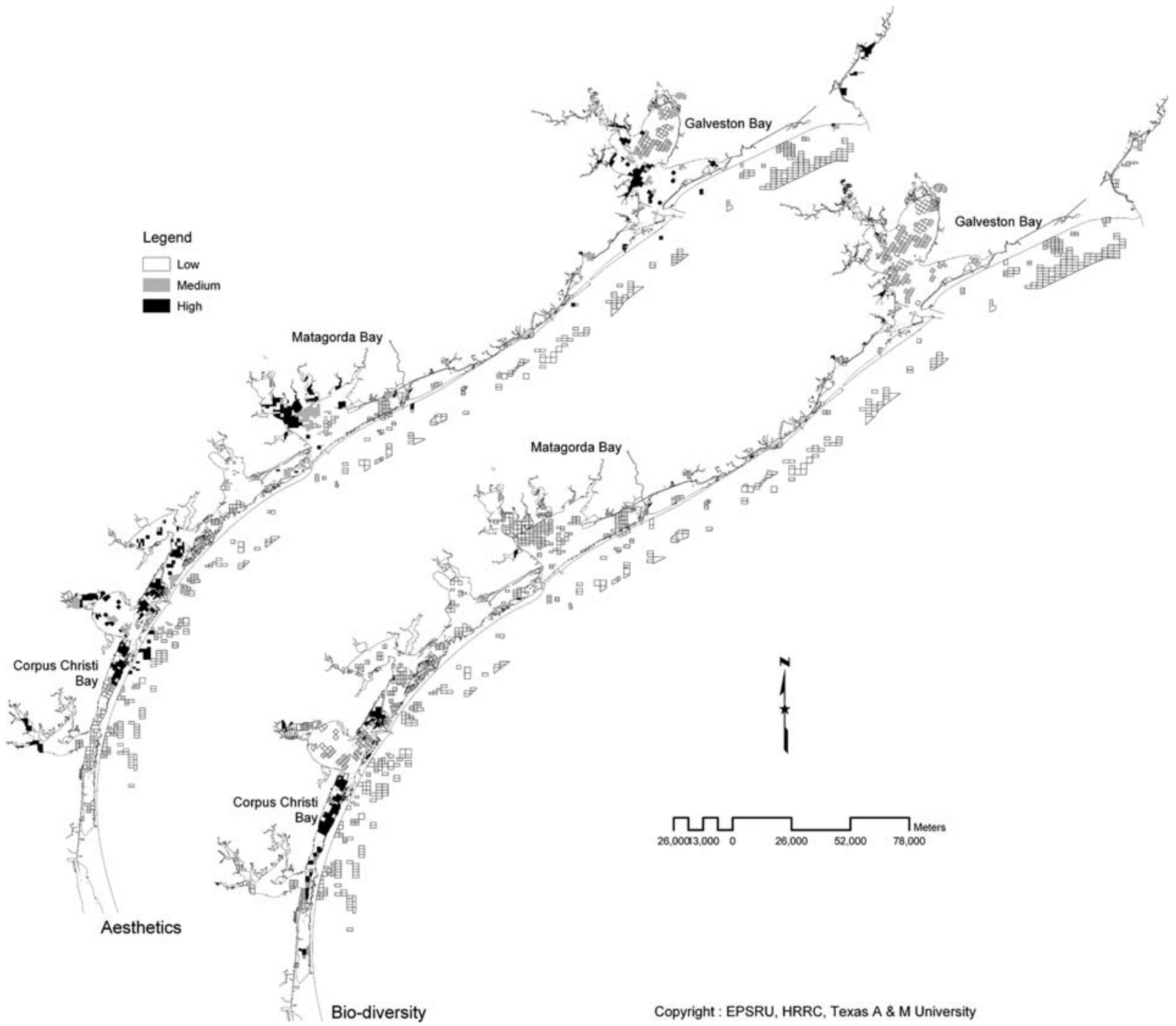

Fig. 2 Distribution of aesthetics and biodiversity use values

Bay. This area is well known for its critical natural habitats for bird and fish species. Warmer water and air temperatures in southern Texas provide more suitable spawning habitats, nesting rookeries for a variety of bird species, including the whooping crane, and a higher diversity of invertebrates that provide the basis of the food chain for birds and fish in the region.

Recreation and tourism values generally correspond spatially with biodiversity values associated with Corpus Christi Bay. These values also score high for lease blocks in other major bays within the study area, particularly at the mouths of tributaries where there are ample fishing and boating opportunities. A concentrated area of high scores occurs in the interior of Matagorda Bay, which attracts recreational fishers and wildlife enthusiasts. Aesthetic stakeholder values also overlap spatially with areas of high recreation and tourism potential. Coastal parks, beach public access points, and boat ramps all provide viewsheds of scenic areas.

