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Reality-based Marine Protected Areas for the Eastern Bering Sea

by
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Abstract

In this paper, we present another example of finding holistic guidance for systemic management; in this case, it involves defining the portion of ecosystems to be established as protected areas. As in previous cases, reality-based management is carried out by mimicking natural examples of sustainability. Although our emphasis is on marine protected areas (MPAs), the approach is one that can be applied in the protection of any area or ecosystem on the planet. To provide a specific example, we have chosen the eastern Bering Sea ecosystem and the management of fisheries in regard to MPAs. Thus, the management questions that can be addressed are exemplified by: *"What portion of the eastern Bering Sea ecosystem should be designated as areas where fishing is prohibited?"* For this example, the consonant research question (to guide the relevant science) is: *"What portion of the eastern Bering Sea ecosystem are areas where each species of marine mammal does not consume resources?"* Answering this question, we quantitatively characterize natural patterns of sustainability both within the greater eastern Bering Sea ecosystem as well as for 21 smaller ecosystems. These patterns provide guidance for the holistic (reality-based) and sustainable management of fisheries involving the portion of each ecosystem to be closed to fishing. Similar patterns for other areas (in either marine or terrestrial settings) would be used for guidance of the kind found within this study.

We conclude that roughly 33% of each of the marine ecosystems in our study should be placed in protected status (designated as MPAs). However, based on the likelihood of a broader pattern, it appears that the portion of an ecosystem to be set aside in sustainable protected status depends on the size of the ecosystem; it will probably be found advisable to set aside larger portions of larger ecosystems. Another natural pattern indicates that, for the eastern Bering Sea, setting aside one single area in protected status would likely suffice. We also conclude that a far more necessary measure in fisheries management in this ecosystem would be the reduction of harvest rates even though establishing MPAs remains as a crucial part of fisheries management. The pattern-based options for the portion of the eastern Bering Sea ecosystem to be set aside as MPAs are quite broad and do not reveal any notable abnormality in current fisheries management. In contrast, reality-based patterns in consumption rates among other species of mammals occupying this ecosystem indicate that current harvest rates are very abnormal and

large reductions in harvest rates are needed in our take from individual species, species groups and the entire ecosystem in order to achieve sustainability. Current harvest rates, as considered in conventional management practices and based on necessarily incomplete data, are all obviously abnormal/unsustainable in parallel with many other aspects of current forms of management.

Further research is needed to specify, reveal and characterize the consonant patterns that will provide information for holistic guidance for the specific timing and precise location of MPAs where fishing would be prohibited in the eastern Bering Sea.

CONTENTS

INTRODUCTION

In contrast to conventional management, one of the first steps in systemic management is to pose a management question (Fowler 2009, Fowler and Hobbs 2011; Fowler and Luis 2014). The primary management question that we begin with is: *"What portion of the eastern Bering Sea ecosystem should be designated as areas where fishing is prohibited?"* Various parts of large ecosystems such as the eastern Bering Sea (Fig. 1) themselves can be considered to be ecosystems also and the same question can be asked about each one. The area shown in Figure 1 is largely an ecosystem defined on the grounds of politics and conventional management rather than on a functional, biological basis, yet serves well to exemplify the use of macroecological patterns. More biologically (or environmentally) oriented definitions would be exemplified by the continental shelf or areas of specified primary production. Other examples of smaller systems would be the geographic ranges of various marine species where they overlap with the larger eastern Bering Sea (EBS) ecosystem. These areas of overlap are relevant as ecosystems of concern regarding marine fisheries interactions and management with respect to individual species. Larger ecosystems would be exemplified by entire continents or ocean basins. The

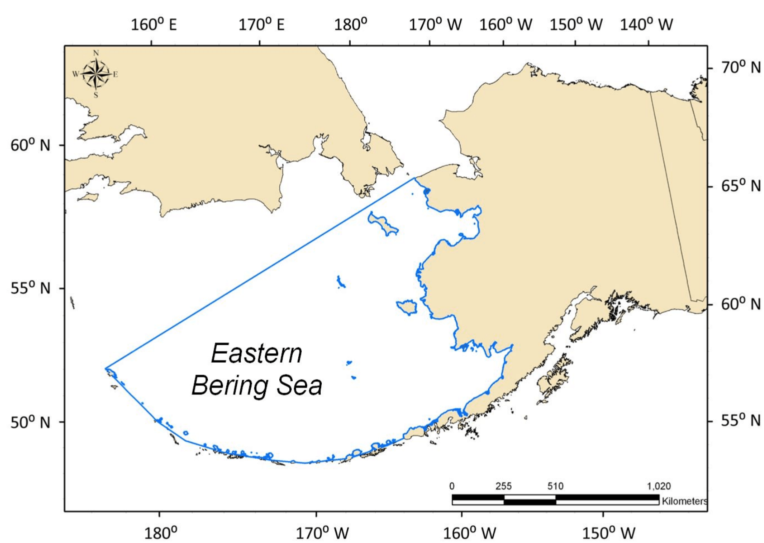

Figure 1. - - Map of the North Pacific Ocean, eastern Siberia, Alaska and the Bering Sea showing the area considered to be the eastern Bering Sea ecosystem (marine waters surrounded by the blue line, excluding islands — a total of 1,464,259 km^2.

approach we are describing in this paper (which involves mimicking natural, empirically observed, examples of sustainability) applies to ecosystems of any definition and the pertinent management question would be phrased to specify and define the area involved in each one.

The next step of systemic management is that of asking a consonant[1] research question. The research question involves the identification of what we try to mimic in following the examples of sustainability found in natural systems while simultaneously identifying patterns useful for avoiding abnormality. The research question that is consonant with the management question posed in the last paragraph is: *"What portion of the EBS ecosystem consists of areas where consumption of resources does not occur by each species of marine mammal found in that region?"* Later, we delve more deeply into the specifics of matching the two questions (management and research) in the application of the concept of consonance. Here, we note several steps accomplished in the progress toward desired one-to-one relationship between the two questions as posed above: 1) both questions involve mammals so that taxonomy is accounted for directly; we (as humans involved in fishing) are mammals and the other species to be studied are mammals, 2) both questions involve the same ecosystem (the same place); the area and its location on the surface of the Earth are the same, 3) the units of measure are the same; the portion of the area of an ecosystem where consumption does not occur is central to both questions, 4) the ecological relationship involved in management and the ecological phenomenon of interest in research are identical; consumption does not occur within the areas being identified (by the individual species being studied, and by our species in management), and, 5) in both cases, species (rather than another organizational level, such as individuals) are involved (species of marine mammals as characterized in research, and our species, *Homo sapiens*, is involved in fisheries management).

In systemic management, additional steps that follow the pairing of management and research questions include characterizing a natural pattern revealed through research that

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[1]Consonance involves a strict isomorphism, one-to-one mapping, and congruence between the management question, the research question, and the pattern providing guidance (see Belgrano and Fowler 2008; Fowler 2009; Fowler and Hobbs 2009, 2011; Fowler and Luis 2014 for more detail and further examples).

addresses the research question. In our case, the pattern is apparent through measurements of the portions of ecosystems where specific species do not occur and, therefore, do not consume resources at any time.[2] Another step is the recognition of the guidance inherent to the pattern, as we will review in the Discussion section. It is at the step of providing guidance (to attain human activities that fall within the normal range of natural variation; Fowler 2009) where our paper stops. In progressing beyond our paper, to the matter of management itself, portions of the ecosystem(s) would be set aside in protected status (in the case of the EBS, what are known as marine protected areas, MPAs; areas wherein no fishing would be allowed). This would be done using the empirically observed pattern to provide guidance regarding the portion of each ecosystem that should be involved. Thus, such management would mimic the sustainable participation in the respective ecosystem(s) by the other mammalian species which have been involved in the respective ecosystems and the biosphere for hundreds of thousands of years. Of crucial importance here is that consonance be maintained from the initial management question through to management action.

Our study is motivated, in part, by the decades of attention to the concept of using MPAs to address the problem of recurring depletion among stocks of fish subject to commercial fishing that is managed conventionally. Although the motivation for establishing MPAs goes well beyond the effects of fishing (see, e.g., Kelleher 1999), one dimension of such protection involves the spatial distribution of fishing. Conventional thinking, with its inherent limits, is behind current management and its selection and use of scientific information which prevents significant progress toward holism in related management action (Fowler 2003, 2009; Belgrano and Fowler 2011; Fowler and Hobbs 2011). With this in mind, one of our goals is to illustrate the process of using science to bring holism (Fowler et al. 2013) to management in regard to

[2]It must be clear here that populations of consumer species (as well as fisheries) can consume resources from many areas owing to the obvious fact that resources from an area where consumption *does not occur* can move to another area where they *are* consumed. We are very specifically focusing on areas where consumption does not occur, regardless of where potentially consumable resources have their origins or find themselves at other times. Part of the interactions among ecosystems (Guerry 2005) involves migratory phenomena — phenomena that are accounted for in the information provided by the integrative nature of natural patterns (Fowler 2009, Belgrano and Fowler 2011, Fowler et al. 2013).

sustainable human influence — in the case of our example, the portion of marine ecosystems where fishing would not be allowed.

In addressing this issue, we illustrate another application of systemic management to provide relevant guidance. We do this for a variety of marine ecosystems to show how systemic management is more holistic than conventional management. Because this approach is reality-based[3], it is also ecosystem-based (ecosystems are part of reality) and evosystem-based (evosystems[4] are part of reality). Reality-based management accounts for the complexity of all such systems in their participation and interacting with each other in the reality of which such systems are integral parts (Belgrano and Fowler 2008, 2011).

In the following sections, we describe the methodology used in finding answers to the research question we have posed and proceed to using the resulting information to illustrate the provision of guidance for management. We extend the approach through parallel consideration of multiple ecosystems within the larger EBS ecosystem — each one corresponding to the geographic range of a specific species as it overlaps with the EBS ecosystem. We are exemplifying an approach that applies to any ecosystem, however it might be defined; the approach can be applied to an infinite set of options, a minuscule sample of which we will describe.

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[3]See Belgrano and Fowler (2008; esp. Section I and box 1), Appendix 4.4 of Fowler (2009), Appendix 12.1 of Belgrano and Fowler (2011), and Appendix 3 of Fowler et al. (2013) for explanation of the reality-based nature of systemic management wherein the holism achieved accounts for all of reality (wherein ecosystems along with all other systems of the universe are included in their full complexity and complex sets of interactions).

[4]Evosystems include all the evolutionary and coevolutionary interactions and relationships among the species involved, as well as those of other ecosystems with which any particular ecosystem interacts. They include all selective forces such as those of the physical environment and extinction. See footnote 1 of Belgrano and Fowler (2011) regarding the history of the concept and the term "evosystem".

METHODS

"What portion of the EBS ecosystem is comprised of areas where consumption does not occur by each species of marine mammal within the system?" This question is addressed in the first part of the research reported in our paper. It is the question produced by the management question posed earlier after a one-to-one mapping (Fowler and Luis 2014) to a research question. To address this question, we measured (see Appendix I for detailed methodology regarding these measurements) portions of the EBS ecosystem which are not occupied by individual marine mammal species; where these species do not occur they do not consume resources.[5] To accomplish this objective, we used digital maps (Appendix II) of the geographic ranges of marine mammals within the Alaska region (Angliss and Lodge 2004)[6]. For purposes of illustration we are assuming that these maps adequately represent areas of the EBS ecosystem where, at one time of year or another, the represented species does occur and does consume resources while there. Conversely, we are assuming that areas falling outside the occupied regions represented by the maps are areas where individuals of the species do not occur and do not consume resources at any time of year. We are also assuming that the areas represented by the maps we used are sufficiently static to support being used for management advice today. We will revisit these (and other) assumptions in the Discussion section.

We repeated this process to determined the portions of the EBS occupied (P_1) by each species of marine mammal (see Appendix II). Each species was represented by a map similar

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[5]We reiterate the notion that these are areas from which at least some resources are undoubtedly consumed elsewhere owing to movement by migration or transport by ocean currents. These are areas in which consumption does not occur for a particular species because the species in question does not occur there — parallel to fisheries not consuming (harvesting) in MPAs by not being allowed to be there. This involves consonance (see footnote 1).

[6]These maps were considered to as reliable as possible in 2003, as published in the marine mammal stock assessments for the Alaska region (Angliss and Lodge 2004). The quality of this information will be treated more fully in the Discussion section.

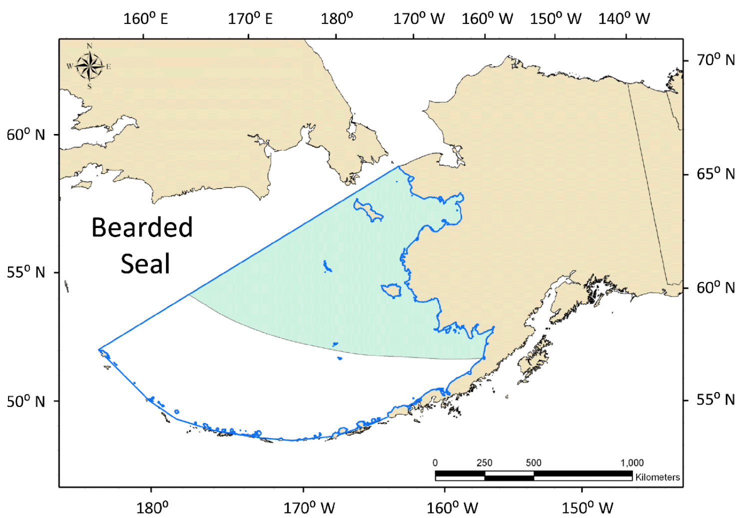

Figure 2. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the bearded seal (*Erignathus barbatus*) and the EBS ecosystem (with borders shown by the blue line). The portion of the ecosystem left unoccupied is shown in white.

to that shown in Fig. 2, with the area occupied shown in color and the area unoccupied shown in white. The portion left unoccupied (P_2) was calculated as the complement of the portion occupied ($P_2 = 1.00 - P_1$). With data for P_2, we calculated means and produced histograms representing the frequency distribution (pattern) of our measurements.

In the second part of our research, the process described above was repeated using a set of smaller ecosystems — each with a different measure of total area. This was done, in part, to illustrate the applicability of systemic management on any spatial scale and to any ecosystem. In this case, each ecosystem was defined on the basis of areas occupied by the individual species included in our study. Thus, a set of different ecosystems was defined as the areas within the EBS thought to be occupied, at some time of the year, by individuals of each distinct species. Each of these (mostly smaller) ecosystems was represented by a map similar to that in Figure 2 (see the maps of Appendix II for the colored areas within the EBS representing all 21 ecosystems). Having defined the areas of the resulting ecosystems[7], the process described above for the full ecosystem of the EBS (Fig. 1) was repeated. In this case, the overlapping areas of the geographic ranges of each marine mammal species (all within the confines of the full EBS) were used to find the portions of the respective ecosystem that are occupied (and find their complements as the portions not occupied, using the same techniques as for the full EBS and as described in Appendix I). Again, the data were compiled and used for calculating statistical means and displaying histograms representing observed variability. In this case, a form of meta-analysis was possible based on a treatment of the means for each ecosystem and their pattern of variation and central tendencies — all involving comparisons among species and ecosystems.

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[7]Ecologists often restrict their use of the term "ecosystem" to all of the species and their physical environment (along with all interactions and relationships) within an area that corresponds to a particular type of habitat — for example a lake, desert, or coral reef. All such definitions make up a subset of the definition used in this paper: all of the species and their interactions within any defined area on the surface of the Earth including their reciprocal interactions with the physical environment of that area. As will be discussed later, such an area can be the geographic range of any particular species, the overlap of geographic ranges of any pair of species, or that of any subset of all species in the biosphere (where there are actual overlaps). We are presenting systemic management as it applies to any ecosystem (with, therefore, an infinite set of options).

RESULTS

Our analysis resulted in information for 21 species of marine mammals (Table 1). The maps in Appendix II are the results of our conversion of the original maps from Angliss and Lodge (2004) to measurable representations of those areas of the EBS (a total of 1,464,259 km^2) occupied by each species. The maps in Appendix II are in the same order, by species, as the order of species represented in Table 1. Table 1 also shows the results of our measurements for the full ecosystem: 1) the area of the geographic range of the respective individual species that falls within the EBS ecosystem (A, in units of km^2), 2) the portion of the full ecosystem that is occupied (P_1 = A/1,464,259 km^2), and 3) the portion left unoccupied ($P_2 = 1.00 - P_1$).

The data that directly address our research question for the full EBS (the P_2 of Table 1) are displayed graphically in Figure 3. To help understand this histogram, consider for example one species, the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*). This is the only species for which the portion of the full EBS ecosystem not occupied is 77%. The portion 0.77 falls between 0.70 - 0.80 so that this species is one of 21 species (1/21 = 0.048 on the Y axis)

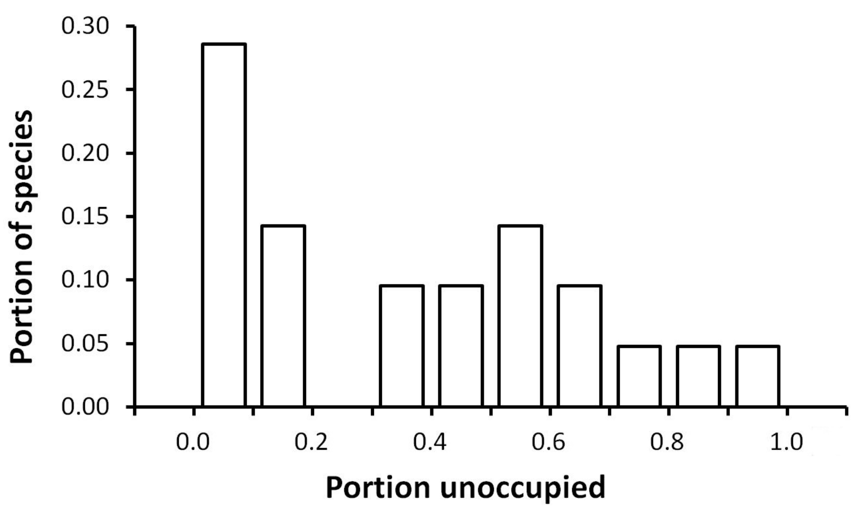

Figure 3. - - The frequency distribution of P_2 from Table 1 showing the portion of species (Y axis) that do not occupy the corresponding portion of the EBS ecosystem (X axis).

Table 1. - - A list of the 21 species of marine mammals found in the EBS ecosystem (a total of 1,464,259 km^2), showing an estimate of the area (A, in km^2) of their global distribution (their geographic range) that is confined to this ecosystem, the corresponding portion of this ecosystem that they occupy (P_1 = A/1,464,259 km^2), and the portion of this ecosystem that is unoccupied (P_2 = 1.00 - P_1).

Species	Common name	Scientific name	A (km^2)	P_1	P_2
S1	Baird's beaked whale	*Berardius bairdii*	719396	0.49	0.51
S2	Bearded seal	*Erignathus barbatus*	733000	0.5	0.5
S3	Bowhead whale	*Balaena mysticetus*	148618	0.1	0.9
S4	Dall's porpoise	*Phocoenoides dalli*	1239074	0.85	0.15
S5	Fin whale	*Balaenoptera physalus*	1464259	1	0
S6	Gray whale	*Eschrichtius robustus*	573735	0.39	0.61
S7	Harbor porpoise	*Phocoena phocoena*	497682	0.34	0.66
S8	Harbor seal	*Phoca vitulina*	226555	0.15	0.85
S9	Humpback whale	*Megaptera novaeangliae*	1463465	0.96	0.04
S10	Minke whale	*Balaenoptera acutorostrata*	1441938	0.98	0.02
S11	Northern fur seal	*Callorhinus ursinus*	1464259	1	0
S12	N.P. beluga whale	*Delphinapterus leucas*	872249	0.6	0.4
S13	N.P. right whale	*Balaena glacialis*	1464259	1	0
S14	Orca whale	*Orcinus orca*	1220522	0.83	0.17
S15	P. white-sided dolphin	*Lagenorhynchus obliquidens*	337782	0.23	0.77
S16	Ribbon seal	*Histriophoca fasciata*	1306386	0.89	0.11
S17	Ringed seal	*Pusa hispida*	646526	0.44	0.56
S18	Sperm whale	*Physeter macrocephalus*	983103	0.67	0.33
S19	Spotted seal	*Phoca largha*	956685	0.65	0.35
S20	Stejneger's beaked	*Mesoplodon stejnegeri*	818236	0.56	0.44
S21	Steller sea lion	*Eumetopias jubatus*	1464259	1	0

to be represented by the left-most of the three shortest bars. The mean of the full set of data is 0.351; for the average species, about 35% (513,885 km^2) of the EBS is unoccupied.[8]

The observation that mean portion of the EBS ecosystem not occupied by individual species is 0.351 (or, that the average nonhuman mammalian species leaves about 35% of the EBS unoccupied) does not mean that 35% of the EBS is free of the presence of marine mammals. No part of this ecosystem is occupied by less than 10 species (although not necessarily simultaneously, Fig. 4). Rather, our data indicate that, on average, individual species leave 35% of the full ecosystem unoccupied year-round. The unoccupied areas measured in our study are areas where an individual species does not occur at any time of year; individual animals of the species are thought never to be present to consume resources in these areas. This lack of consumption is parallel to (consonant with) the lack of fishing in MPAs (as we are defining them).