High coastal development values are distributed more broadly across the study area compared to other values, reflecting the widespread importance of structural development along the Texas coastline. Development values are strongest within all three major bays, particularly at the mouths of tributaries. High values are also located inshore, or parallel to the shoreline around the mouths of bays, where piers, docks, breakwaters, and shoreline protection projects are likely to occur. Areas with significant historical

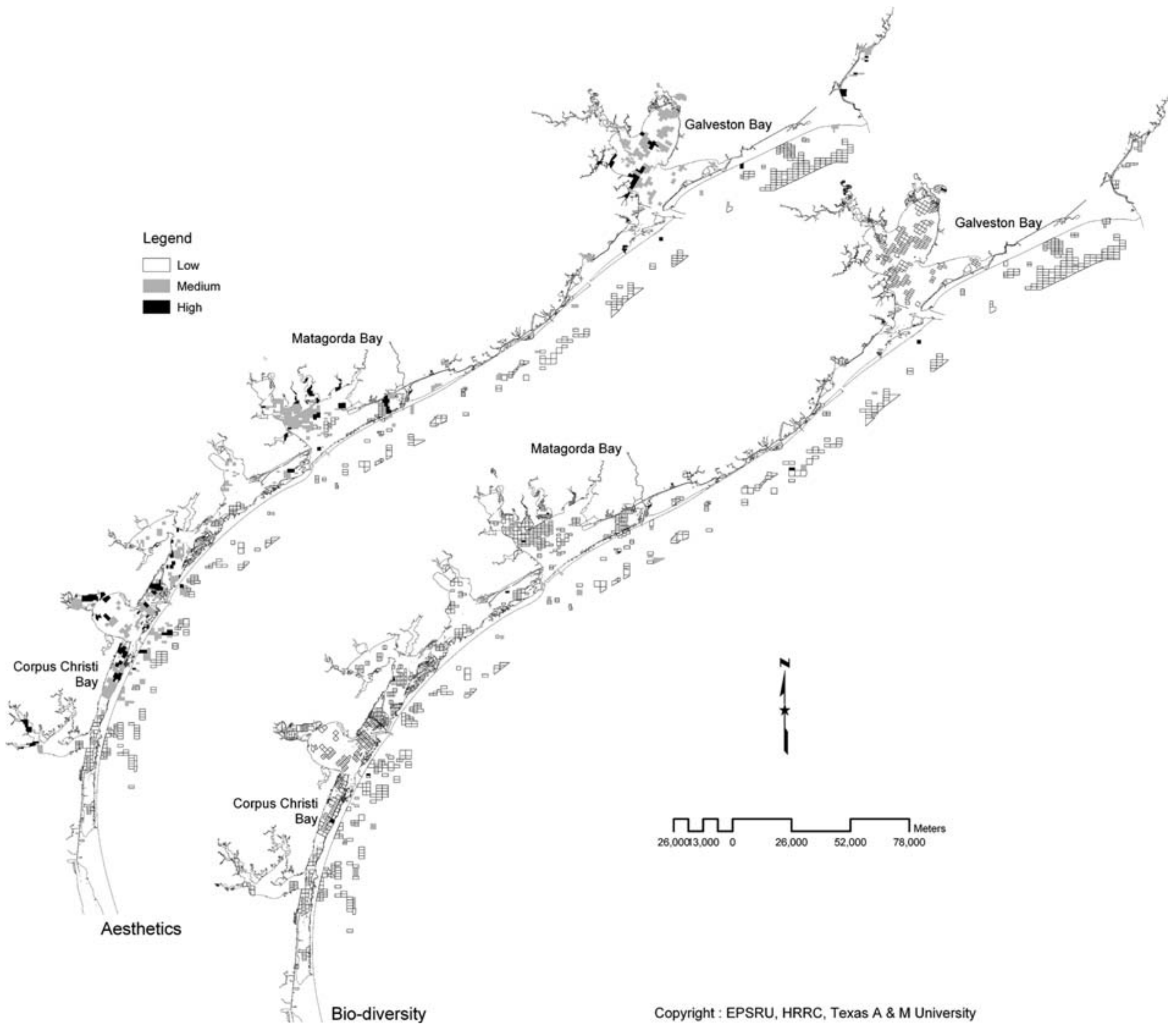

Fig. 3 Distribution of coastal development and commercial fishing use values

value are comparatively more concentrated, with high value scores occurring mostly in bay interiors where shipwrecks, past battle locations, and historic military operations are prevalent. In contrast, high marine transportation values occur spatially in linear configurations extending offshore and into bays with major ports or marine centers. Lease blocks with high marine transportation values are located mostly in shipping channels and shipping safety fairways. Offshore energy production facilities in these areas thus have the potential to infringe on the efficient movement of goods and services within coastal waters. Commercial fishing and bioproductivity values have one of the lowest occurrence rates of all values. When there are blocks with medium or high values, they are concentrated primarily offshore at the mouths of major bays. Finally, research and education values affect less than 3% of the lease blocks in the sample and appear insignificant from a spatial perspective.