*"What portion of the geographic range of the bearded seal (*E. barbatus*) within the EBS ecosystem should be designated as areas where fishing is prohibited?"* This management question applies to an ecosystem that is smaller than the full EBS; it is one that occurs within the larger EBS ecosystem (Fig. 2). Any other species could have been chosen; the area of the EBS occupied by the bearded seal serves only as an example. This ecosystem involves 73,3000 km^2, with its location illustrated by the shaded area of Figure 2. The research question that is consonant with this management question is: *"What portion of the geographic range of the bearded seal (*E. barbatus*) within the EBS ecosystem is made up of areas within which consumption of resources does not occur by each of the other species of marine mammals found in that region?"* The results of our research to address the second of these two questions (the research question) are based on measurements using methods identical to those we used in addressing the first, more general, pair of questions in their application to the full EBS.

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[8]Keep in mind that there are areas outside of the EBS that are occupied by all of the marine mammals listed in Table 1 and shown in Figure 4. These areas (including the option of the entire geographic range of any species) can be considered ecosystems in their own right. Data for such ecosystems can be treated exactly as those in our study — ecosystems being treated as any area with a defined geographic boundary whether determined geologically, ecologically, biologically, politically, arbitrarily or any combination thereof.

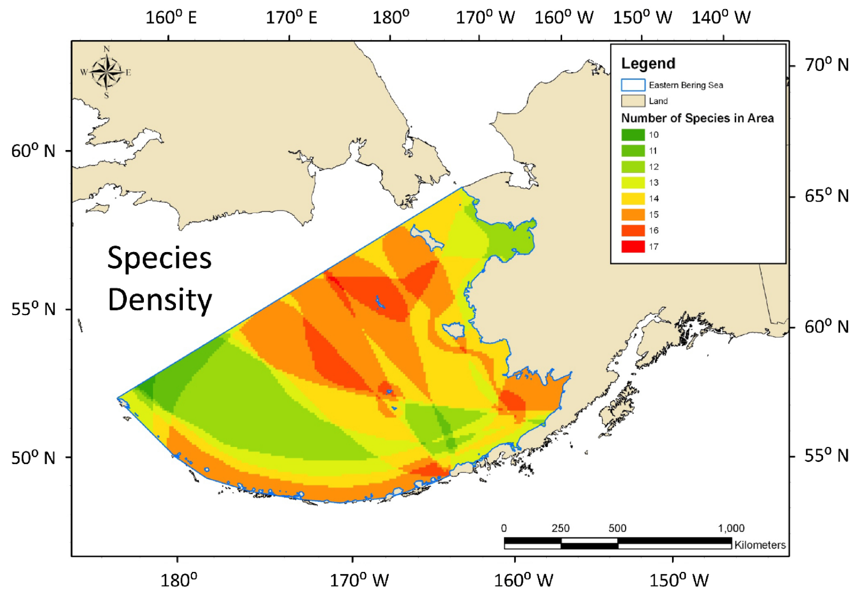

Figure 4. - - Map of the EBS showing the density of the 21 species of marine mammals (the number of marine mammal species per unit area) in various regions of the EBS ecosystem. This count represents the number of overlapping geographic ranges, not the number of species expected to be present at any one time.

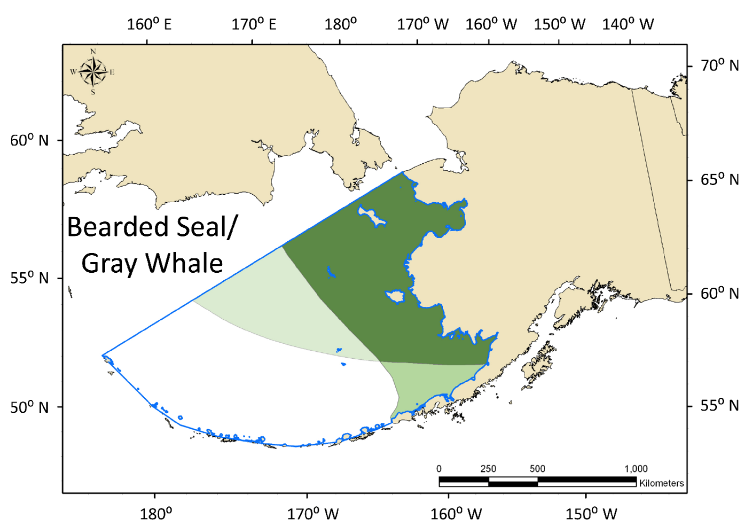

Figure 5. - - A map of the overlap between the geographic range of the bearded seal (*E. barbatus*) and the gray whale (*E. robustus*) in the EBS (Fig. 1). This map is a combination of the information in Figures A2.3 and A2.7 (Appendix II) showing the overlap between the two species in the dark shaded area in the northeastern part of the EBS.

Thus, Figure 5 shows the overlap between the geographic range of the bearded seal (*E. barbatus*) and the gray whale (*E. robustus*) within the EBS. Measurements (Appendix I) of this overlap indicate that it has an area of 564,410 km^2. Thus, the area of this smaller ecosystem[9] occupied by gray whales (at one time of the year or another) is 77% (0.77) of the 73,3000 km^2 occupied by the bearded seal. The area not occupied by gray whales in this smaller ecosystem thus represents 23% (1.00 - 0.77 = 0.23) of the ecosystem's total area (the area of the bearded seal ecosystem within the EBS). The other 19 species all have ranges that overlap with that of the bearded seal as displayed graphically in Appendix III (one map per overlapping species in the same order as Table 1). Table 2 (with the same structure as Table 1) is a presentation of the results of measurements of the overlapping areas for all 20 species within the bearded seal ecosystem. The data mentioned above for the gray whales is shown in line S6 of this table.

Figure 6 (similar to Fig. 3) is a histogram illustrating the frequency distribution of the data in the last column of Table 2 (the portion of the bearded seal ecosystem that is

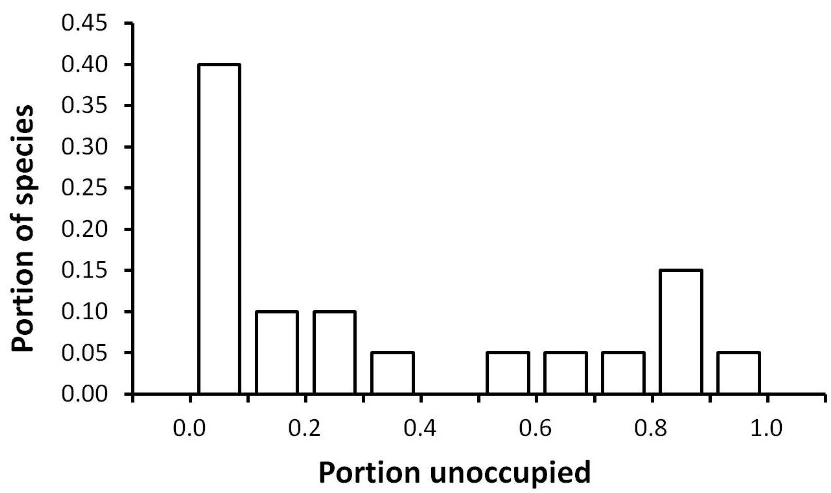

Figure 6. - - The frequency distribution of P_2 from Table 2 showing the portions of the geographic range of the bearded seal (*E. barbatus*) where it overlaps with the EBS ecosystem (733,000 km^2) that are not occupied by the other 20 species.

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[9]Keep in mind that the "bearded seal ecosystem" is defined as that area (within the overall EBS) where the bearded seal's geographic range overlaps with the full EBS (shown in Fig. 2).

Table 2. - - A list of the 20 species of marine mammals found in the ecosystem defined as the overlap of the geographic range of bearded seals (*E. barbatus*, or S2 of Table 1 — and omitted from this table) with the EBS ecosystem (Fig. 2, a total of 733,000 km^2), showing the same measures defined in Table 1 (A = area in square kilometers; $P_1 = A/733{,}000$; $P_2 = 1 - P_1$).

Species	Common name	Scientific name	A (km^2)	P_1	P_2
S1	Baird's beaked whale	*B. bairdii*	117280	0.16	0.84
S3	Bowhead whale	*B. mysticetus*	146600	0.2	0.8
S4	Dall's porpoise	*P. dalli*	520430	0.71	0.29
S5	Fin whale	*B. physalus*	733000	1	0
S6	Gray whale	*E. robustus*	498440	0.68	0.32
S7	Harbor porpoise	*P. phocoena*	278540	0.38	0.62
S8	Harbor seal	*Phoca vitulina*	80630	0.11	0.89
S9	Humpback whale	*M. novaeangliae*	733000	1	0
S10	Minke whale	*B. acutorostrata*	733000	1	0
S11	Northern fur seal	*C. ursinus*	733000	1	0
S12	North Pacific beluga whale	*D. leucas*	725670	0.99	0.01
S13	North Pacific right whale	*B. glacialis*	733000	1	0
S14	Orca whale	*O. orca*	564410	0.77	0.23
S15	P. white-sided dolphin	*L. obliquidens*	36650	0.05	0.95
S16	Ribbon seal	*H. fasciata*	601060	0.82	0.18
S17	Ringed seal	*P. hispida*	637710	0.87	0.13
S18	Sperm whale	*P. macrocephalus*	337160	0.46	0.54
S19	Spotted seal	*P. largha*	725670	0.99	0.01
S20	Stejneger's beaked whale	*M. stejnegeri*	205240	0.28	0.72
S21	Steller sea lion	*E. jubatus*	733000	1	0

unoccupied by each respective species). The construction of this histogram is identical to that of Figure 3. Here, the right-most bar represents the Pacific white-sided dolphin with its portion of the geographic range of the bearded seal that is not occupied (0.95; see Fig. A3.14 in Appendix III), as one of 20 species or 0.05 (= 1/20) on the Y axis. The mean portion of the bearded seal ecosystem left unoccupied among the other marine mammals is about 0.327 or 239,324 km^2.

There are 21 species of marine mammals involved in the EBS ecosystem (Table 1). The geographic range of each one can be treated as an ecosystem; in particular, the portion of that range that overlaps with the EBS ecosystem can be treated as an ecosystem as was done for the bearded seal above (each displayed in a corresponding map as presented in Appendix II). The portions of each such ecosystem that are not occupied by each of the other species can be determined, just as they were for the bearded seal. These measurements can be displayed in tabular form as they were for the bearded seal in Table 2; in particular, the measurements defined by our research question can be listed in a column identical to the last column of Table 2, one column per species. Had we reported our treatment of the other species with the specificity of our treatment of the bearded seal, there would be 20 more tables like that of Table 2, and 20 more appendices like Appendix III (there were a total of 210 species-specific pairs of overlaps).

Table 3 shows the collection of the right-most columns of species-specific tables like that of Table 2, had we constructed them for all 21 species. Thus, the second column of Table 3 (E2) is identical to the last column of Table 2 (with a dash representing the overlap of the geographic range of the bearded seal with the ecosystem defined as that of the geographic range for this species within the EBS ecosystem — there being an identity between the two). In other words, if we had constructed a table similar to Table 2 for the ecosystem of each species, the last column (i.e., P_2) of such tables would be the columns displayed in Table 3. Within the columns (ecosystems) of Table 3, each row represents the portion of the corresponding ecosystem that is not occupied by the respective species as identified by that row. For example, column E8, row S6, of Table 3, contains the value 0.53. This is the portion of the ecosystem (E8, the geographic range of the harbor seal, *P. vitulina*) as it is left unoccupied by the gray whale (S6, *E. robustus*).

The columns of Table 3 are presented graphically (as histograms) in Figures A4.22 - A4.39 — all similar to Figure 6, as discussed below.

Table 3. - - Portions of 21 ecosystems (identified by the columns), that are not occupied by the 21 species (identified by row) within the larger EBS ecosystem. Thus, S2 (Table 1) is the bearded seal, *E. barbatus*, and its geographic range defines the ecosystem of the third column (E2). This same species (S2) does not occupy portions of other ecosystems as measured by entries in the third row. Column 3 of this table (under the heading E2) corresponds to the last column (P_2) of Table 2.

Species	Ecosystem																				
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21
S1	-	0.84	1.00	0.42	0.51	1.00	0.67	0.53	0.51	0.52	0.51	0.79	0.51	0.47	0.33	0.45	0.96	0.27	0.78	0.12	0.51
S2	0.84	-	0.00	0.58	0.50	0.13	0.44	0.66	0.50	0.49	0.50	0.17	0.50	0.54	0.88	0.54	0.02	0.66	0.24	0.75	0.50
S3	1.00	0.80	-	0.91	0.90	0.74	0.85	1.00	0.90	0.90	0.90	0.83	0.90	0.96	1.00	0.89	0.77	0.95	0.84	1.00	0.90
S4	0.00	0.29	0.22	-	0.15	0.39	0.42	0.35	0.15	0.16	0.15	0.25	0.15	0.10	0.15	0.08	0.34	0.00	0.24	0.00	0.15
S5	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S6	1.00	0.32	0.00	0.72	0.61	-	0.34	0.53	0.61	0.60	0.61	0.39	0.61	0.66	0.71	0.68	0.21	0.89	0.40	1.00	0.61
S7	0.77	0.62	0.49	0.77	0.66	0.43	-	0.08	0.66	0.67	0.66	0.66	0.66	0.72	0.24	0.74	0.55	0.83	0.64	0.80	0.66
S8	0.85	0.89	1.00	0.88	0.85	0.81	0.58	-	0.85	0.85	0.85	0.90	0.85	0.83	0.47	0.89	0.87	0.88	0.87	0.86	0.85
S9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S10	0.03	0.00	0.00	0.02	0.02	0.00	0.03	0.05	0.02	-	0.02	0.00	0.02	0.00	0.05	0.02	0.00	0.02	0.00	0.03	0.02
S11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S12	0.75	0.01	0.00	0.47	0.40	0.05	0.41	0.60	0.40	0.40	0.40	-	0.40	0.42	0.82	0.43	0.00	0.56	0.10	0.65	0.40
S13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S14	0.10	0.23	0.66	0.12	0.17	0.29	0.32	0.08	0.16	0.15	0.17	0.19	0.17	-	0.07	0.16	0.26	0.10	0.18	0.10	0.17
S15	0.69	0.95	1.00	0.77	0.77	0.83	0.49	0.21	0.77	0.78	0.77	0.93	0.77	0.74	-	0.79	0.93	0.76	0.86	0.73	0.77
S16	0.00	0.18	0.02	0.03	0.11	0.27	0.32	0.37	0.11	0.11	0.11	0.15	0.11	0.10	0.18	-	0.21	0.00	0.16	0.00	0.11
S17	0.96	0.13	0.00	0.66	0.56	0.11	0.42	0.64	0.56	0.55	0.56	0.26	0.56	0.61	0.86	0.61	-	0.75	0.32	0.86	0.56
S18	0.00	0.54	0.67	0.21	0.33	0.82	0.66	0.47	0.33	0.33	0.33	0.50	0.33	0.27	0.31	0.25	0.63	-	0.50	0.00	0.33
S19	0.70	0.01	0.00	0.41	0.35	0.00	0.31	0.44	0.35	0.34	0.35	0.02	0.35	0.35	0.61	0.39	0.00	0.52	-	0.62	0.35
S20	0.00	0.72	1.00	0.34	0.44	1.00	0.67	0.50	0.44	0.45	0.44	0.68	0.44	0.39	0.34	0.37	0.82	0.17	0.67	-	0.44
S21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-

As documented above, the mean portion of the bearded seal ecosystem left unoccupied among the other species is 0.327. Table 4 shows similar means for all 21 ecosystems represented in Table 3; thus, the means listed in Table 4 are the means of the columns of Table 3. In other words, entries in the last column of Table 4 are the mean portions of various ecosystems that are left unoccupied by the other 20 species of marine mammals found in the larger EBS ecosystem (excluding cases of no overlap). Each specific ecosystem is also represented by a measure of its area (km^2 — with a map in Appendix IV), and a histogram representing the pattern of areas left unoccupied (identified by the Fig. Number from Appendix IV). Entries in the fourth column that are shown in parentheses are for species that occupy the entire EBS ecosystem.

Figure 7 shows the pattern among the means from the last column of Table 4. For example, in this pattern, the mean portion of the geographic range of the bowhead whale (the part found within the EBS, Fig. A2.4, Appendix II) that is not occupied as measured for the other 18 species (two species do not have any overlap in geographic ranges with that of the bowhead) is 0.129. This locates the shortest bar (on the left) in its position on the X axis, with a height of 1/21 = 0.476 (one ecosystem out of 21). The mean of this distribution is 0.334.

As will be discussed in greater detail in the Discussion section, the means of Table 4 (as shown in Fig. 7) do not include values of 1.00 (complete lack of overlap). This is because millions of species[10] fit such a category and cannot all be included in our analysis (the number of ecosystems that species participate in involves a distinctly different pair of management and science questions). This is consistent with our treatment of the full EBS ecosystem; the lack of overlap among most other species (and marine mammal species in particular) was not included in our analysis. An example of this for the smaller ecosystems involves the bowhead whale and the harbor seal. The range of the bowhead whale (Fig. A2.4, Appendix II) in the EBS does not overlap that of the harbor seal (Fig. A2.9, Appendix II). The portion of each ecosystem (E3 and E7, respectively) that is not overlapped by the other species is 1.00 in each case.

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[10]This value would also be representative of most other species. For example it would represent the howler monkey (*Alouatta caraya*) of Central and South America. This, and all other such species, were not included in the means reported in Table 4.

Table 4. - - The means of the columns of Table 3 ($\overline{X}$) as the mean portions of the various ecosystems (identified in the first column) that are left unoccupied by the other 20 species of marine mammals found in the larger EBS ecosystem (excluding cases of no overlap).

Ecosystem	Ecosystem (by species name)		Histogram	km^2	$\overline{X}$
E1	Baird's beaked whale	*B. bairdii*	A4.22	719396	0.316
E2	Bearded seal	*E. barbatus*	A4.23	733000	0.327
E3	Bowhead whale	*B. mysticetus*	A4.24	148618	0.129
E4	Dall's porpoise	*P. dalli*	A4.25	1239074	0.366
E5	Fin whale	*B. physalus*	(A4.26)	1464259	0.367
E6	Gray whale	*E. robustus*	A4.27	573735	0.271
E7	Harbor porpoise	*P. phocoena*	A4.28	497682	0.347
E8	Harbor seal	*P. vitulina*	A4.29	226555	0.29
E9	Humpback whale	*M. novaeangliae*	A4.30	1463465	0.366
E10	Minke whale	*B. acutorostrata*	A4.31	1441938	0.365
E11	Northern fur seal	*C. ursinus*	(A4.26)	1464259	0.367
E12	North Pacific beluga whale	*D. leucas*	A4.32	872249	0.336
E13	North Pacific right whale	*B. glacialis*	(A4.26)	1464259	0.367
E14	Orca whale	*O. orca*	A4.33	1220522	0.358
E15	Pacific white-sided dolphin	*L. obliquidens*	A4.34	337782	0.317
E16	Ribbon seal	*H. fasciata*	A4.35	1306386	0.365
E17	Ringed seal	*P. hispida*	A4.36	646526	0.329
E18	Sperm whale	*P. macrocephalus*	A4.37	983103	0.368
E19	Spotted seal	*P. largha*	A4.38	956685	0.34
E20	Stejneger's beaked whale	*M. stejnegeri*	A4.39	818236	0.307
E21	Steller sea lion	*E. jubatus*	(A4.26)	1464259	0.367

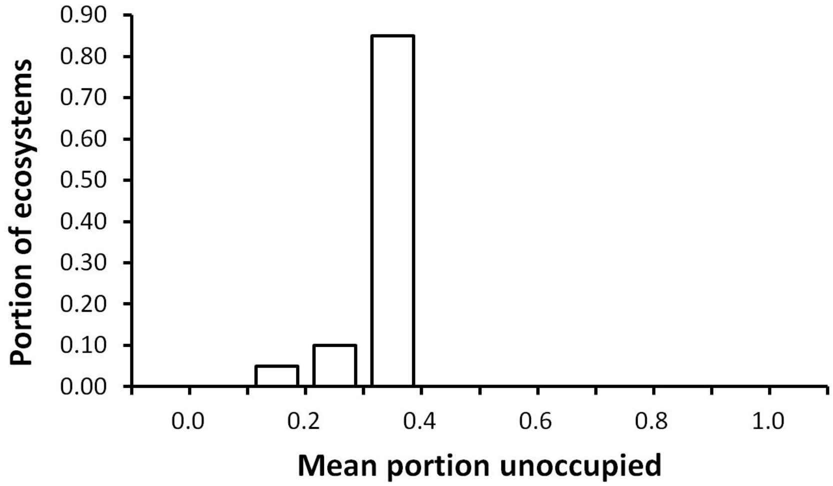

Figure 7. - - The frequency distribution of $\overline{X}$ from Tables 3 and 4 showing the portion of ecosystems (Y axis) that are represented by the corresponding mean of their unoccupied areas (measured as portions, X axis).

At the other extreme, the geographic ranges of species such as the fin whale (S5, *B. physalus*), the northern fur seal (S11, *C. ursinus*), the North Pacific right whale (S13, *B. glacialis*), and the Steller sea lion (S21, *E. jubatus*) include the entire EBS ecosystem ($P_2 = 0.00$ in Table 1). The respective species-specific ecosystems are represented by maps in Appendix IV that are nearly identical to that in Figure 4 (they involve one less species owing to the fact that one species was used to define the ecosystem; every species fully occupies its own ecosystem).

Figure 6 represents the pattern in portions of the bearded seal ecosystem that are not occupied by other marine mammal species in the region of the EBS ecosystem. In parallel with the pattern in the number of overlapping geographic ranges (Fig. 4 for the full ecosystem, and species-specific ecosystem maps in Appendix IV), patterns are seen in the portions of species-specific ecosystems that are not occupied by the other marine mammal species in the region. These are illustrated by Figures A4.22-A4.37 in Appendix IV (without repeating the histograms for E11, E13, and E21 which are mathematically identical to E5, Table 4). Table 4 shows the area (km^2) of each of the respective species-specific ecosystems and the means of the distributions presented graphically in Appendix IV. Figures A4.30 and A4.31 are visually identical to Figure A4.26 although the data they represent are not mathematically equivalent.

DISCUSSION

Asking Questions

Any form of effective management involves posing a management question early in the process. As pointed out by Fowler and Hobbs (2009, 2011), this rarely happens, even in published literature in the field of applied ecology (Fowler and Luis 2014). Walters (2000) asks, in the title of his paper, *“How large should protected areas be?”* This question is not only an example of the rare occurrence of a management question in the published literature, it is especially rare in being a question that involves MPAs. It is a question closely related to those that we are addressing in this paper. For an ecosystem application of this kind of question, an effective formulation of the question involves the portion of an ecosystem (as addressed in this paper) to be involved. With estimates of what portion should be involved, and information on the size of the ecosystem, the total area can be expressed (e.g., about 490,000 km^2 based on the data we present for the EBS).

Asking questions about (and getting information to provide guidance regarding) the portion of an ecosystem to set aside in MPAs leads to further questions. One, also stimulated by the question asked by Walters (2000), is that of how many MPAs should be involved? In particular: *“How many marine protected areas should be established in the EBS within each of which fishing is not allowed any time of year?”* If we take the same kind of approach that we took for addressing the question concerning what portion of the ecosystem should be involved, we then ask the research (or science) question of: *“How many distinct areas of the EBS are not occupied by each of the marine mammal species found within this ecosystem?”* In looking at the maps found in Appendix II, we find that the orca (Fig. A2.15) involves two; all others involve just one. This is another empirically observed integrative pattern that provides guidance. Based on the information in this pattern, we would conclude that a single marine protected area of approximately 490,000 km^2 would serve quite well in the management of fisheries in this ecosystem. Setting up a large number of small MPAs would be abnormal (Appendix V).

With the size and numbers of MPAs for the EBS treated systemically, we are faced with determining location. Because most species do not occupy the green-shaded area north of the

Aleutian Islands, toward the west, (Fig. 4), this would be an area for serious consideration as a proper location for one or more MPAs[11]. Based on relatively current information, this is an area subject to very little fishing (Appendix V); nothing about current fishing appears to be abnormal in this regard. Attention to overlap with the geographic ranges of other species (species other than marine mammals) might help specify location; however, given the variance shown among species in Appendix IV (Figs. A4.22-A4.39), there seems to be little reason to be particularly concerned about such issues at this point.

What is seen in the distribution of fishing (Append. V) does show that fishing overlaps the distribution (geographic ranges) of many of the marine mammals in the EBS and particularly areas where there are concentrations of overlapping geographic ranges (compare Fig. A5.1 with Fig. 4). Both marine mammals and fisheries are, among other things, making use of information regarding locations where resources are available. This emphasizes the importance of fishing at rates that are sustainable in those areas in a way that is consistent with harvest rates for each species involved in harvests, harvests from species groups, and harvests from the ecosystem as a whole (all issues to be treated with the process we are exemplifying in this paper; i.e., each with its own management question and empirical information to provide guiding information).

Question Refinement

As we made clear above, the data which we used in our analysis pertains to areas of the various ecosystems wherein consumption by each individual species would not occur at any time of year. This means that the management question to which our data apply would be better phrased: *"What portion of the EBS ecosystem should be designated as areas where fishing is prohibited throughout the year?"* This rephrasing of the management question is an example of

[11]On the surface, this seems counterintuitive. Conventional thinking would lead us toward protecting areas occupied by other species that we think of as needing our protection. However, this prevents dealing with the complexity of things, such as solving actual problems involving human activities affecting those species. These would be exemplified by competition caused by overfishing; overfishing requires addressing the specific matter of rates at which fish are harvested. The issue of locations for MPAs will be dealt with again later in this section.

refinement (making the management question more specific to the actual management action combined with the extenuating circumstances and their complexity)[12]. It exemplifies the use of scientific information to refine the management question; the pattern we revealed through our study involved areas in which no consumption is believed to occur because the species are thought to never be represented by individuals in those areas at any time of year.

Another example of refinement was demonstrated by our subdivision of the larger EBS ecosystem into 21 sub-areas — ecosystems in their own right, and corresponding to the overlap between the full ecosystem and the geographic ranges of individual species. This allowed for the explicit treatment of each of these smaller ecosystems with the same management question posed for the larger ecosystem (i.e., dealing with the portion of the ecosystem that should be set aside in areas where fishing would be prohibited any time of year). As we will see below, spatial scale can also be expanded to treat larger ecosystems and the biosphere; no spatial scale is excluded — an example of bringing holism to management insofar as we can ask all of the management questions (see Fowler 2008, and Fowler and McCluskey 2011 for applications involving harvest rates as they are involved in systemic management on any spatial and temporal scale).

All of the questions that we addressed directly in this paper are questions that themselves need to be addressed through specific management action. More questions bring more complexity to the matter of management when the factor of time is considered directly. The explicit treatment of seasonal (or monthly) differences in the extent of MPAs is very important. Thus, our initial management question (*"What portion of the EBS ecosystem should be designated as areas where fishing is prohibited?"*) can be refined (and rephrased) to: *"What portion of the EBS ecosystem should be designated as areas where fishing is prohibited during March?"* The consonant research question would be: *"What portion of the EBS ecosystem is made up of areas where consumption does not occur by the species of marine mammal found in that region of the world during March?"* In this pair of questions, the word "March" can be replaced by any month, or any season (spring, fall, etc.) — any temporal unit, of any scale. This

[12]See Fowler and Hobbs (2011) for more detail regarding the process of refinement in asking management questions.

question can be rephrased to apply to *any* ecosystem (e.g., those defined as species-specific ecosystems in this paper, any continent, the geographic range of any species — any area bounded by defined borders). Our point here is that systemic management can be applied on all scales of time and space (Appendix II). Further direct inclusion of holism involves all scales of time in combination with any spatial scale, as developed above, combined with any scale of hierarchical organization as developed elsewhere[13].

Quality of Data

This paper exemplifies the choice of the most useful *kind (or category)* of data for management. Specifically, this is information from an empirically observed integrative pattern that is consonant with each management question — a matter of overarching importance. The matter of the *quality* of data, and the *quality* of research producing it, are also extremely important. It is critical that we make a distinction between kind and quality for both data and research; we treat quality in this section with emphasis on data.[14]

The quality of data depends heavily on the quality of the methodology involved in the science brought to bear in the task. Specifically for our case, this involves the degree to which the maps that we used are maps that adequately represent the actual areas of the EBS ecosystem (and the smaller species-specific ecosystems) left unoccupied by individual species. Are they accurate, precise, and free of bias? In this study we drew upon the results of work compiled by Angliss and Lodge (2004); we assume that, given the constraints of resources (e.g., funds, personnel, time) these authors did the very best job possible in their interpretation and use of information available to them. For the most part, this information was produced and published by other authors. We also assume that those authors (see the references in Angliss and Lodge's

[13]See Fowler (2003, 2009) and Fowler and McCluskey (2011) for the incorporation of trophic level, levels of biological organization (single species, species groups, ecosystems, etc.), and factors such as body size.

[14]The matter of kind involves consonance which has been largely missing in conventional management (Fowler 2003, 2009; Belgrano and Fowler 2011; Fowler and Hobbs 2011; Fowler and Luis 2014).

(2004) work) were also attentive to ensuring the best quality possible for their research. The point we are emphasizing here is that decisions regarding the portion of the EBS ecosystem (and sub-systems) to set aside in year-round MPAs is dependent on data of adequate quality. We need not remind any experienced field biologist of the costs involved in producing quality data, now of the kind necessary to holistically address management questions under consideration. Failure to meet the standards of quality can often lead to misleading management advice.

Thus, we want to make clear that the advice stemming from the work we are reporting in this paper is subject to the quality of the information we used. Most field biologists (including, especially, the authors of all of the research represented) will understand that this information is subject to a variety of potential errors and bias. In the end, however, the data we used in this paper is the best available and illustrates our point regarding the need for, choice of, and use of, information that is consonant with management questions (emphasizing the importance of asking the management questions; Fowler and Luis 2014).

As distinct from quality, then, there is the matter of consonance as exemplified in this paper. Without consonance, management is easily misled by short-term, incomplete, largely anthropocentric factors such as the influence of public opinion (Agardy 1994, Badalamenti et al. 2000; often encouraged: Kelleher 1999, but always influential: Sumaila et al. 2000, Walters 2000, and Pollnac et al. 2001), and economics (overtly included: e.g., Rassweiler et al. 2012, often encouraged: Agardy 1994, Kelleher 1999, Badalamenti et al. 2000, and Walters 2000, but always involved: Sumaila et al. 2000, Pollnac et al. 2001). The same holds true for many other factors such as politics, ignorance, and world views (paradigms)—all inherently accounted for in the integrative patterns behind the data used in this paper.

Another specific concern regarding the nature of data we used involves our assumption that the information published in 2004, and representing studies conducted even earlier, is information that can help guide management today. It is entirely possible that the geographic ranges of various species are shifting (owing to changes, for example, in mean local and global temperatures, including sea-surface temperatures; e.g., see Doney et al. 2012.). More current information would be preferable to the historical data that we had available to us. The guidance provided by the information we present is subject to potential bias owing to its dated nature.

Further Questions

We started with one primary management question (involving one large ecosystem) and went on to address the same question for 21 distinct ecosystems (mostly smaller ecosystems within the larger one). Had we chosen to do so, we could have defined ecosystems on the basis of the geographic range of *any* species in its overlap with the EBS. This could have included the geographic range of the walleye pollock (*Gadus chalcogrammus*) or any of the areas where this species is concentrated during specific periods of its life cycle (e.g., spawning, reproductive maturation, etc.). It could have been the overlap of the geographic range of the walleye pollock with the continental shelf, or any particular type of benthic habitat. The same is true for any species of fish, cephalopod, sea bird, phytoplankton, zooplankton or bacteria — any species. The location and size of those areas would be treated exactly as we treated the areas[15] represented by the maps in Appendix II.

A distinct management question can be asked in each case of the virtually infinite set of ecosystems—exemplified by those that can be defined as described in the last paragraph. As we are using the term, ecosystems can be defined politically (e.g., states, provinces, or countries), geographically, or ecologically. As mentioned in the introduction, ecosystems can be defined on the basis of environmental consistency (areas such as the continental shelf, ocean basin, or areas of specified depth). The template for such questions is: *"What portion of ecosystem X should be designated as areas where direct human influence is not allowed?"* "Ecosystem X" would be replaced by the specific ecosystem (area) defined by the concerns of managers or scientists (as described and exemplified in the preceding paragraph; see also Appendix II). The possibilities are unlimited — part of the holism achieved in systemic management.

The potential for this holism involves ecosystems anywhere they occur. The coral reefs of the world are ecosystems that many see as needing protection from human influence,

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[15]Again being mindful of all other species represented by populations in the specified area, all of their ecological and evolutionary interactions and their interactions with the physical elements of that area — the full set of factors involved in the complexity of any ecosystem.

including through the implementation of MPAs (e.g., see Mora, et al. 2006). The geographic range of any species found on any coral reef can be treated as an ecosystem and given protection guided by data of the kind we have presented in this paper (requiring research, in most cases, beyond budgetary constraints, but emphasizing the potential and need for meaningful research). As in the case of the EBS, there are a plethora of other management questions to be addressed (including those related to sustainable rates of harvesting, and sustainable selectivity regarding life history features, in addition to selectivity in regard to spatial distribution as covered in this paper).

As noted earlier, we did not include, in this study, species that had no overlap with the ecosystems we chose for exemplifying systemic management. Thus, there were only 16 species (out of the total of 21) included in our data for the bowhead whale ecosystem (Fig. A2.4); for example the distribution of the Baird's beaked whale (Fig. A2.2) does not overlap that of the bowhead whale. This is true for many (most) other species, including other marine mammals that have their geographic ranges well outside the area of the EBS — species such as the spinner dolphin (*Stenella longirostris*), the Antarctic fur seal (*Arctocephalus gazella*), and harp seals (*Pagophilus groenlandicus*). The number of species that leave the ecosystems we studied unoccupied is huge. Even if we included no more than all other species of marine mammals (about 100 species; Rice 1998), the right-hand bars ($P_2 = 1.00$) of Figures 3, 6 and A4.22 - 4.39 (Appendix IV), would have overwhelmed the other bars. Under these circumstances, the means of the distributions would have been approximately 0.88 compared to the 0.33 we observed (the mean of means, Fig. 7). There would have been an even larger difference if we had included all mammals.

These observations all lead to recognition that most species do not occupy (to any extent) very many ecosystems of the size we typically consider. If we choose to harvest from the EBS, the other species that are present in this ecosystem give us our first substantive clue as to what portion of the ecosystem to set aside in year-round protected status. There is, then, another question that is taking shape. A first approximation of this question might be *"In how many ecosystems can we sustainably take harvests from areas that are not designated as protected areas?"* A challenge encountered in this question is that of defining the size of an ecosystem —

they can be of virtually any size and defined quite arbitrarily. This not an insurmountable impasse owing to the fact that there is a highly related and relevant dimension for all species that can be measured: the size of its geographic range. The management question then becomes: *"How large is a sustainable geographic range for the human species?"*[16]

Perhaps more relevant to the matter of MPAs, and on a larger spatial scale, is the management question: *"With how many geographic ranges of other species can the geographic range of our species sustainably overlap?"* This issue would result in a research question along the lines of : *"Within the geographic range of individual species of human body size, how many geographic ranges of other species are overlapped?"* Elements of the study of island biogeography would be brought to the task of conducting the resulting science — emphasizing the multidisciplinary nature of systemic management and an unending need for research.

Our point in the last few paragraphs is that concerns about the asking of one question can provide motivation and basis for asking entirely different management questions. Asking a completely distinct question is often a matter involving a different dimension in the measures of species rather than refinement of a question for which the species-level dimension is already identified. For example, asking a question about the amount of biomass that can be harvested sustainably in the EBS is highly related, but distinct from the question of what portion of the ecosystem to be set aside in MPAs. Asking questions about the sustainability of harvests from any particular resource species is important, as is asking about the sustainability of harvests from any group of species.

The same holds for measures of the environment — measures that can involve many dimensions. The size of an ecosystem illustrates this point. Across broad spatial scales, what portion of an ecosystem's area should be protected if we directly account for ecosystem size (specifically, the area of the ecosystem)? Do larger ecosystems (ecosystems covering greater areas) require leaving larger portions in protected status? Figure 8 provides preliminary

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[16]Fowler and Hobbs (2003) treat this question to find that the mean geographic range for other mammals is about 226,400 km^2 while that for humans is about 473-fold larger, a discrepancy that is much larger if we consider the marine environment where we harvest resources as part of our geographic range.

indications that the area of an ecosystem does in fact make a difference. As would be expected on general principles, larger ecosystems include more area outside the geographic ranges of species with which they overlap. In Figure 8, the collection of points represented by data from this study are represented by filled diamonds in the central part of the graph (the last column of Table 4, as the portion unoccupied, plotted against the fourth column of Table 1, the size of the ecosystem). In essence, the complete EBS ecosystem is represented by several points for which geographic ranges occupy the entire area. The filled square at the top of the graph represents the entire planet as an ecosystem (with the mean portion of the total area unoccupied based on data from Agosta and Bernardo 2013). The filled triangle represents the mean portion of North America unoccupied by the geographic ranges of mammals in that continent (Hobbs and Fowler 2008). The line is fit to pass through 0.0, the data from this study, and the point for the entire Earth; it is meant only to draw attention to a probable macroecological pattern in need of much more research and data. If such a relationship is substantiated through further research, there is real potential that the size of an ecosystem might be useful as a means for providing a first approximation of what portion should be set aside in protected status (protection from direct effects by humans).

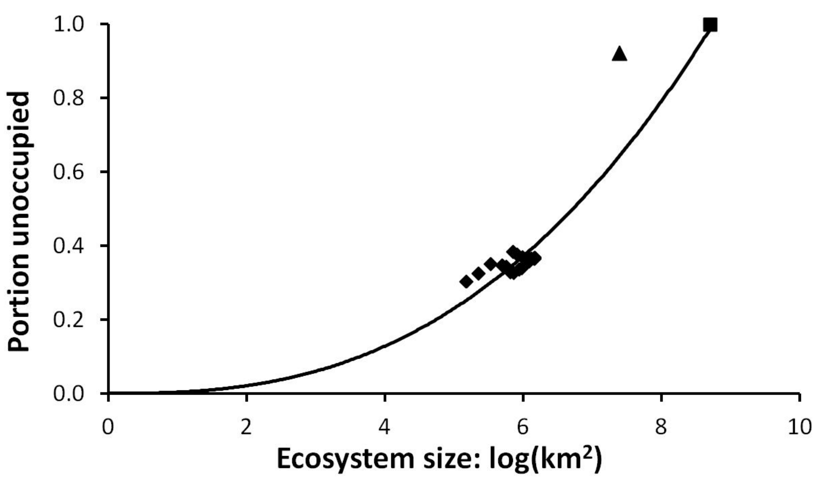

Figure 8. - - A preliminary illustration of the portion of an ecosystem that is unoccupied by mammalian species as a function of the size of the ecosystem (area) and serving as an estimate of the portion that should be set aside for protection from direct effects by our species (see text for details).