Whereas mapping value proxy scores illustrates general spatial trends for areas where energy production facilities might cause stakeholder conflicts, descriptive statistical tests enable us to better understand how scores vary significantly across geographic and temporal dimensions. The data were categorized into the following dichotomous variables: onshore/offshore, northern most bay/southern most bay, producing leases/nonproducing leases, and blocks leased during 1990 or earlier/before 1990. As previously mentioned, we selected 1990, the year an offshore

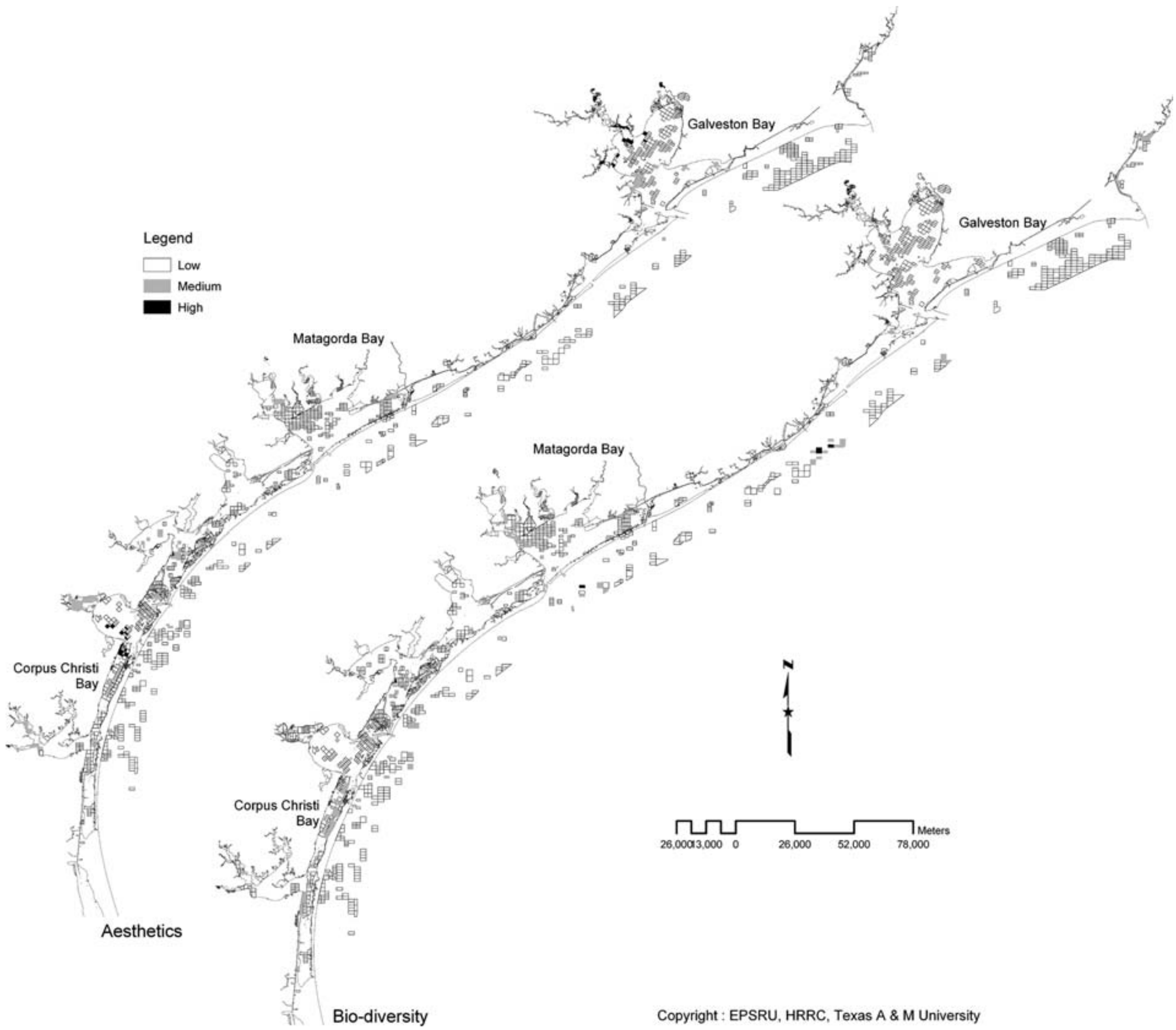

Fig. 4 Distribution of historical/cultural and marine transportation use values

drilling moratorium went into effect, as a possible point in time when a significant shift occurred in the way that domestic energy companies selected lease sites.

Independent two-sample *t*-tests (as shown in Tables 3–6) indicate that, except for commercial fishing, cumulative and individual value proxy scores are significantly higher ($P < 0.001$) in onshore versus offshore areas. CVPSs are also significantly higher in Corpus Christi Bay at the southern most part of the study area, where biodiversity and aesthetic values are more prevalent than in bays to the north. Producing lease blocks (those tracts with structures actively producing oil or gas) are located in areas with significantly (albeit moderately) higher ($P < 0.1$) CVPSs than nonproducing or terminated lease blocks. Scores are especially higher for coastal development ($P < 0.05$) and historical/cultural ($P < 0.05$) values associated with producing lease blocks. Interestingly, there is no statistically significant difference between producing and nonproducing blocks for biodiversity/critical habitat values. Finally, older lease blocks are correlated with significantly higher CVPSs ($P < 0.001$), indicating that companies gave more consideration to other stakeholder values when selecting sites for the most recent leases. This temporal trend is most pronounced for values associated with recreation and tourism, aesthetic, and coastal development.