Interpretation/Guidance

What do the results of our analysis mean for management in the EBS? If we take the mean of 0.351 (Fig. 3) as a standard for the EBS ecosystem, mimicry of the sustainability observed for other mammalian species would result in management in which about 35% of this ecosystem would be set aside in MPAs within which no fishing would be allowed any time of year. The location of these MPAs (or more appropriately one MPA, as based on the count of areas left unoccupied by other species; Append. V) would be guided by information such as that shown in Figure 4 by placing the MPAs in locations occupied by the fewest species (and fishing in areas where most mammalian species consume resources[17]). In both the case of size and location, further information would help provide guidance regarding where and when fishing is advisable based on more specific and reliable information regarding the spatial-temporal dynamics of the presence and absence of other mammalian[18] species (especially of our body size).

The lack of well defined patterns within the limits of 0.00 to 1.00 (the extremes of the X axis of Fig. 3, and Figs. A4.22-A4.39 in Appendix IV) might be seen as basis for concluding that a broad range of options are realistic; neither abandoning fishing, nor fishing in the entire ecosystem(s), would be particularly abnormal compared to the pattern observed among other species (keeping in mind that this conclusion is valid only in regard to other marine mammal species that have geographic ranges in the region of the Bering Sea). The fact that the mode of all of the patterns in unoccupied areas is near 0.0 (Append. IV) emphasizes this possibility. This would bring us to the tentative conclusion that MPAs are not as important as is reflected in the current scientific literature (see e.g., Gaines et al. 2010). However, this very tentative conclusion

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[17]This is consistent with the notion of fishing where there are fish to be harvested as indicated by where marine mammals find such resources — something fishers already understand. The matter of fishing at sustainable rates is another and distinct issue and itself one to be dealt with by consonant patterns (e.g., Fowler et al. 2013). See also footnote 11.

[18]Using other mammalian species as natural examples of sustainability for humans to mimic is an example of directly accounting for our (human) mammalian taxonomic status.

is only pertinent to the EBS and is not necessarily meant to be applicable to other, especially larger, ecosystems (Fig. 8).

The main strength of an argument that a portion of these ecosystems *should* be devoted to MPAs lies in the pattern displayed in Figure 7; this calls into question the tentative conclusion of the last paragraph. In the case of nearly all means among the species-specific ecosystems, guidance for the recommended portion of the ecosystem to be set aside in MAPs is close to 0.33 or 1/3 of the ecosystem — nearly the same as that for the entire ecosystem. Thus, the guidance emerging from our work is the advice to set aside about 1/3 of the EBS in areas where fishing is prohibited year-round, and to locate them in the green-shaded portions of Figures 4 and A4.1-A4.21. We emphasize that this is not guidance coming from us as the authors of this paper as much as it is from guiding information found in the natural systems — information observed through the study of the distribution of other species.[19] It is information that is integrative far beyond that achievable through the integrated ecosystem management approach that is often advocated today (e.g., Kelleher 1999); human limitations in such approaches prevent the holism that is achievable in systemic management (Fowler 2009; Fowler et al. 2013).

However, given the fact that nothing we are doing now is clearly abnormal or pathological in regard to MPAs in the EBS (with the possible exception of there being far too many; Appendix V), emphasis is placed on solving problems wherein our involvement in that ecosystem is clearly atypical among species. Priorities become clarified in regard to establishing MPAs versus reducing harvest rates[20] when we note that harvesting, as measured in tons per year

[19]In other words, the advice coming from us is more a matter of encouragement to use natural patterns for guidance than that one third of the EBS should be set aside in MPAs. That advice comes from the information found in the integrative empirical patterns. This is parallel to what transpires in the medical realm; medical doctors may indicate that an appropriate body temperature is 37° C, but the guidance actually comes from the information involved in integrative natural patterns of body temperature.

[20]Managing fisheries to control harvest rates and controlling where fishing can and cannot occur (establishing MPAs) are two distinct issues for management. They each involve distinct management questions and require distinct empirically observed natural patterns to provide guidance. In conventional thinking we find a balance between the two; in systemic thinking we take advantage of the balance found in nature.

(as well as other metrics such as portion of standing stock harvested per year), is from 7 to 17 times too large to maximize biodiversity within this ecosystem[21]. The conclusion that reducing harvest rates is both important to accomplish, and effective, is consistent with the results of early experience in using MPAs; the effect of reduced fishing is clear (e.g., Jennings, et al. 1996; Roberts, et al. 2001; Micheli, et al. 2005). Reduced harvesting ecosystem-wide will have an impact. The distribution of harvests (within areas open to harvesting—i.e., outside the MPAs) remains as an issue to be treated directly (e.g., see Fowler and Crawford 2004), both in terms of their allocation over time and space — important, in part, because of the matter of spatial and temporal selectivity and its evolutionary implications.

Holism/Reality

We are obviously limited in our capacity to ask all of the management questions that need to be asked; full holism in that regard is impossible.[22] How is holism achieved for those questions that we can ask (and can address with consonant science, and carry out management with the resulting guidance based on empirical patterns)? How do we account for factors such as those listed by many of the publications treating the concept of MPAs (e.g., Hyrenbach, et al 2000 and Pollnac, et al. 2001)? The holism not achieved through asking further questions

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[21]In the late 1980s, the biomass consumption from the full ecosystem was 7.14-fold too large, the consumption of walleye pollock (*G. chalcogrammus*) was 17.9 times too large, and the harvest of finfish was 15 times too large to maximize the biodiversity of the respective consumption/production systems (Fowler 2008).

[22]This impossibility is a human limitation that expresses itself in conventional thinking/management in our inability to take into account the full complexity of reality (a problem solved by using integrative natural patterns consonant with management questions, Fowler 2009, Fowler et al. 2013).

(including their refinement) *is* achieved through the integrative nature of natural patterns[23]. Thus, each question addressed through the use of such patterns (e.g., those of exemplified, in our case, by Fig. 3) is addressed in a way where everything is taken into account exactly as it actually contributed to the observed pattern.

In other words, advice stemming from natural patterns (such as those displayed in most of the graphs of this paper) is holistic; it is reality-based. This makes systemic management ecosystem-based in that ecosystems are part of reality (and we applied the approach to a variety of ecosystems[24]). It also includes being evosystem-based in that evosystems are parts of reality (and the selectivity involved in the resulting advice accounts for selectivity of harvesting across space, both within and among species). What we see, as examples of sustainable participation in the reality of complex systems, are examples that we can mimic to achieve sustainability for our species (along with the sustainability of all other species, all ecosystems, and the biosphere). Agardy (1994) advocates "field-testing" marine protected areas before implementing them in long-term policy; what we see in natural patterns involves "field-testing" (involving thousands of replications over evolutionary time scales) by nature to reveal what is holistically sustainable and good for long-term implementation. By using natural role models for guidance, we can avoid reliance on artificial models that are necessarily partial and incomplete. Models (e.g., Walters et al. 1999; Walters 2000), are very useful for improving our understanding and in supporting progress toward asking better questions; they help see the benefits, consequences,

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[23]Basically, the concept is one of everything being an expression of the complexity of its origins (thereby generically embracing the concepts of emergence and interconnectedness) and its effects on everything else (thereby accounting for all risks and consequences). Nothing is left out, everything is taken into account (including the impacts of any form of management being practiced). As Einstein so succinctly put it: "(God) integrates empirically." (Infeld 2006). See footnote 3 for specific references for further explanation of the integrative nature of natural patterns as they account for things holistically.

[24]Any area on the surface of the Earth, of any size, can be considered an ecosystem in regard to the matter of the portion to be set aside in protected status (Fig. 8). The approach exemplified in our work would, for example, apply to each of the areas of Figure 4 identified by a different color or any of the overlapping geographic ranges shown in the figures of Appendix III. See also footnotes 7 and 15.

and drawbacks of management (and particularly the implementation of MPAs). Despite their utility, models are subject to human limitations, bias and error in serving to actually guide management. As much as models make it possible to evaluate and reveal the benefits of MPAs (Sumaila et al. 2000), they fail to achieve the holism made possible through guidance based on consonant natural patterns. No model can be considered as a valid substitute for the reality it is intended to represent (Badalamenti, et al. 2000).

The guidance found in natural patterns regarding MPAs in the EBS, as developed and presented in this paper, is reality-based guidance just as it is for patterns providing guidance for sustainable harvest rates, sustainable selectivity, and the other innumerable ways we function as a species (Fowler 2008, 2009). This last sentence exemplifies numerous broad sweeping statements that we have made about the utility and advantages of systemic management. This may make it sound as though we are claiming that such management is foolproof and perfect: it is neither. It remains subject to human limitations. Compared to conventional management; however it represents a major improvement. As described above, in conventional management human limitations directly affect the guidance produced—economics, emotions, opinions, politics, and belief systems are made part of the decision-making process. Decision-making in such management is explicitly designed to include stakeholders, scientists, managers, and environmentalists—overtly subjecting decisions to human limitations. By contrast, in systemic management, the direct influence of human limitations is confined to the inability to ask all management questions, the inability to conduct perfect science, and the inability to implement holistic guidance in management itself (including decisions not to). The holism of systemic guidance, however, automatically accounts for such limitations *a priori*; as far as we are aware, it is the only form of management that accounts for itself (Fowler et al. 2013).

SUMMARY

We measured preliminary information on the overlap of the geographic ranges of 21 species of marine mammals within the EBS ecosystem to characterize the pattern in the portion of the total ecosystem area not occupied by these species. This pattern is holistic information that is consonant with the management question regarding the portion of this ecosystem that should be set aside in MPAs where fishing would be prohibited year-round—sustainably. We repeated this process for 21 distinct smaller ecosystems, all within the EBS, each one corresponding to the area within the larger ecosystem occupied by an individual species of marine mammal. In all cases (including the complete EBS), the area to be set aside in MPAs that would be consistent with these patterns is about 1/3 of the respective ecosystem. The patterns involve species that have participated in these ecosystems for thousands of years to exemplify long-term systemic sustainability.

In spite of the consistency among ecosystems, there is variability within each one that would allow for a wide set of options—based on the modes of patterns consonant with the management question no marine protected areas would be needed at all. Little that we are doing now in these ecosystems appears particularly abnormal in regard to the areas in which commercial fishing is allowed. This is in contrast to the clear abnormality in the rates at which fish (and biomass in general) are harvested from individual species, species groups and the ecosystem as a whole. If measures of the extent of abnormality serve as a basis for establishing priorities, more focus needs to be placed on reducing fishing rates than on establishing MPAs. This does not mean that setting aside 1/3 of the ecosystems is unimportant; it means that reducing harvest rates (in takes from individual species, species groups, and the full ecosystem) is of much more critical importance.

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Appendix I

Methods Used to Measure the Area of Ecosystems within the Eastern Bering Sea

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Introduction

This appendix describes the production of the maps used in both the main body of our paper and in Appendices II-IV. These methods allowed for making the measurements central to the main objective of our paper. In essence, this involved using digital processes for determining the size of sub-areas within the overall region represented by Figure A1.1.

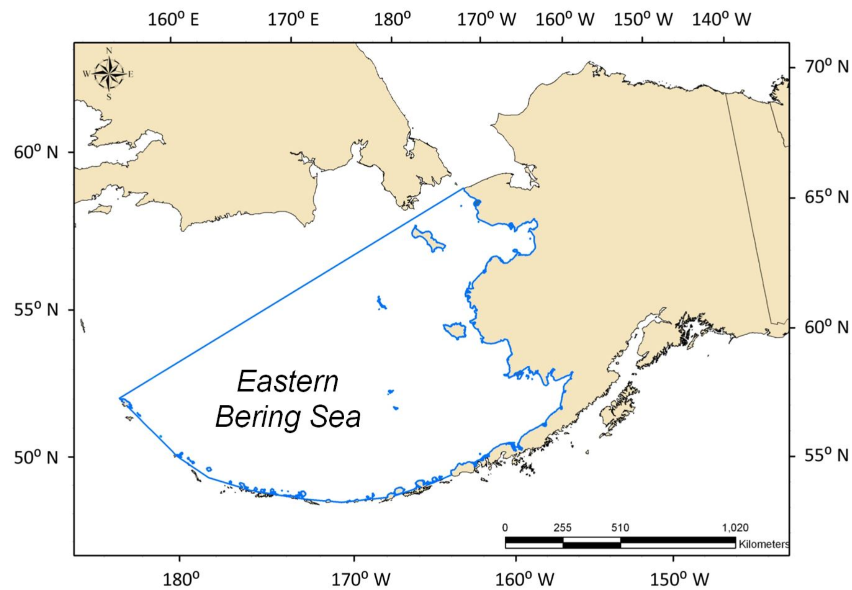

Figure A1.1. - - Map of the area including the eastern Bering Sea ecosystem, parts of the North Pacific Ocean, Alaska, and Siberia.

This work started with the construction of the full map of the region (Fig. A1.1) in digital form. Other parts of this effort included the construction of maps for, and the determination of the sizes of, various areas within the overall boundaries of the region. One of the first steps in this process was that of finding the total area of what managers and scientists have defined as the eastern Bering Sea (EBS, as labeled in Fig. A1.1) and, specifically, the production of spatial data representing that area for use in subsequent analyses.

Also necessary were spatial datasets describing the geographic ranges of various marine mammals found in the area of the Bering Sea, specifically those with geographic ranges that overlap with the area defined as the EBS ecosystem. The ultimate objective of this work was to obtain estimates of the area of specific ecosystems that do not fall within the geographic ranges of the marine mammals but which do fall within the EBS ecosystem. The ecosystems for which this was accomplished included the entire EBS as well as a number of smaller ecosystems defined on the basis of the overlap of the geographic range of each individual species with the EBS ecosystem.

The details of the methods we used in accomplishing these ends are presented below.

The Eastern Bering Sea Ecosystem

Because the focus of this paper is on areas of the marine environment, land (such as the terrestrial areas of Alaska, various islands, and eastern Asia) had to be removed from consideration. This was accomplished by producing a digital file ("shapefile"[1]) representing all land masses within the boundaries of the map shown in Figure A1.1.[2] Then, a shapefile was produced for the EBS ecosystem by using another shapefile of a marine mammal range that was larger than (but included all of) the EBS, and using the "Erase" function of ESRI (Environmental Systems Research Institute, Redlands, CA) ArcInfo 3.3 software to remove the land area. This area was then clipped so that the boundaries (shown in Fig. A1.1) conformed to those defining the ecosystem under study (thus excluding marine areas outside the ecosystem itself). This shapefile was given its own file name (another shapefile, "eastern Bering Sea.shp"); it represented the total marine area of the ecosystem under study in the main research project.

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[1]A shapefile is a geospatial vector data format used in geographic information systems software.

[2]This required merging a variety of shapefiles representing various areas of land into one (a shapefile named "Land.shp")

Marine Mammal Ranges within the Eastern Bering Sea

Each marine mammal species was represented by a polygon shapefile (digital version of the data found in Angliss and Lodge, 2004). The shapefiles representing these maps were modified, again by using the "Erase" function of ArcInfo, to remove the land area from the range area for each species. The resulting modified shapefiles were then renamed (with one new shapefile for each species).

Using these species-specific shapefiles, the portion of the range for each species that fell within the EBS was separated from the part that fell outside. This was accomplished by using the "clip" function of ESRI ArcView 3.33 to extract only that portion of the mammal's range which overlapped the larger ecosystem. These new shapefiles were then saved with different file names, one for each species.

Finally, XToolsPro3 software was used to calculate the area in square kilometers of both the total area of the EBS and the area involving the range of a particular species where it overlapped with the area of the full ecosystem. Dividing the second estimate by the first gives the portion of the EBS that is occupied by the respective species. The portion that is not occupied is the complement of the portion occupied (e.g., if the portion occupied is 0.2, the portion unoccupied is 0.8 = 1.0 - 0.2). The maps of the unoccupied areas depict areas that are ecosystems unto themselves (but not as ecosystems treated in this study).

Marine Mammal Range Overlaps

Using ArcView3, a clip function was used to produce another set of shapefiles. The range of each individual species located in the EBS as it overlapped another species' range was clipped so that the area of this overlap (i.e., the overlap between the geographic ranges of each species pair within the EBS) could be determined. In each case, the resulting file is a complex polygon representing the area that both of the two species occupy. Again, XToolsPro was used to calculate the area, in square kilometers, for the overlapping ranges for each pair of species involved (there were a total of 21 species, and a total of 210 areas, each represented by a separate file, $210 = (21^2 - 21)/2$)).

The measured area of an overlapping range was found by dividing the area occupied by one species by the area of the overlap with a second species' range to answer a question such as, "What portion of the Baird's Beaked Whale range does the Bearded Seal occupy?" In this particular case, the portion is 0.16; 114052.55 km^2 (area of overlap between the two species)/719395.57 km^2 (range area of Baird's Beaked Whale in the EBS) = 0.16. Thus, the portion that is not occupied is 0.84 (= 0.1 - 0.16).

Number of Overlapping Ranges for All Species

Producing the map in Figure 4 required a grid of small areas where the number of overlapping ranges of the individual species could be counted. To accomplish this, a grid was created for an area slightly larger than, and including all of, the EBS. This grid consisted of 100 km^2 divisions (10 km x 10 km squares) and was created using the tools available in XToolsPro. With this file, the clip function of ArcView was used to crop the gridded file to correspond exactly to the map of the EBS. Following this, the ArcView GIS 3.x3 extension titled "Count Overlapping Polygons" was downloaded from the ESRI3 website[3]. This software was used to count the number of ranges overlapping each element of the grid based on a map produced by merging all of the files representing the ranges for the individual species into a single file. Specifically, using ArcView 3.3, the "Count Overlapping Polygons" extension was used to calculate the number of polygons within the species range shapefile that fell into each grid square within the EBS ecosystem. The result was a grid file with the number of polygons in each grid recorded in the attribute table. By setting the symbology to display the grid by the number of overlapping polygons in a color ramp, it was possible to produce a map (Fig. 4) showing the location of varying counts of range overlaps for the species of marine mammals in the EBS.

Although not reported in this paper, a file was produced which identifies which particular species were located within specific grid squares. All of the species individual ranges were joined to the grid using the intersect function in ArcView. Following this, all of the intersected

[3]This extension was created by Bob Smith, Mosaic Conservation, February 27th, 2004.

files were merged. The result was a gridded file that, when clicked in a given area with the identify tool, would list the species that are located at the corresponding point.

Citations

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Appendix II

Maps of Areas Occupied by Marine Mammals in the Eastern Bering Sea

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Geographic Ranges

This appendix contains 21 maps of the geographic ranges of marine mammals whose ranges overlap with the eastern Bering Sea ecosystem. These maps are all based on maps published in Angliss and Lodge (2004) and used as described in more detail in the main body of this paper. Figure A2.1 shows the eastern Bering Sea with the area defined as the full ecosystem. Figures A2.2 - A2.22 illustrate the species-specific portions of the full ecosystem that are, at some time of the year, thought to be occupied by individuals of the species identified (as based on the information synthesized by Angliss and Lodge 2004). Figure A2.23 illustrates the number of overlapping geographic ranges in various areas of the eastern Bering Sea. This represents the count of species that, at one time or another, are thought to occur in these various areas.

For purposes of addressing the primary management question dealing with the portion of the eastern Bering Sea which should be set aside in marine protected areas (MPAs), the areas of importance in the maps of this Appendix are the white areas (not shaded). These are the unoccupied areas (making up a portion of the overall ecosystem, consonant with management question). Measures the portions of the full ecosystem that are not occupied are presented in Table 1 in the main text (P_2, the ratio of the white areas in the species-specific maps to that of the full ecosystem, Fig. A2.1).

In addition to being information that addresses the main question, the maps within this appendix represent ecosystems in their own right. We present the sample of ecosystems in maps below as species-specific ecosystems to exemplify the approach that we are illustrating more generically. The maps could have been the geographic ranges of any species (any virus to any whale). They could have been the areas defined by the overlap of any subset of species. For example Figure A3.3 (Appendix III) shows the overlap between the geographic range of Dall's porpoise (*Phocoenoides dalli*) and that of the bearded seal (*Erignathus barbatus*) in the eastern Bering Sea ecosystem. This overlap could have been considered as an ecosystem of interest. An ecosystem could be defined as the overlap of any partiuclar set of species (such as the area represented by the overlap of 15 species of marine mammals in Fig. A2.23).

Thus, we see that any area within the eastern Bering Sea could have been used. It could be a random area and would be represented by a map like those in Figures A2.2 - A2.22. It could be the area where the water column is between 40 and 100 m in depth (and would be represented by a map like those in Figures A2.2 - A2.22). It could be an area defined on the basis of mean primary production, on the basis of water temperature, salinity or any other aspect of the physical environment. It could have been any of the areas not occupied by the a particular species (e.g., white areas of Figures A2.2 - A2.22 within the eastern Bering Sea). The options are essentially infinite.

Literature Cited

Angliss, R.P., and K.L. Lodge. 2004. Alaska marine mammal stock assessments, 2003. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-144, 230 p.

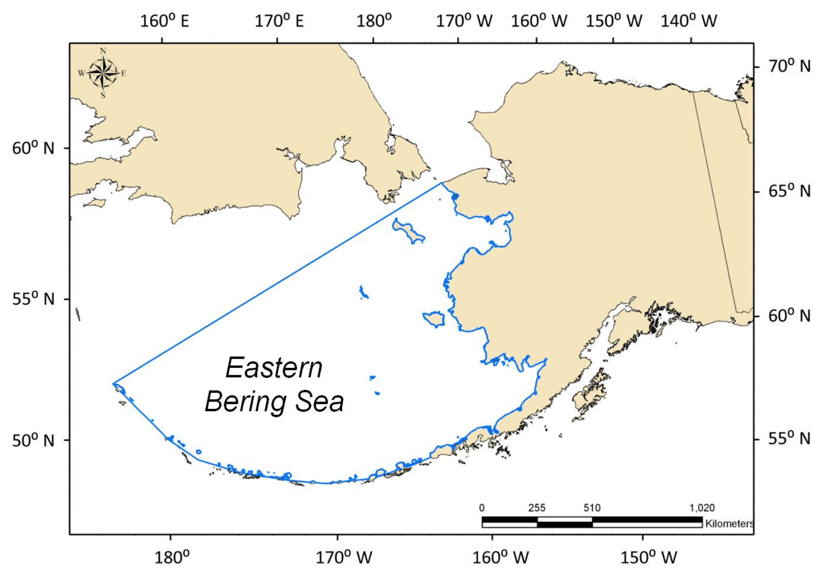

Figure A2.1. - - Map of the eastern Bering Sea showing the area considered to be the eastern Bering Sea ecosystem (marine waters surrounded by the line, excluding islands). The maps that follow will show areas occupied by marine mammals as located within this ecosystem.

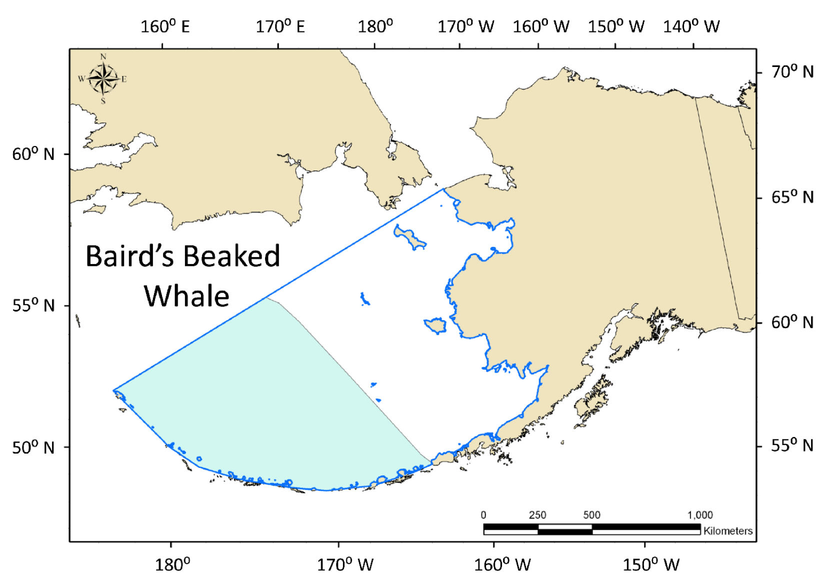

Figure A2.2. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the Baird's beaked whale (*Berardius bairdii*) and the eastern Bering Sea ecosystem.

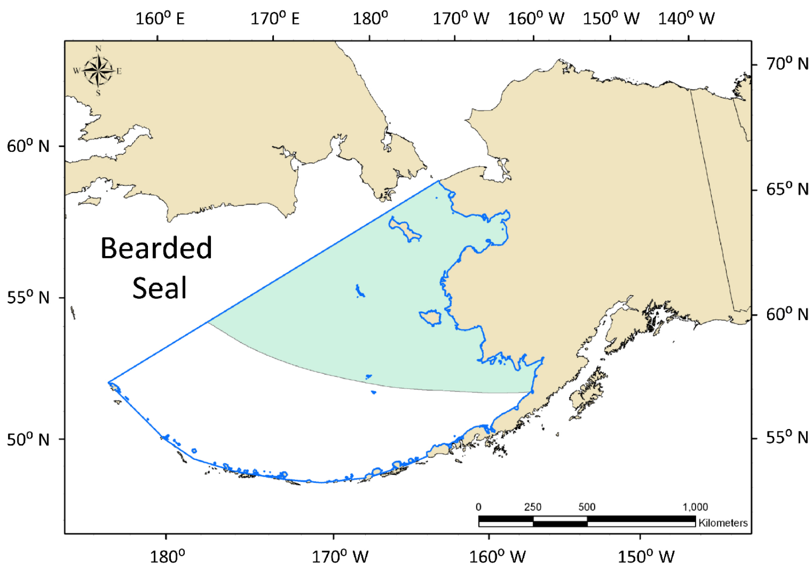

Figure A2.3. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the bearded seal (*Erignathus barbatus*) and the eastern Bering Sea ecosystem.

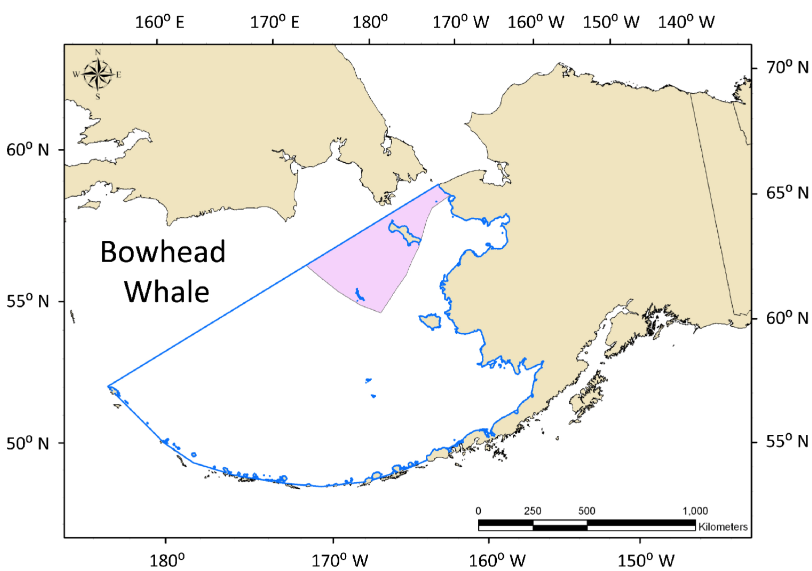

Figure A2.4. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the bowhead whale (*Balaena mysticetus*) and the eastern Bering Sea ecosystem.

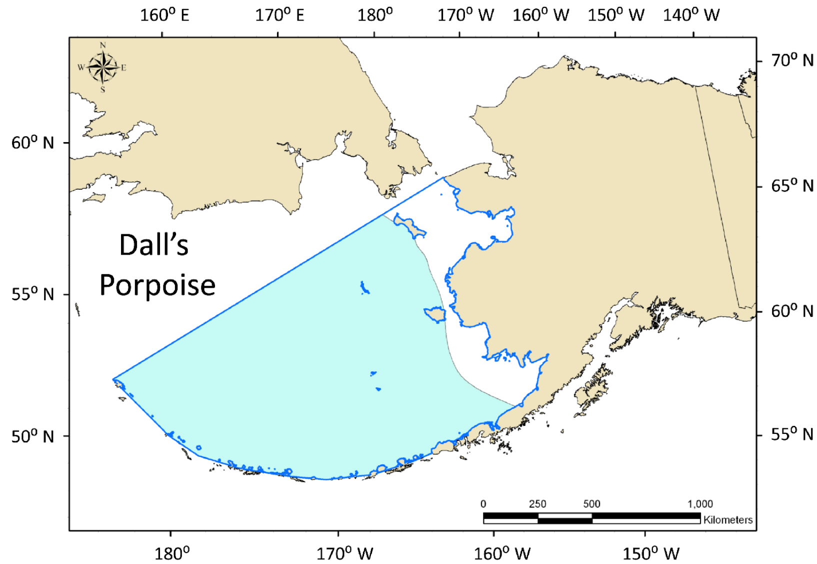

Figure A2.5. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the Dall's porpoise (*Phocoenoides dalli*) and the eastern Bering Sea ecosystem.

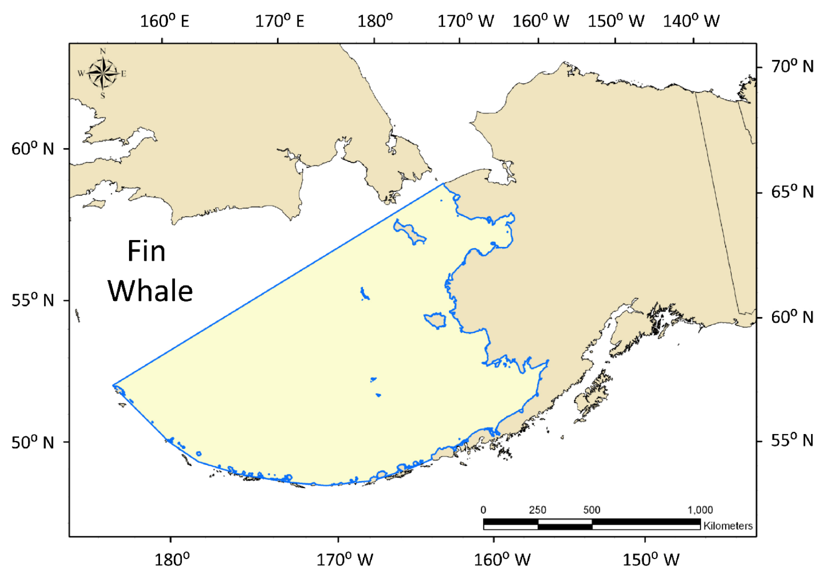

Figure A2.6. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the fin whale (*Balaenoptera physalus*) and the eastern Bering Sea ecosystem.

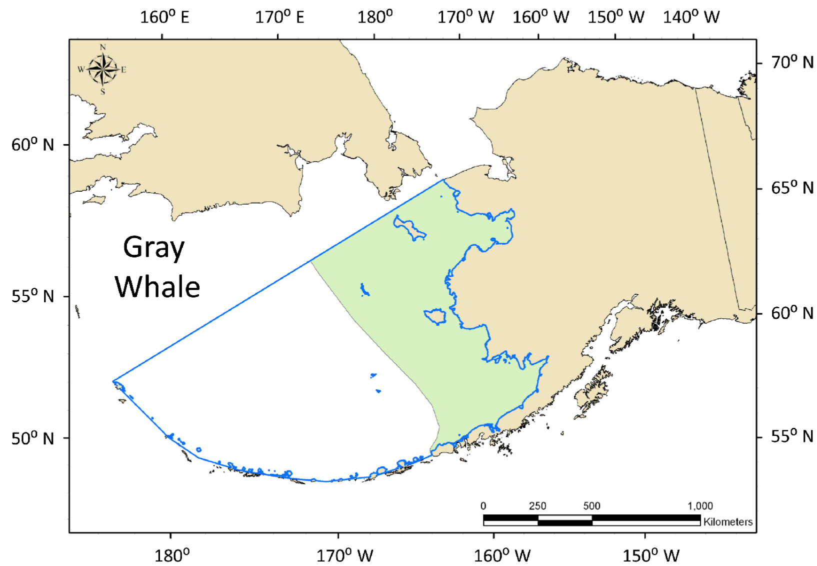

Figure A2.7. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the gray whale (*Eschrichtius robustus*) and the eastern Bering Sea ecosystem.

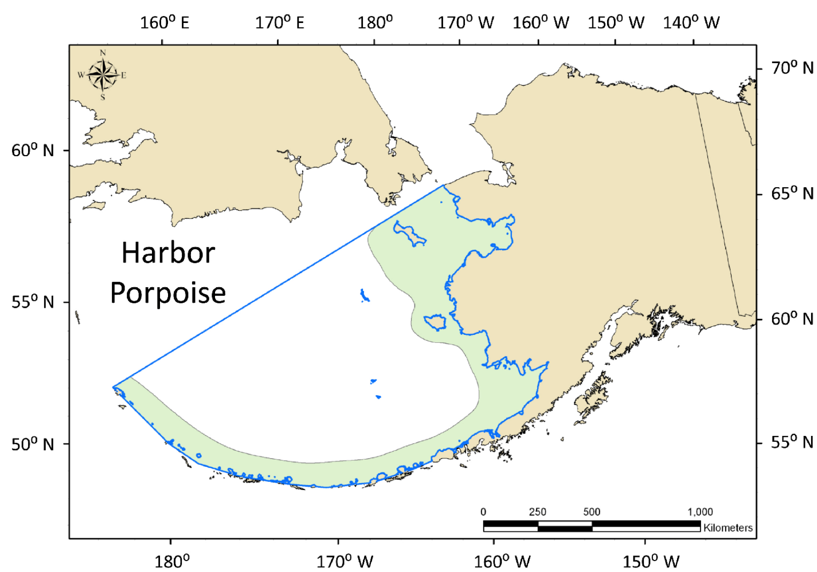

Figure A2.8. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the harbor porpoise (*Phocoena phocoena*) and the eastern Bering Sea ecosystem.

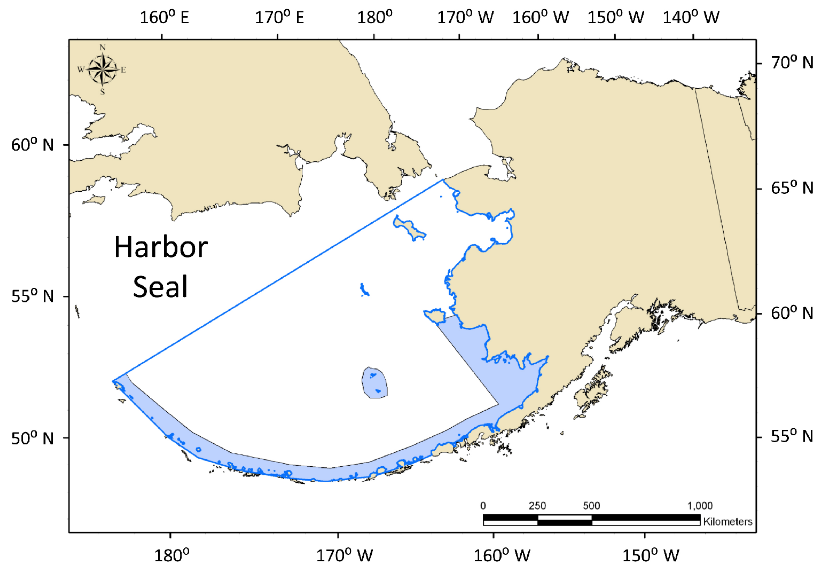

Figure A2.9. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the harbor seal (*Phoca vitulina*) and the eastern Bering Sea ecosystem.

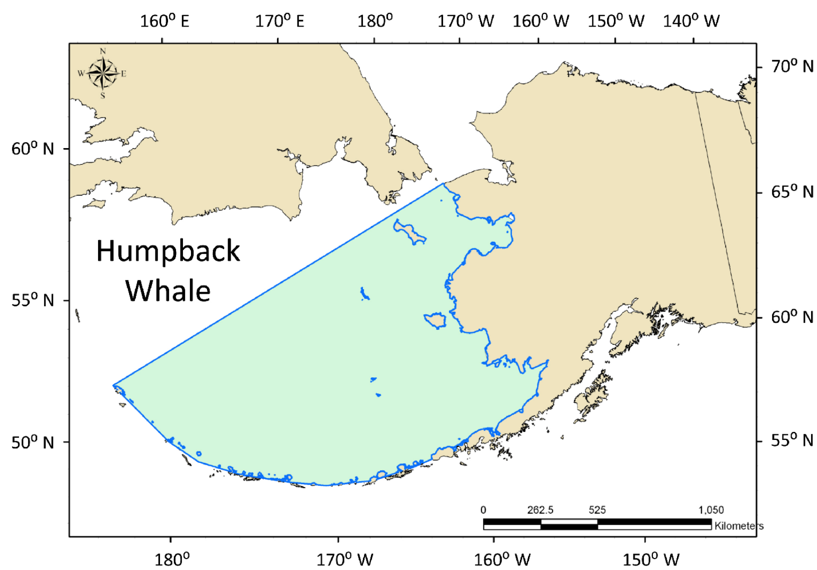

Figure A2.10. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the humpback whale (*Megaptera novaeangliae*) and the eastern Bering Sea ecosystem.

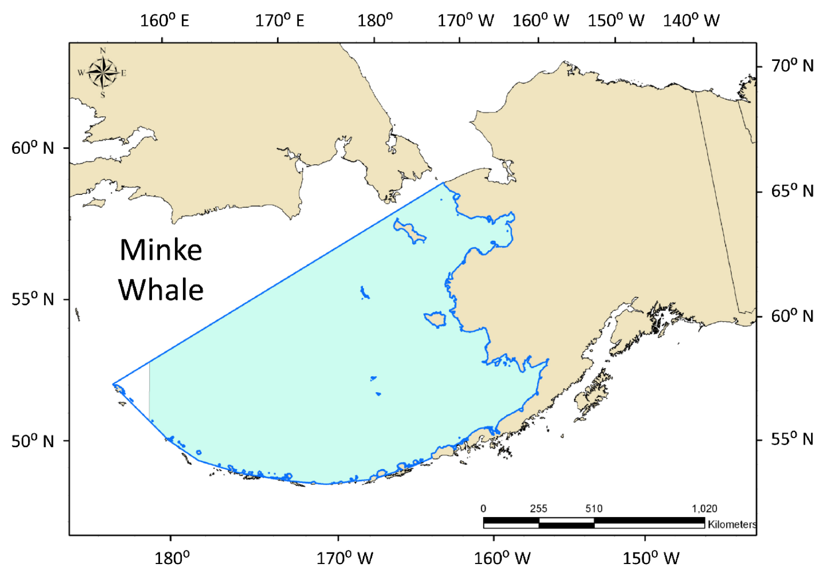

Figure A2.11. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the minke whale (*Balaenoptera acutorostrata*) and the eastern Bering Sea ecosystem.

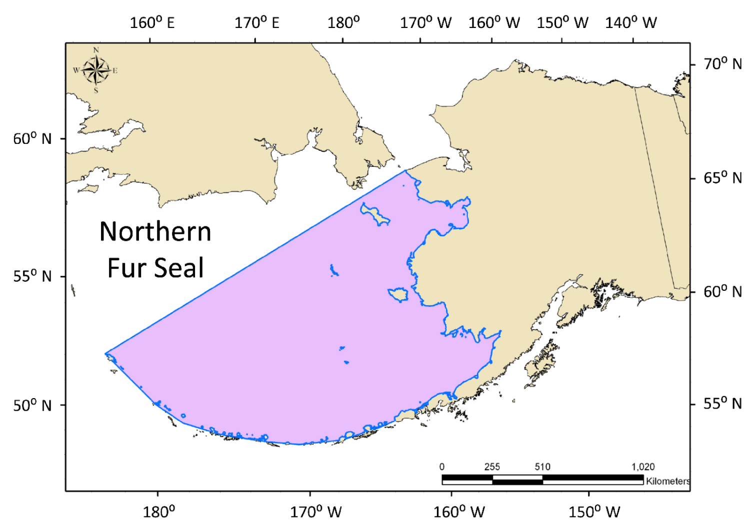

Figure A2.12. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the northern fur seal (*Callorhinus ursinus*) and the eastern Bering Sea ecosystem.