Discussion

Visual and statistical analyses of the data indicate that oil and gas lease blocks within Texas coastal waters vary in their potential to generate conflict among

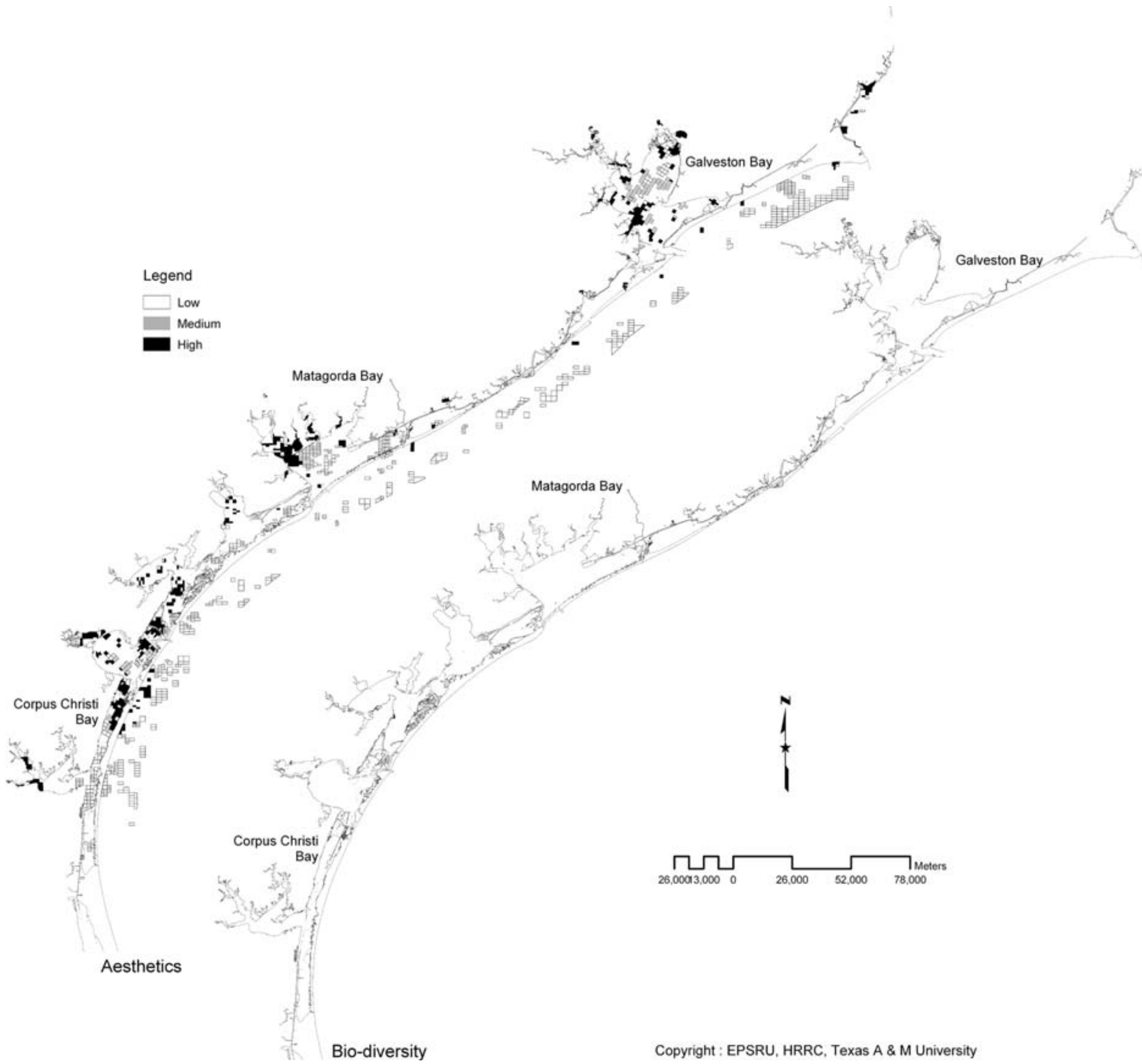

Fig. 5 Distribution of recreation and research use values

multiple stakeholders. This variation follows a clear spatial profile within the study area. First, energy production in blocks at the southern portion of the state, in and around Corpus Christi Bay, might generate the greatest degree of controversy due to overlapping stakeholder values. This portion of the study area received the highest concentration of CVPSs, due primarily to predominant coastal development and aesthetic marine values. This result is especially noteworthy because energy facilities can replace or greatly reduce the feasibility of other types of structural development, such as marinas, resorts, piers, and so forth. Oil or gas production structures are also criticized as eyesores, detracting from the scenic viewsheds that attract visitors and money to coastal communities. Given these potential hot spots of conflict, both public- and private-sector entities should be careful to use conflict management techniques involving the participation of multiple stakeholders when initiating offshore drilling activities. In general, coastal development and aesthetic opportunities (which can also be conflicting) are the most prevalent and important stakeholder values along the Texas coast that should be considered when constructing offshore energy facilities.