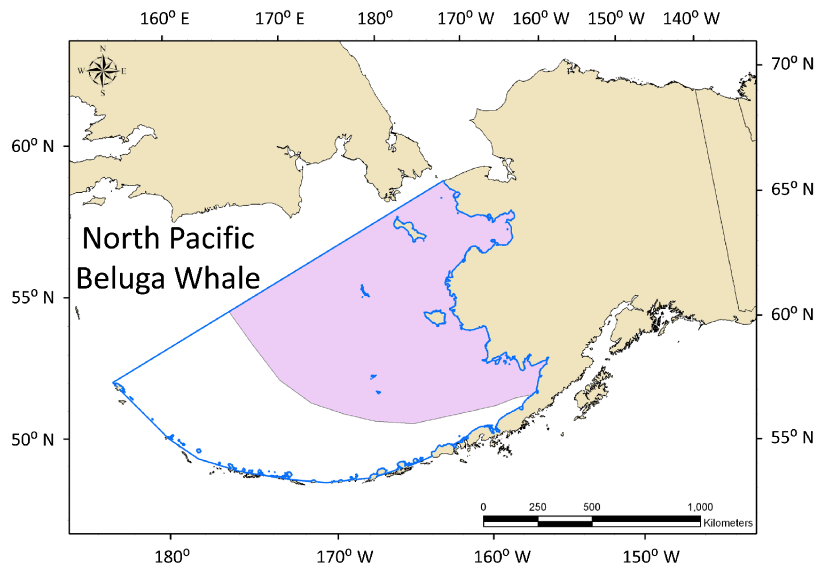

Figure A2.13. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the North Pacific beluga whale (*Delphinapterus leucas*) and the eastern Bering Sea ecosystem.

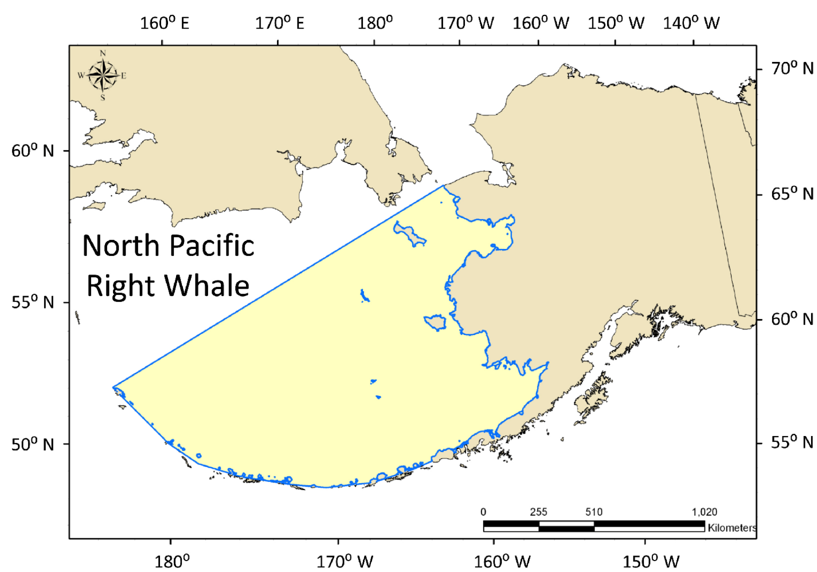

Figure A2.14. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the North Pacific right whale (*Balaena glacialis*) and the eastern Bering Sea ecosystem.

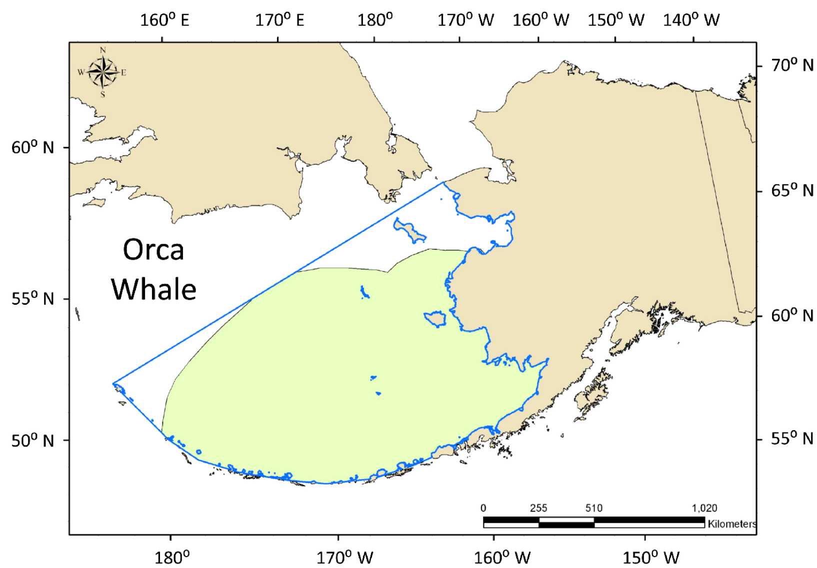

Figure A2.15. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the orca whale (*Orcinus orca*) and the eastern Bering Sea ecosystem.

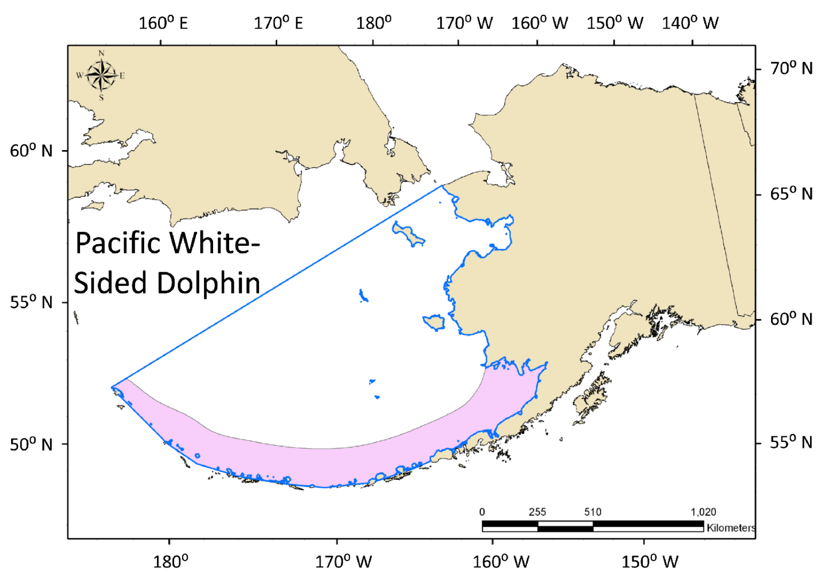

Figure A2.16. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) and the eastern Bering Sea ecosystem.

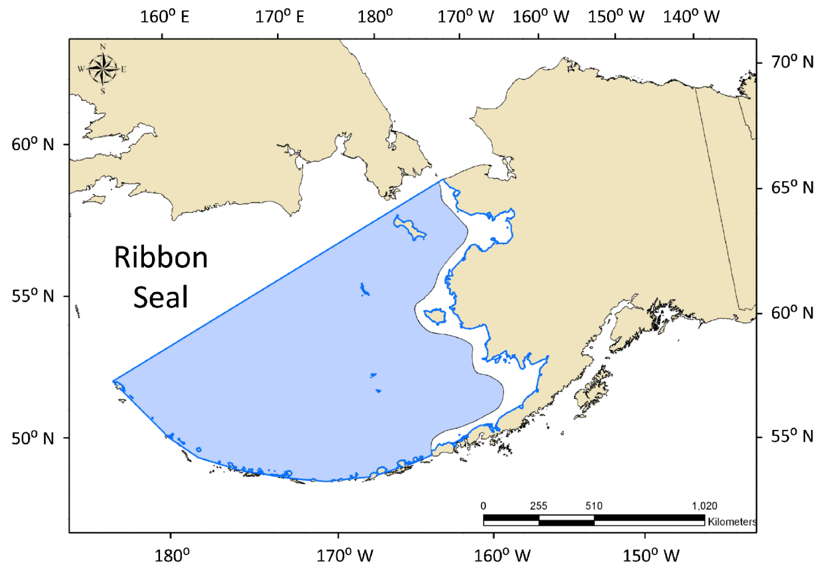

Figure A2.17. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the ribbon seal (*Histriophoca fasciata*) and the eastern Bering Sea ecosystem.

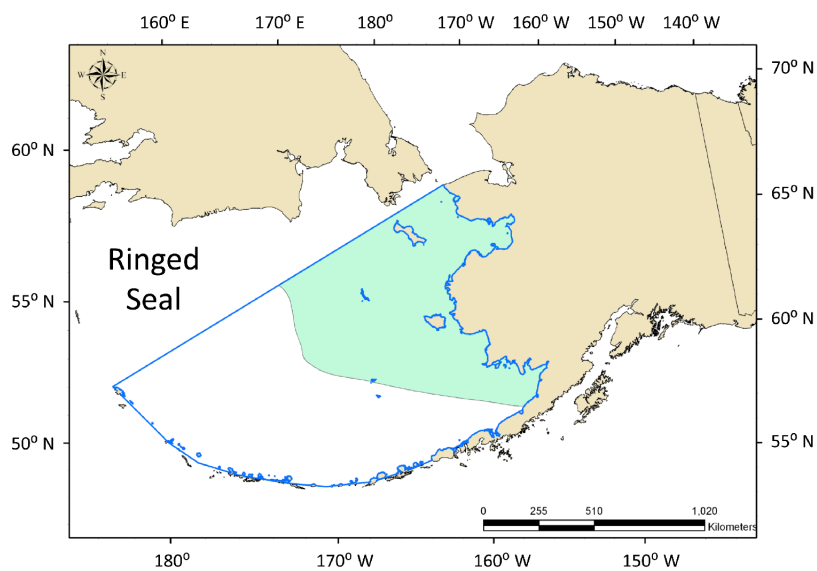

Figure A2.18. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the ringed seal (*Pusa hispida*) and the eastern Bering Sea ecosystem.

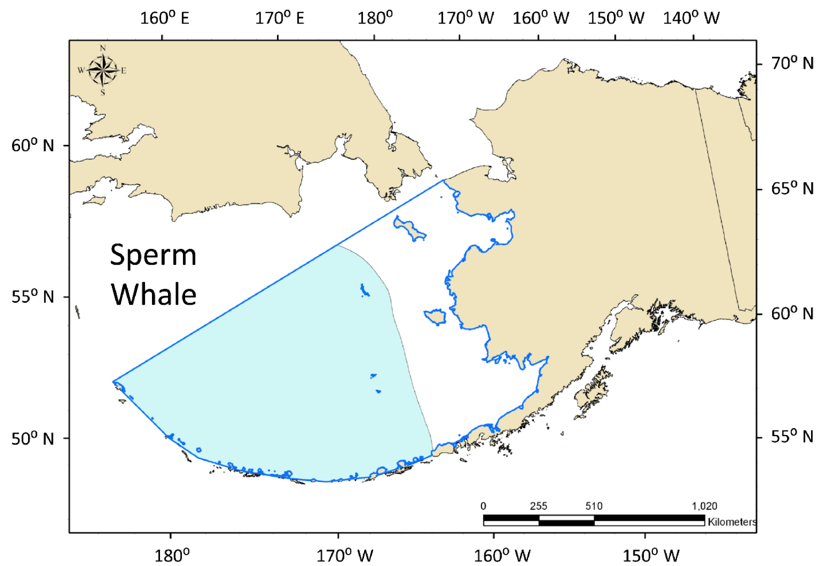

Figure A2.19. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the sperm whale (*Physeter macrocephalus*) and the eastern Bering Sea ecosystem.

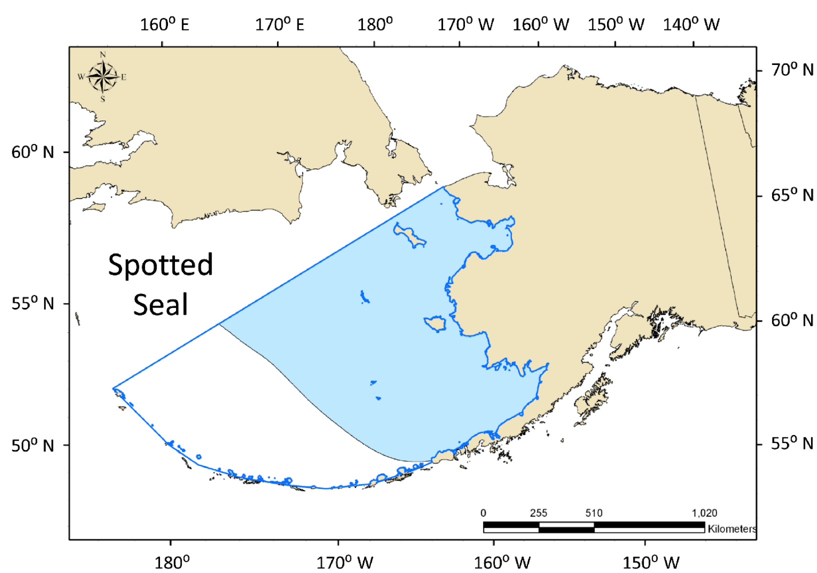

Figure A2.20. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the spotted seal (*Phoca largha*) and the eastern Bering Sea ecosystem.

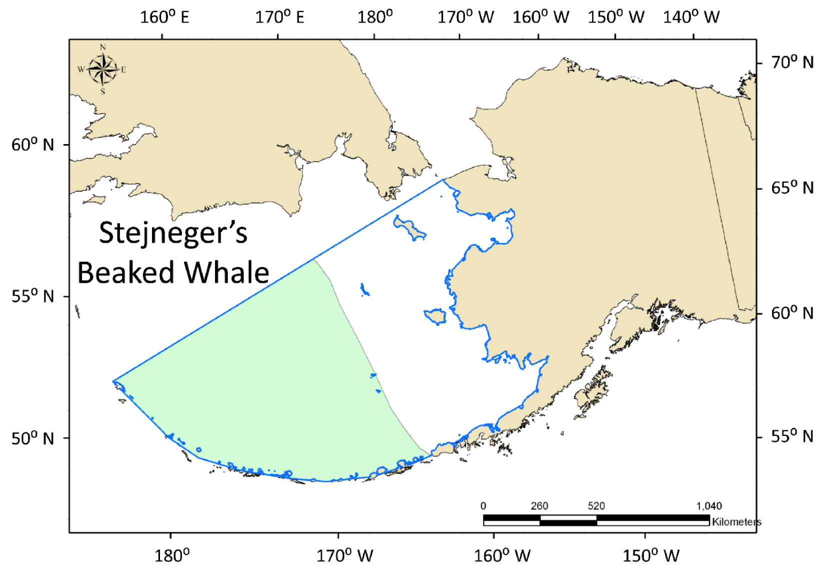

Figure A2.21. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the Stejneger's beaked whale (*Mesoplodon stejnegeri*) and the eastern Bering Sea ecosystem.

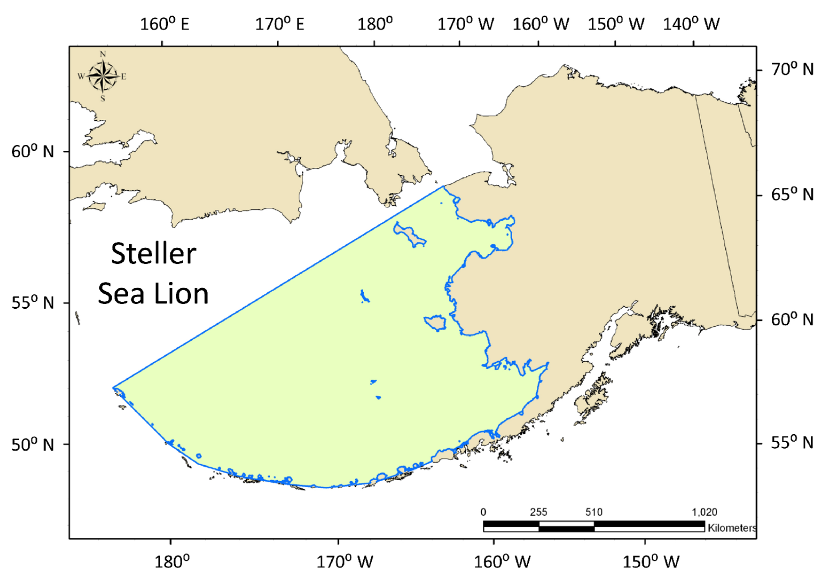

Figure A2.22. - - Map of the eastern Bering Sea showing the overlap of the geographic range of the Steller sea lion (*Eumetopias jubatus*) and the eastern Bering Sea ecosystem.

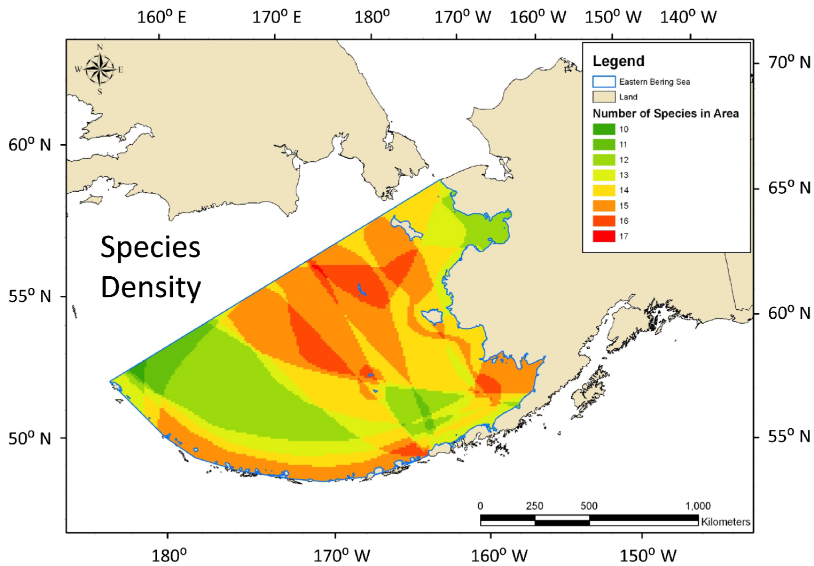

Figure A2.23. - - Map of the eastern Bering Sea showing the density of the 21 species of marine mammals (the number of marine mammal species per unit area) in various regions of the eastern Bering Sea ecosystem.

Appendix III

Maps of Areas of the Geographic Range of Bearded Seals Occupied by Other Marine Mammals in the Eastern Bering Sea

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The Bearded Seal Ecosystem

In Appendix III, we present 20 maps (Figs. A3.1 - A3.20), each of which displays the overlap of the geographic range of another species of marine mammal with that of the bearded seal (*Erignathus barbatus*), all within the eastern Bering Sea (EBS) ecosystem. For example, Figure A3.1 shows the overlap (dark shaded area) of the geographic range of Baird's beaked whale (*Berardius bairdii*) with that of the bearded seal, both within the confines of the EBS ecosystem.

These maps provide useful information regarding the unoccupied portion of the bearded seal ecosystem resulting in the information listed in Table 2 (following the protocol used in defining the same information for the larger ecosystem in Table 1). A similar set of maps defined the overlaps of the other 20 species-specific ecosystems (each one of the maps in this Appendix would have been included). For example, Figure A3.3, represents not only the overlap of the Dall's porpoise (*Phocoenoides dalli*) with the bearded seal, but also the overlap of the bearded seal with the Dall's porpoise. Second, the overlaps represent another category of ecosystems; these ecosystems are represented by the areas defined as the overlaps between each pair of species. Thus, the dark shaded area of Figure A3.3 would be the ecosystem specific to the pair of species involved (the Dall's porpoise, *and* the bearded seal). There would be 210 such ecosystems (Appendix I) and their sheer numbers combined with space limitations, led us to decide that the examples we provide in single-species approaches were sufficient to convey the concept of applying systemic management to the question of marine protected areas (MPAs). Such overlaps could include any number of species. Overlaps within and among the numerous species within the EBS present an overwhelming set of options for the application of systemic management.

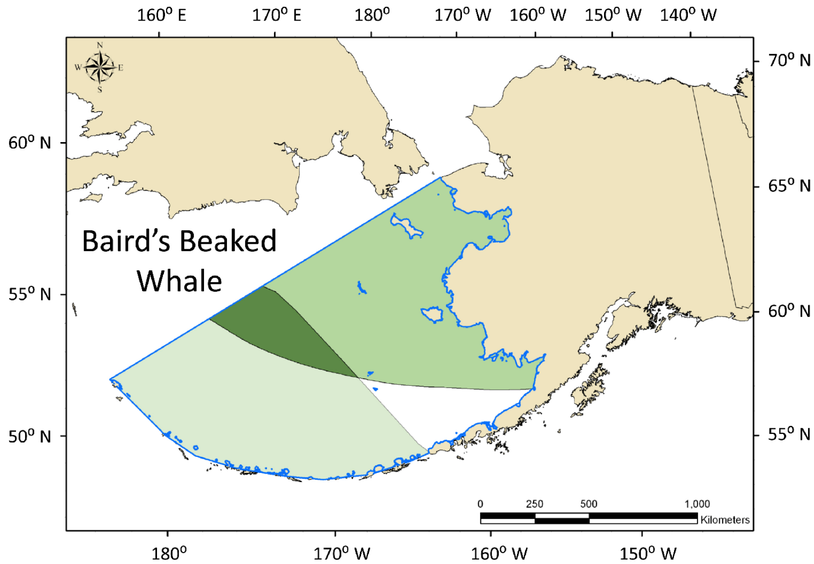

Figure A3.1. - - The overlap (dark shaded area) between the geographic range of Baird's beaked whale (*Berardius bairdii*) and that of the bearded seal (*Erignathus barbatus*) in the EBS ecosystem.

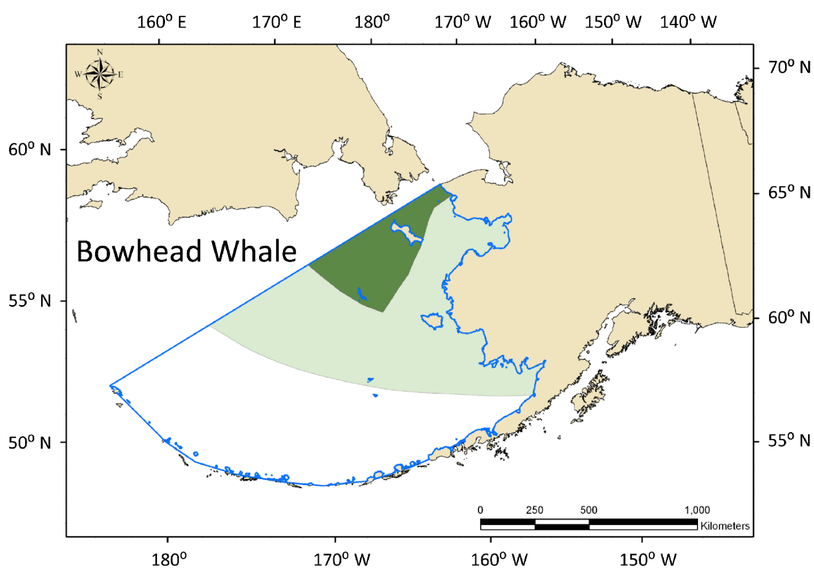

Figure A3.2. - - The overlap (dark shaded area) between the geographic range of the Bowhead whale (*Balaena mysticetus*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

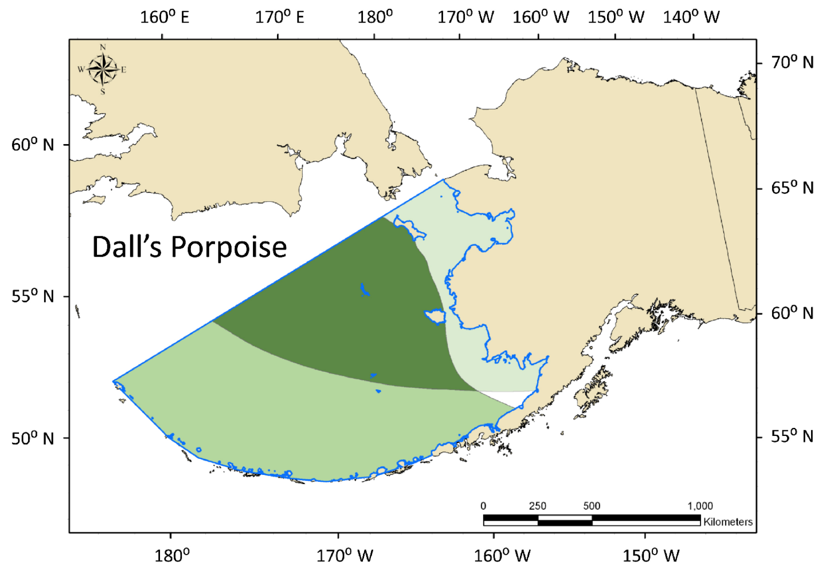

Figure A3.3. - - The overlap (dark shaded area) between the geographic range of Dall's porpoise (*P. dalli*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

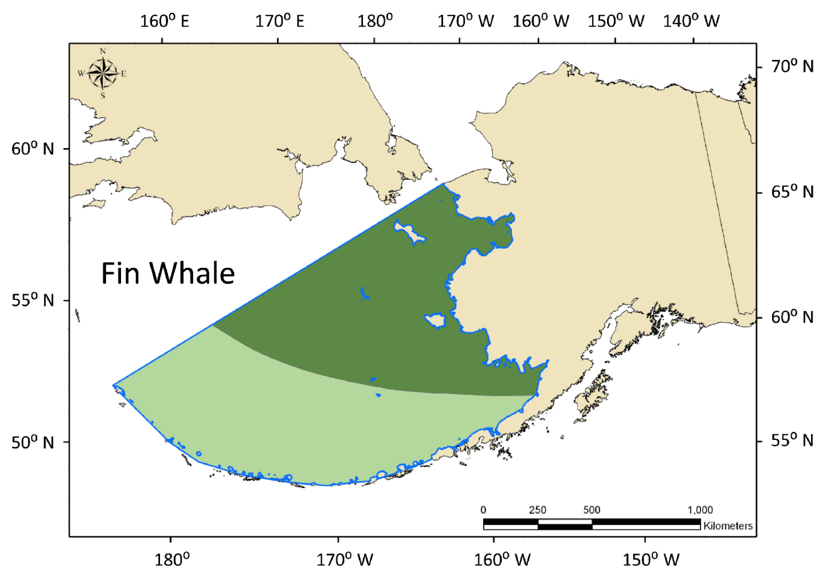

Figure A3.4. - - The overlap (dark shaded area) between the geographic range of the fin whale (*Balaenoptera physalus*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

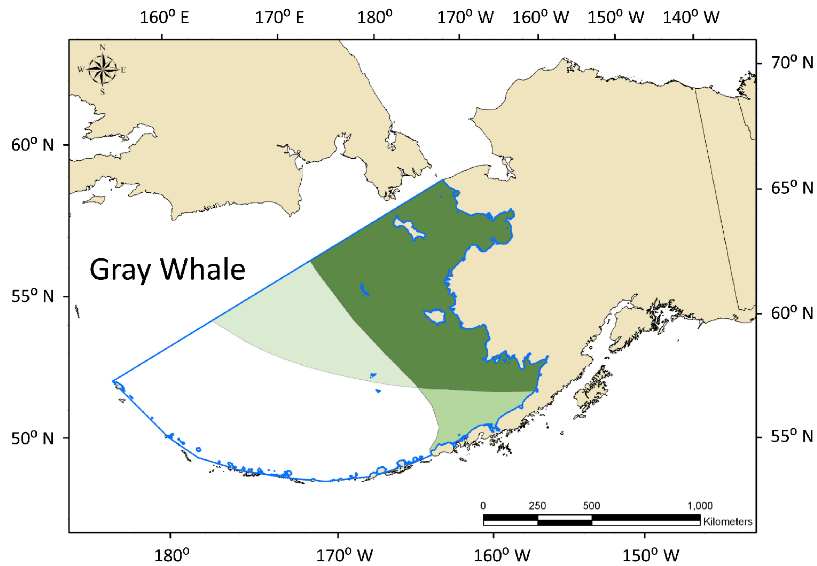

Figure A3.5. - - The overlap (dark shaded area) between the geographic range of the gray whale (*Eschrichtius robustus*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

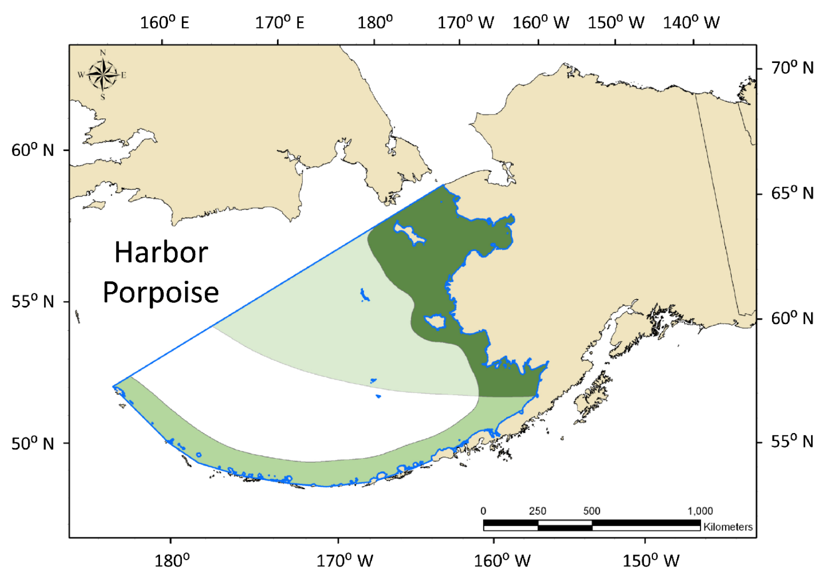

Figure A3.6. - - The overlap (dark shaded area) between the geographic range of the harbor porpoise (*Phocoena phocoena*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

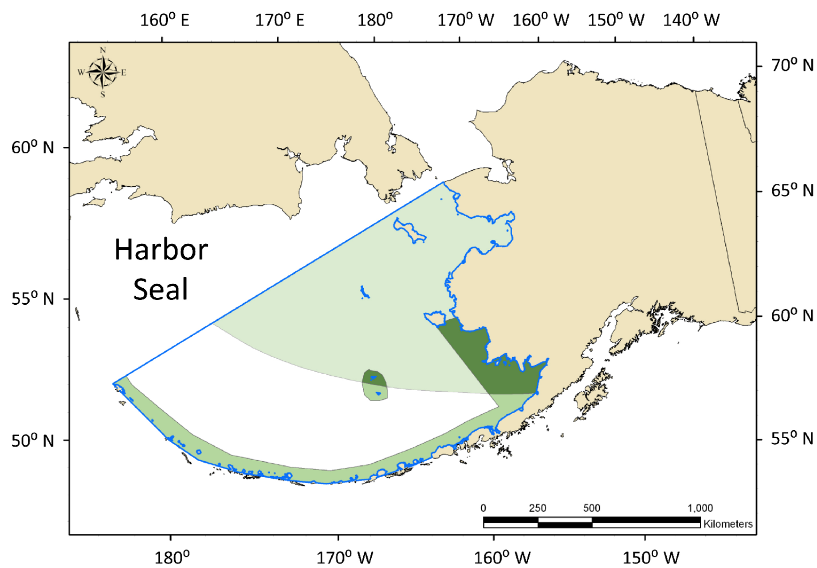

Figure A3.7. - - The overlap (dark shaded area) between the geographic range of the harbor seal (*Phoca vitulina*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

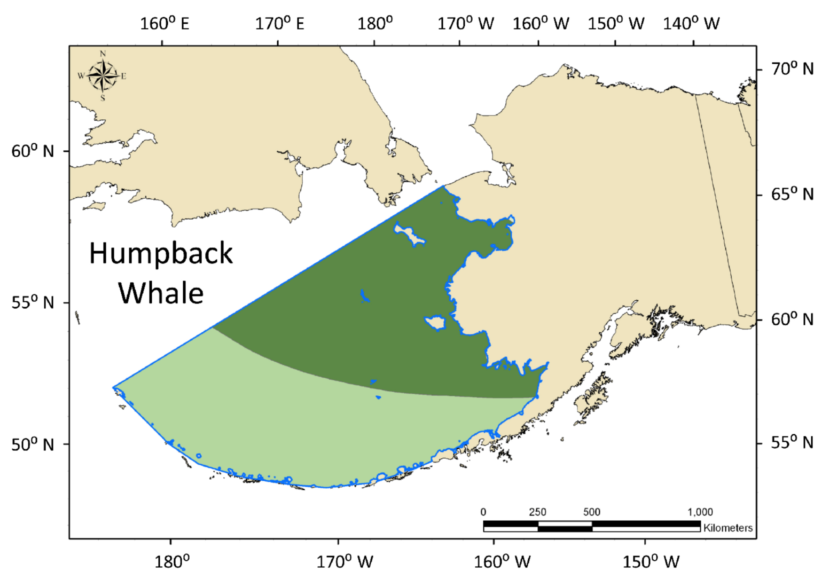

Figure A3.8. - - The overlap (dark shaded area) between the geographic range of the humpback whale (*Megaptera novaeangliae*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

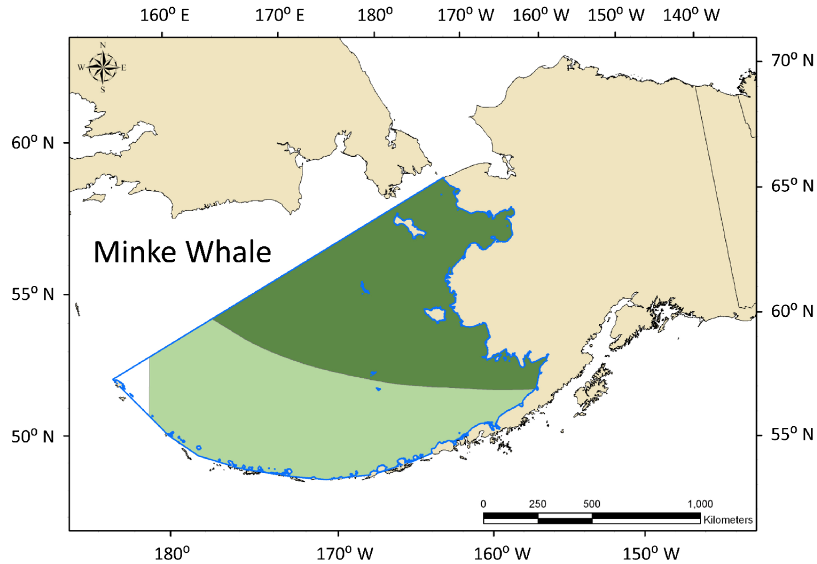

Figure A3.9. - - The overlap (dark shaded area) between the geographic range of the minke whale (*Balaenoptera acutorostrata*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

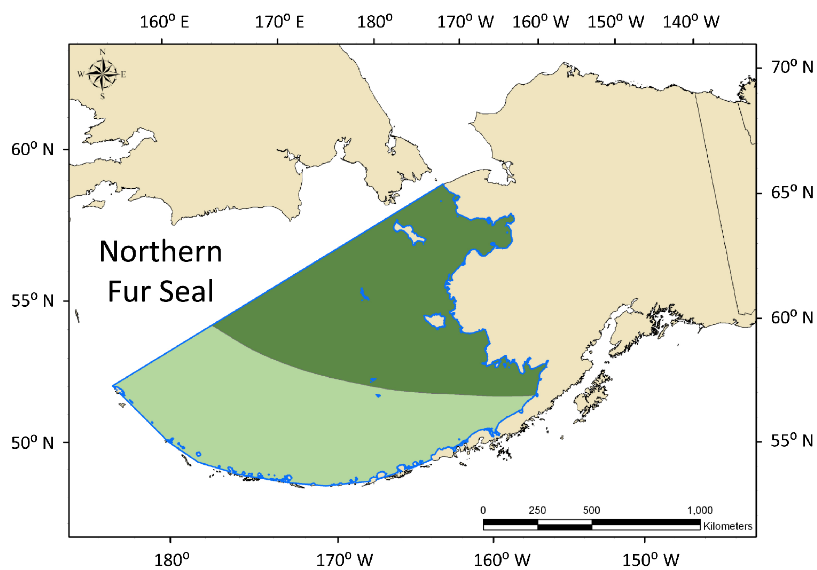

Figure A3.10. - - The overlap (dark shaded area) between the geographic range of the northern fur seal (*Callorhinus ursinus*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

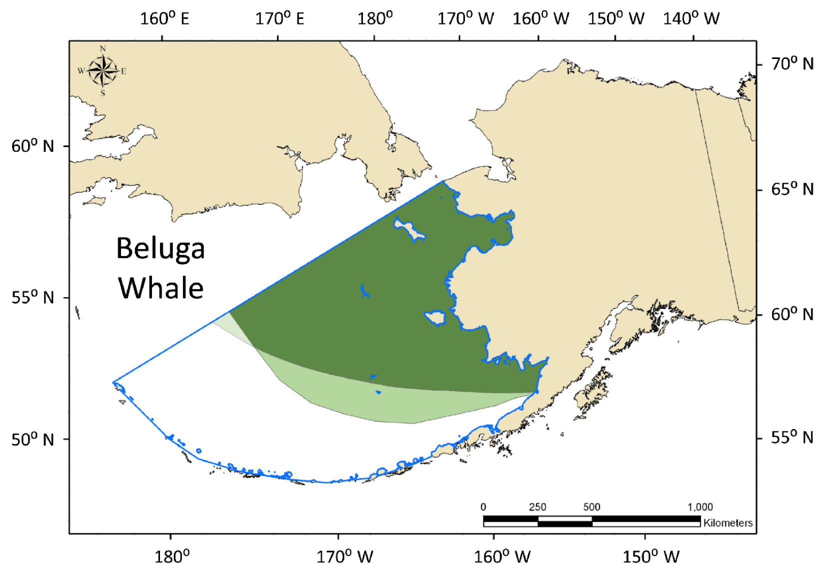

Figure A3.11. - - The overlap (dark shaded area) between the geographic range of the North Pacific beluga whale (*Delphinapterus leucas*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

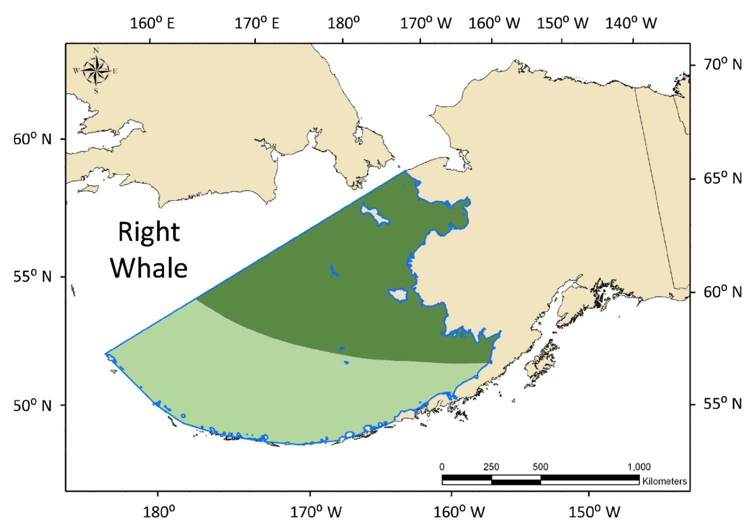

Figure A3.12. - - The overlap (dark shaded area) between the geographic range of the North Pacific right whale (*Balaena glacialis*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