Second, according to the results, research/education and commercial fishing values score the lowest, making them the least potential stakeholder groups to

Fig. 6 Distribution of cumulative value scores

oppose offshore energy production activities. Research and education initiatives along the Texas coast and in the Gulf of Mexico in general have been historically limited compared to other higher-profile coastal systems (e.g., Chesapeake Bay, Gulf of Maine, etc.). Lack of funding for such activities combined with a comparatively low number of protected areas and research stations are contributing factors that make these values a low priority within the study area. It should be noted that research/education activities were the most difficult to represent spatially due to limited data. No physical institution is located in or near a lease site and exact research monitoring stations are unavailable. Because most research and education activities take place in protected areas, we used this designation as a suitable proxy. However, lack of data might contribute to low CVPSs. Although commercial fishing is a viable economic sector for the

Table 3 Results of independent *t*-test comparing onshore leases to offshore leases

Value proxies	Inshore Mean	Std. dev.	Std. error mean	Offshore Mean	Std. dev.	Std. error mean	*t*-Test	*P*-Value (Sig.–two-tailed)
Aesthetic	0.358	0.169	0.006	0.062	0.139	0.007	34.286	0.000
Biodiversity/ critical habitat	0.072	0.127	0.004	0.000	0.002	0.000	11.773	0.000
Coastal development	0.378	0.190	0.006	0.076	0.145	0.007	32.548	0.000
Commercial fishing & bioproductivity	0.000	0.000	0.000	0.072	0.153	0.007	–9.798	0.000
Historical/ cultural sites	0.070	0.101	0.003	0.009	0.019	0.001	17.777	0.000
Marine transportation	0.053	0.122	0.101	0.027	0.101	0.005	4.241	0.000
Recreation and tourism	0.241	0.117	0.004	0.046	0.102	0.005	31.559	0.000
Research and education	0.001	0.016	0.001	0.000	0.001	0.000	2.624	0.009
CVPS	1.173	0.518	0.017	0.292	0.430	0.021	31.003	0.000

Total lease blocks evaluated = 1385 (year 2004); onshore $N = 947$, offshore $N = 438$

For *t*-tests, equal variances not assumed, * = equal variances assumed

Table 4 Results of independent samples *t*-tests comparing Galveston Bay leases to Corpus Christi Bay leases

Value proxies	Galveston Bay mean	Std. dev.	Std. error mean	Corpus Christi Bay mean	Std. dev.	Std. error mean	*t*-Test	*P*-Value (Sig.–two-tailed)
Aesthetic	0.354	0.137	0.009	0.430	0.105	0.009	–6.078	0.000
Biodiversity/ critical habitat	0.012	0.041	0.003	0.023	0.029	0.002	–2.997	0.003
Coastal development	0.385	0.122	0.008	0.448	0.170	0.014	–3.914	0.000
Commercial fishing & bioproductivity	0.000	0.000	0.000	0.000	0.000	0.000	—	—
Historical/ cultural sites	0.102	0.140	0.009	0.067	0.089	0.007	2.942	0.003
Marine transportation	0.041	0.041	0.110	0.050	0.120	0.010	–0.785*	0.433
Recreation and tourism	0.257	0.085	0.006	0.275	0.094	0.008	–1.972*	0.049
Research and education	0.000	0.000	0.000	0.002	0.016	0.001	–1.690	0.093
CVPS	1.151	0.393	0.026	1.296	0.364	0.029	–3.702*	0.000

Galveston Bay $N = 235$; Corpus Christi Bay $N = 152$

For *t*-tests, equal variances not assumed, * = equal variances assumed

state [in 2000, *e.g.,* Texas caught a total of 110,518,075 lbs of fish and shellfish, valued at $293,609,298 (NMFS 2004)], much of commercial harvesting occurs further offshore, where it is less likely to interact with oil and gas production operations (there are more than twice as many lease blocks onshore than offshore) and other stakeholder values. It should be noted that low CVPSs and spatial coverage for the commercial harvesting/biodiversity value could also be a product of limited data and understanding of where fish stocks are actually located.

Third, despite perceptions that offshore drilling is adversely affecting areas of high biodiversity and critical habitat, our results indicate that this stakeholder value does not play as strong a role in generating potential conflict as previously expected. Biodiversity values affect less than a third of all lease blocks in the sample and have a well-below-average CVPS. This result is somewhat surprising given the historical controversy between energy production and the natural environment, as well as the wealth and precision of spatial data available with which to assess this value. This is not to conclude that oil and gas production does not adversely impact areas of high biodiversity. Our results only indicate a low degree of potential conflict between existing areas of biodiversity and existing active oil/gas lease tracts. In fact, an alternative explanation for low biodiversity scores is that biotic communities have already been adversely impacted from past coastal development and there is little left to measure as a value. Sustained development of infrastructure and energy sources along the coast might have resulted in a significant reduction in critical habitats, causing us to observe low scores for biodiversity indicators in the region. This explanation certainly cannot be substantiated through the results of this study but it does raise questions for future research.

Fourth, more recent leases are located in areas of significantly lower overlapping stakeholder values (as

Table 5 Results of independent *t*-tests comparing producing lease blocks to all other leases[a]

Value proxies	Producing mean	Std. dev.	Std. error mean	All other means	Std. dev.	Std. error mean	*t*-Test	*P*-Value (Sig.–two-tailed)
Aesthetic	0.284	0.200	0.012	0.260	0.213	0.006	1.652*	0.099
Biodiversity/ critical habitat	0.044	0.100	0.006	0.050	0.113	0.003	–0.932	0.352
Coastal development	0.312	0.206	0.013	0.275	0.230	0.007	2.561*	0.011
Commercial fishing & bioproductivity	0.022	0.093	0.006	0.023	0.092	0.003	–0.066	0.947
Historical/ cultural sites	0.061	0.090	0.006	0.048	0.089	0.003	2.137*	0.033
Marine transportation	0.042	0.118	0.007	0.045	0.116	0.004	–0.418	0.667
Recreation and tourism	0.194	0.140	0.009	0.176	0.145	0.004	1.787	0.074
Research and education	0.001	0.012	0.001	0.001	0.013	0.000	0.507	0.612
CVPS	0.960	0.568	0.035	0.879	0.656	0.020	1.867	0.062

Producing N = 269; all other leases N = 1115

For *t*-tests, equal variances not assumed, * = equal variances assumed.
[a]Compensatory Royalty Agreement (only lease of its type, was excluded)

Table 6 Results of independent *t*-tests comparing leases acquired in 1990 or earlier to all leases acquired after 1990

Value proxies	1990 & before mean	Std. dev.	Std. error mean	After 1990 mean	Std. dev.	Std. error mean	*t*-test	*P*-Value (Sig.–two-tailed)
Aesthetic	0.371	0.182	0.013	0.244	0.210	0.006	7.695	0.000
Biodiversity/critical habitat	0.058	0.125	0.009	0.047	0.108	0.003	1.182	0.237
Coastal development	0.374	0.200	0.015	0.265	0.227	0.007	6.120	0.000
Commercial fishing & bioproductivity	0.011	0.060	0.004	0.025	0.096	0.003	–1.915	0.056
Historical/cultural sites	0.064	0.084	0.006	0.046	0.088	0.003	2.690*	0.008
Marine transportation	0.056	0.125	0.009	0.044	0.116	0.003	1.320	0.187
Recreation and tourism	0.262	0.124	0.009	0.164	0.143	0.004	8.755	0.000
Research and education	0.001	0.011	0.001	0.001	0.014	0.000	0.398*	0.691
CVPS	1.198	0.581	0.043	0.837	0.638	0.019	7.191	0.000

1990 and earlier N = 183; after 1990 N = 1134

For *t*-tests, equal variances not assumed, * = equal variances assumed

measured by CVPSs). However, additional research is needed to firmly establish 1990 as a critical year after which site-selection criteria became more sensitive to other interests. This result has two possible explanations: (1) Increasing public awareness of and opposition by other organizations over the negative impacts of offshore drilling in recent decades has pressured the energy industry to be more considerate of competing stakeholder values or (2) all of the most controversial sites were leased before 1990 so that the remaining leases are by default located in areas with lower CVPSs. We suspect corporations are more strategic in their decisions over where to lease to avoid public scrutiny, lawsuits, or negative public relations. In any case, it should be noted that the vast majority of leases in our dataset occurred after 1990.

Fifth, comparing producing versus nonproducing lease blocks indicates the degree to which actual offshore drilling operations infringe upon or impact other stakeholder values. The result that producing leases (those with rigs and other active structures) have significantly higher (albeit moderately so) CVPSs suggests that drilling operations are located in high-impact and potentially controversial areas. In other words, the offshore rigs are not in the most desirable locations when considering other stakeholder values for all lease blocks in the study area and these facilities could be exacerbating opposition by other marine interests. Again, the biodiversity/critical habitat value does not play as strong a role in contributing to high CVPSs for producing leases, as might be expected. Results show that producing blocks do not significantly interact with biodiversity/critical habitat values, which is another indication that the offshore energy industry is not degrading important ecological areas, as is often suspected by the public.

Conclusion

Using GIS to identify and map areas of potential stakeholder conflict associated with offshore oil and gas production lease blocks can inform public and private entities on how to proactively mitigate intractable disputes over this increasingly important coastal resource use. This study is not meant to replace existing site-selection processes, but, instead, provides a model for how multiple representative marine user values in addition to those associated with energy production could be incorporated into strategic decisions for where and when to commence drilling activities. Thus, our approach should serve as a supplemental technique that cannot outweigh the importance of the location of energy reserves or financial constraints for selecting lease blocks for oil and gas extraction. Nevertheless, opposition from various government organizations and interest groups has made it increasingly more difficult for companies to site offshore energy facilities in the United States, and conflict identification and management should be seen as essential ingredients to successful offshore energy production in coastal waters.

Our results provide useful information for public and private decision-makers; however, no study is without limitations and this one is no exception. First, the range of value proxies analyzed is not fully representative of all possible interests within the coastal zone. This study selected eight spatially representative values for an initial analysis to test the efficacy of the mapping technique. Second, as is usually the case, stakeholder values are not mutually exclusive, thus making interpretation of the results more difficult. Third, differences in the specificity of spatial data layers are a limiting factor in measuring value proxies. For example, although exact locations of boat ramps are available in digital format, the same level of specificity is not available for commercial fish species. However, as with most exploratory GIS analysis projects, it is cost-prohibitive to develop multiple data layers geared to the specific needs of the research. Fourth, combining spatial data layers with different levels of specificity and from different sources compounds spatial error. Spatial data, in all cases, are merely representations of reality and no data are free of error (Openshaw 1989). Fifth, the impact of several values, such as aesthetic, historic/cultural, and education, might extend beyond the actual site where the value is located. To accommodate this limitation, we generated buffer zones to recognize viewsheds, as described in Appendix B. However, this technique lacks precision, and more sophisticated visual analysis should be conducted in future studies. Sixth, this study is based on the assumption that the more value proxies present in a lease tract, the more potential conflict there might be associated with oil/gas production. However, there could be cases where some values generate more potential conflict than others or some values reduce conflicts associated with oil and gas production. Seventh, the representative marine user values analyzed in our study are based on past values measured at one point in time. However, values constantly shift over time with changing political and biophysical conditions that might limit the usefulness of our results for policy making in the future. Finally, the calculation of value proxy scores was based on the best available data and information. Analyses were limited to existing publicly available spatial data layers. Use of additional data would only enhance the reliability of the results. For example, additional spatial information on biodiversity, such as algae and specific locations of offshore research and education sites, would improve the quality of the findings.

This article provides a first step in identifying the degree of conflict in existing oil and gas lease blocks based on multiple stakeholder values; further research is needed on the topic. First, our study uses relatively simple methods for measuring the response of values and conflict vectors (occurrence and spatial coverage). More sophisticated methods for scaling and weighting spatial data that can be understood by decision-makers and the public would refine the measurement of spatial conflict. For example, through stakeholder surveys, weights of importance can be assigned to specific values. Also, future studies could use scales (instead of presence/absence) to better recognize the possibility that some values might be complementary to oil and gas production rather than cause potential conflict. Second, the series of value proxy maps needs to be more thoroughly tested against the interests of actual stakeholders within the study area. Validating the graphic results through surveys or personal interviews would add insight into the accuracy and usefulness of the mapping techniques. Secondary data on stakeholder interests might also be obtained. For example, Environmental Impact Statements developed in association with state and federal agencies could document the concerns of actual stakeholders. Finally, and most importantly, the methods described in this article need to be applied in an actual planning exercise where planners and planning participants use conflict maps to guide the planning process. Only then can the effectiveness of using GIS to identify potential conflict be fully explored.

Appendix A: Rationale for selecting and measuring spatial data layers

Value proxies	Spatial data layer	Rationale for using this data layer	Measurement
Oil & gas production industry			
	Oil & Gas Leases	Currently leased areas of the Texas coast are assumed to be representative of the known oil and gas fields. Assumption: all leased blocks contain oil or gas.	Total area of each lease block. Blocks are of differing sizes, average small lease block is 640 acres.
Biodiversity/ critical habitat			
	Audubon Sanctuaries	Presence of waterbirds is a measure of biodiversity.	1. Presence/absence 2. Area
	Colonial Waterbird Rookery Areas	Presence of waterbirds is a measure of biodiversity.	1. Presence/absence 2. Area
	Seagrass Areas	Seagrass is a critical habitat for many species of invertebrates, and also provides a nursery ground for many juvenile fish species.	1. Presence/absence 2. Area
	National Wildlife Refuges	Areas of habitat and wildlife importance.	1. Presence/ absence 2. Area
	Priority Protection Habitat Areas	Critical coastal habitat. Assumption: positive value exists with only the high and medium priority areas.	1. Presence/ absence 2. Area– Only measuring high and medium priority areas
Recreation and tourism			
	City and County Parks	Parks provide the public with areas for recreation	1. Presence/absence 2. Area
	Beach Access Points	Beaches are public land, used for swimming, surfing, and other forms of recreation.	1. Presence/absence 2. Area within arc of viewshed. (Figure 2)
	Audubon Sanctuaries	Birding is a popular and growing tourism industry in the Texas coastal zone, Audubon Sanctuaries being one high concentration area for birding.	1. Presence/absence 2. Area
	Texas Artificial Reefs	Artificial reefs provide boaters a destination for fishing, scuba diving and spearfishing.	1. Presence/absence 2. Calculated using radius of two boats' use. 400G radius circle around the location. 500,000 ft^2 = area
	Boat Ramps	Access to bays and other water bodies via boat ramps is an indicator of recreation because most watercraft activities will originate in these locations.	1. Presence/absence 2. Area within arc of viewshed (Figure 2).
	State Parks/Wildlife Management Areas (TPWD)	Parks provide the public with areas for recreation. Examples include camping, picnics, hiking, nature viewing, etc.	1. Presence/absence 2. Area
Aesthetic values			
	Audubon Sanctuaries	Bird sanctuaries provide a natural environment in which the coast can be appreciated in its natural state.	1. Presence/absence 2. Area
	Boat Ramps	Provide public access to the coast.	1. Presence/absence 2. Area of viewshed from point (5 km) (Figure 2).
	State Parks/Wildlife Management Areas (TPWD)	Provide public access to the coast.	1. Presence/absence 2. Area
	City and County Parks	Provide public access to the coast.	1. Presence/absence 2. Area
	Marinas	Provide access to the coast. Not all marinas provide public access.	1. Presence/absence 2. Area within viewshed
	Beach Access Points	Provide public access to the coast.	1. Presence/absence 2. Area of viewshed from point (5 km)

Appendix A: Continued

Value proxies	Spatial data layer	Rationale for using this data layer	Measurement
Commercial fishing & bioproductivity			
	Private Oyster Leases	Provide submerged lands for harvest of oysters, enhances coastal commercial fishery.	1. Presence/absence 2. Area
	SEAMAP data live bottom 1982-1999	Seafloor areas rich in living benthic organisms provide higher bioproductivity.	1. Presence & absence 2. Area. Calculate area by a. presence (=100%) or create buffer around each point. Area is intersection of block.
	SEAMAP data fishery species 1982-1990	Presence of commercially important fish species is a positive indicator for commercial values.	1. Presence/absence 2. Area. If a dot is present in a block, then give block 100% area coverage.
Marine transportation			
	Gulf Intracoastal Waterway/ Ship Channels	Areas dedicated to the movement of vessels enhance marine transportation.	1. Presence/absence 2. Area will be measured by making lanes into polygons.
	Shipping Safety Fairways	Areas dedicated to the movement of vessels enhance marine transportation values.	1. Presence/absence 2. Area
	Anchorage Areas	Anchorage areas are a positive value for marine transportation as they provide ships a place to wait to come into port.	1. Presence/absence 2. Area
Coastal development			
	Boat Ramps	Boat ramps increase the value of coastal property by providing access to the water.	1. Presence/absence 2. Area of viewshed from point
	Marinas	Enhance development by providing residents of areas with marinas boat access and storage for their watercrafts.	1. Presence/absence 2. Area
	Coastal Leases (Point Locations)	These features protect coastal communities by providing physical support to coastal features.	1. Presence/absence 2. Area. Determine how to calculate area from points.
Historical/cultural sites			
	Archeological Sites	Provide historical, cultural value. Important to national heritage and history.	1. Presence/absence 2. Area calculated as a factor of the density of archaeological sites.
Research and education			
	Audubon Sanctuaries	Provide an area for research and education opportunities.	1. Presence/absence 2. Area
	National Wildlife Refuges	Provide an area for research and education opportunities.	1. Presence/absence 2. Area. Actual areas do not go into lease blocks or calculate a buffer along perimeter of refuges; this will allow us to calculate percentage of blocks to be protected.
	State Parks/Wildlife Management Areas (TPWD)	Provide an area for research and education opportunities.	1. Presence/absence 2. Area

Appendix B: Rational for buffer zone delineation of selected spatial data layers

Spatial data layer	Logic
Texas Artificial Reefs	These are usually visited by tourist boats and researchers. A buffer of around 500 m around these reefs was plotted so as to include a safe anchoring and movement area for the visiting vessels.
Beach Access	These are public access locations for beaches. The concept of viewshed was introduced in order to provide adequate weighting to the visual aesthetics along the beach. A visual distance of 5 km toward the horizon was plotted to cater to the visual reach from the access points (Firestik Antenna Company 2004).
Boat Ramps	A buffer of 10 km was plotted to cater to the extended visual coverage (by boat).
Marinas	A buffer of 10 km was plotted to cater to the extended visual coverage (by boat).
Coastal Leases	These include locations of structures and activities permitted by the GLO such as piers, docks, breakwaters, and shoreline protection project sand so forth. In order to cater to the influence zone of such structures, a buffer zone of 1 km was plotted around these point locations.

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