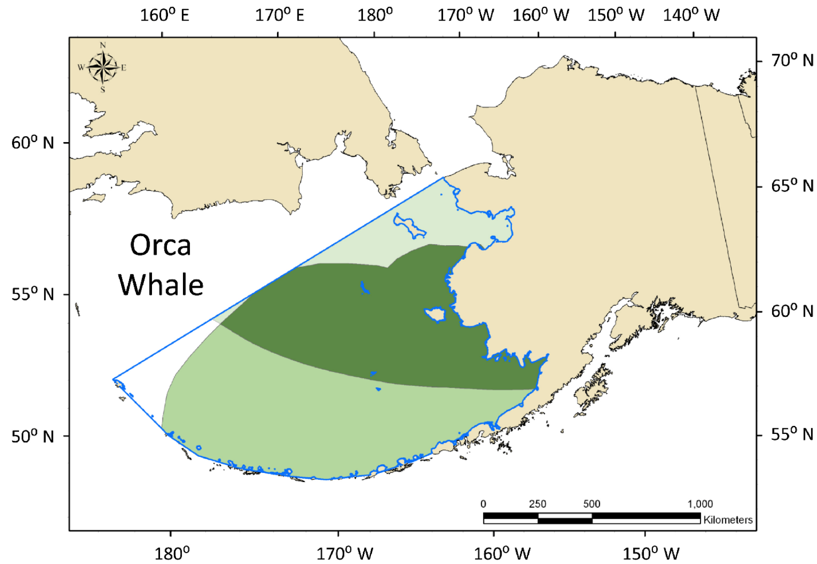

Figure A3.13. - - The overlap (dark shaded area) between the geographic range of the orca whale (*Orcinus orca*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

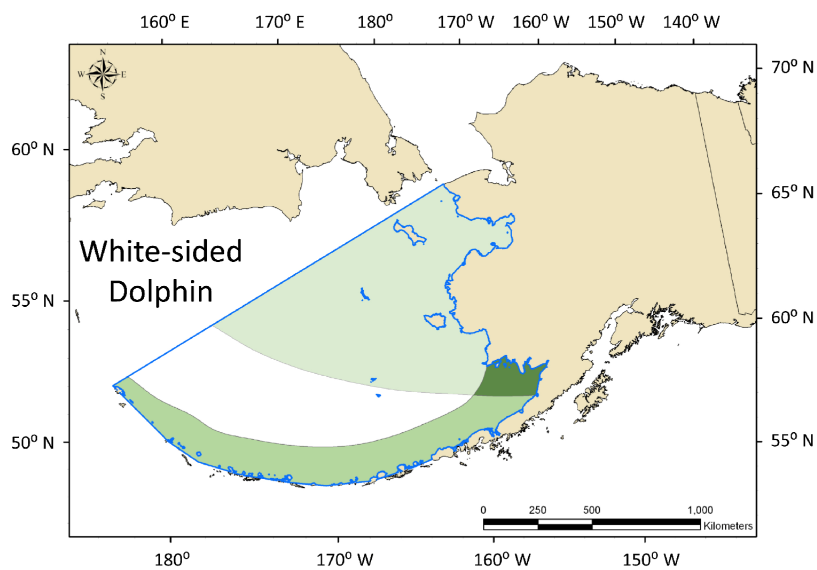

Figure A3.14. - - The overlap (dark shaded area) between the geographic range of the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

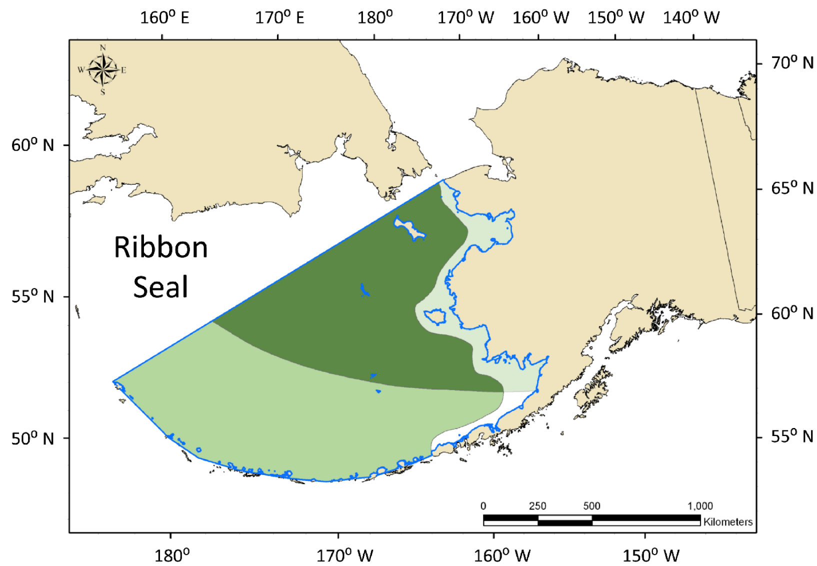

Figure A3.15. - - The overlap (dark shaded area) between the geographic range of the ribbon seal (*Histriophoca fasciata*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

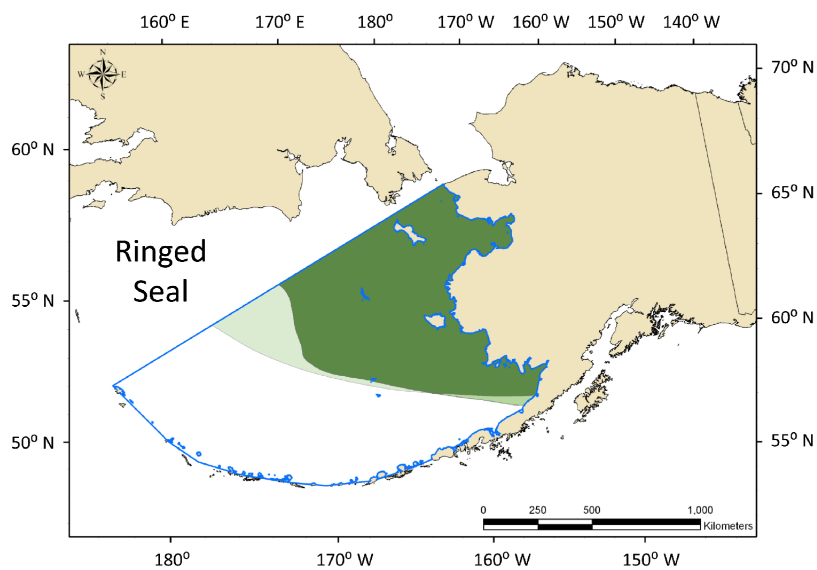

Figure A3.16. - - The overlap (dark shaded area) between the geographic range of the ringed seal (*Pusa hispida*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

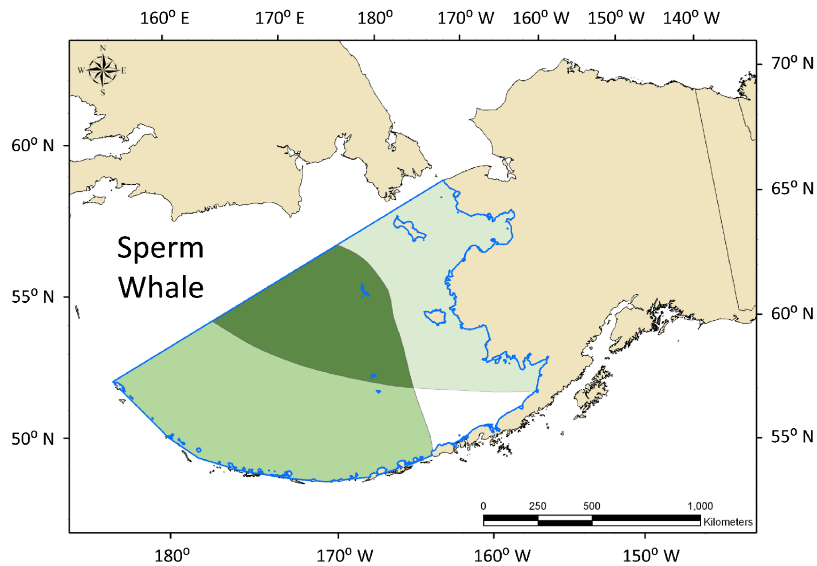

Figure A3.17. - - The overlap (dark shaded area) between the geographic range of the sperm whale (*Physeter macrocephalus*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

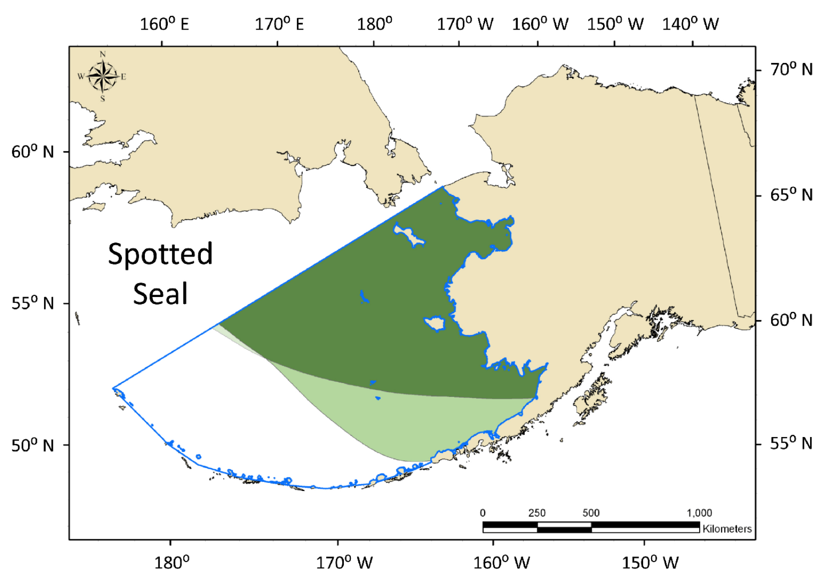

Figure A3.18. - - The overlap (dark shaded area) between the geographic range of the spotted seal (*Phoca largha*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

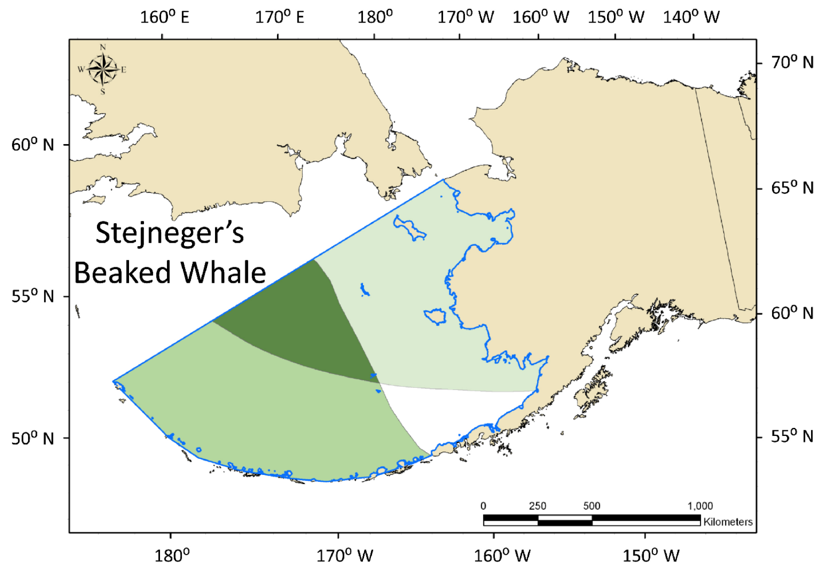

Figure A3.19. - - The overlap (dark shaded area) between the geographic range of Stejneger's beaked whale (*Mesoplodon stejnegeri*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

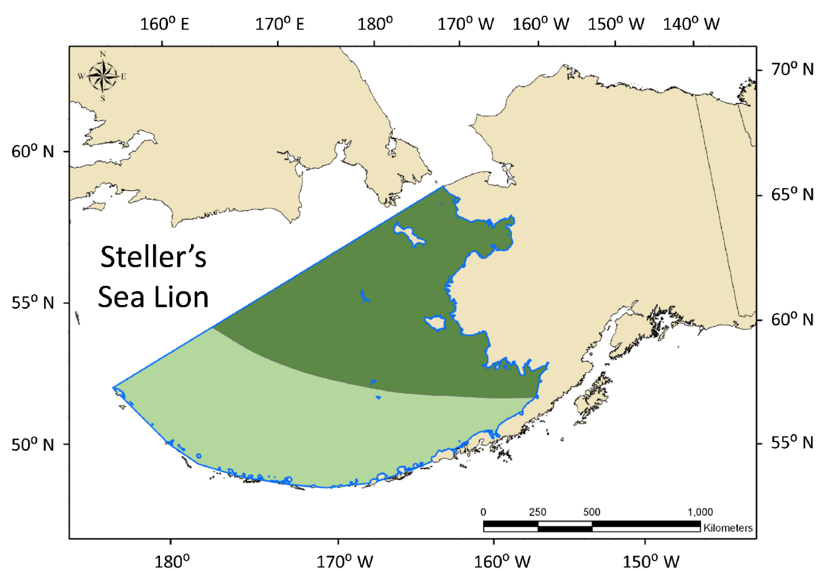

Figure A3.20. - - The overlap (dark shaded area) between the geographic range of Steller's sea lion (*Eumetopias jubatus*) and that of the bearded seal (*E. barbatus*) in the EBS ecosystem.

Appendix IV

Species-Specific Ecosystems within the Eastern Bering Sea: Density and Diversity of Overlapped Geographic Ranges

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Ecosystems Within the Eastern Bering Sea

In Appendix IV we present 21 maps for 21 ecosystems and 18 histograms which illustrate information regarding the portion of the respective ecosystem that should be set aside in marine protected area (MPA) status—all within the larger ecosystem of the eastern Bering Sea (EBS).

The maps (Figs. A4.1 - A4.21) correspond to the species-specific ecosystems involving the overlap of the geographic range of each of 21 species of marine mammals with the EBS (shown in Appendix II). Each map illustrates the number of overlapping geographic ranges for the corresponding species-specific ecosystem. The areas represented by these maps are essentially subsections of the full ecosystem as displayed in Figure 4, with one less species involved in each case (i.e., the species for which the ecosystem is defined). The information illustrated in these maps is of the kind needed to guide the placement of MPAs (consonant with the question of proper location). The location of MPAs would correspond, as far as possible, to areas occupied by few species. In other words, these are areas that tend to be left unoccupied by marine mammals and indicate what works in their species-level participation in these systems (over evolutionary time scales). Note that this is contrary to what often would be decided in conventional management wherein areas with high concentrations of marine mammals would be areas specifically chosen for MPA status to avoid conflict with legally protected species. The harvest rates that would be sustainable in areas of high concentrations of overlapping geographic ranges would be determined on the basis of consumption rates by the marine mammals feeding within those areas, and would be a declining function of the number of species as it appears to be with the number of predators feeding on a particular resource species (Fowler et al. 2009).

The histograms (Figs. A4.22 - A4.39) are graphic presentations of the patterns in portions of the respective ecosystems that are left unoccupied. These graphs represent the data from the columns of Table 3. Each histogram was constructed using the same method employed in the construction of Figure 6. The means of these frequency distributions are presented in Table 4. Note that the mode in every case is close to 0.0.

Citations

Fowler, C.W., T.E. Jewell, and M.V. Lee. 2009. Harvesting young-of-the-year from large mammal populations: an application of systemic management. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-192, 65pp.

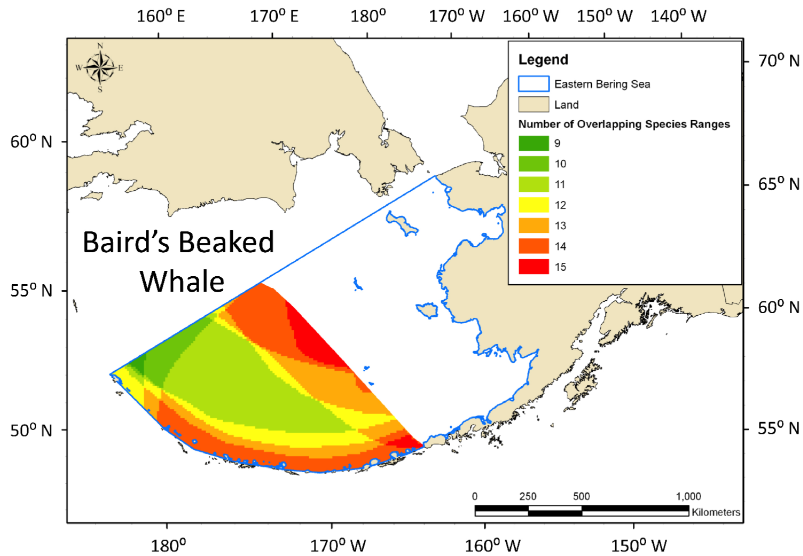

Figure A4.1. - - Map of the ecosystem (E1 of Table 4) represented by the geographic range of the Baird's beaked whale (*Berardius bairdii*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

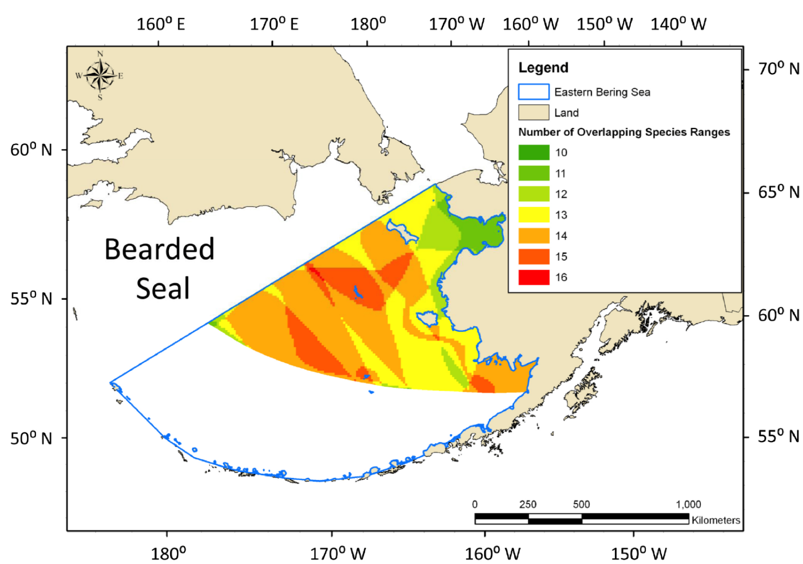

Figure A4.2. - - Map of the ecosystem (E2 of Table 4) represented by the geographic range of the bearded seal (*Erignathus barbatus*) in the EBS showing the number and lcation of overlapping geographic ranges of the other species of marine mammals.

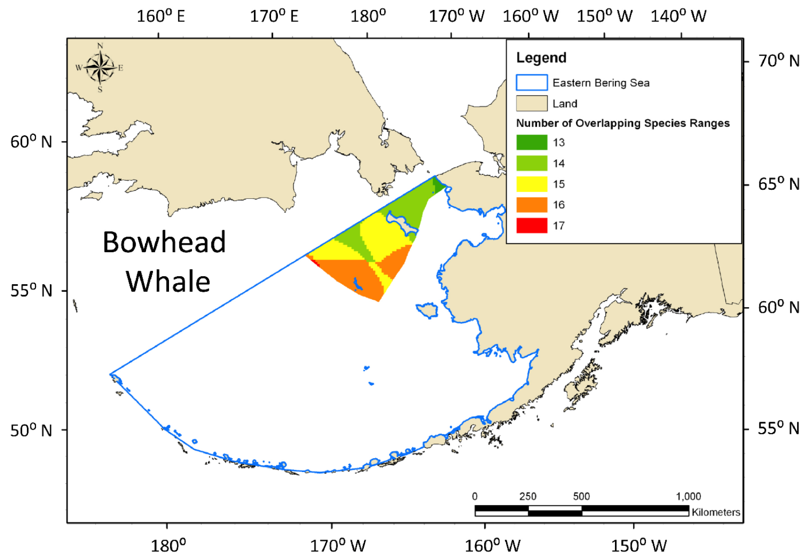

Figure A4.3. - - Map of the ecosystem (E3 of Table 4) represented by the geographic range of the bowhead whale (*Balaena mysticetus*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

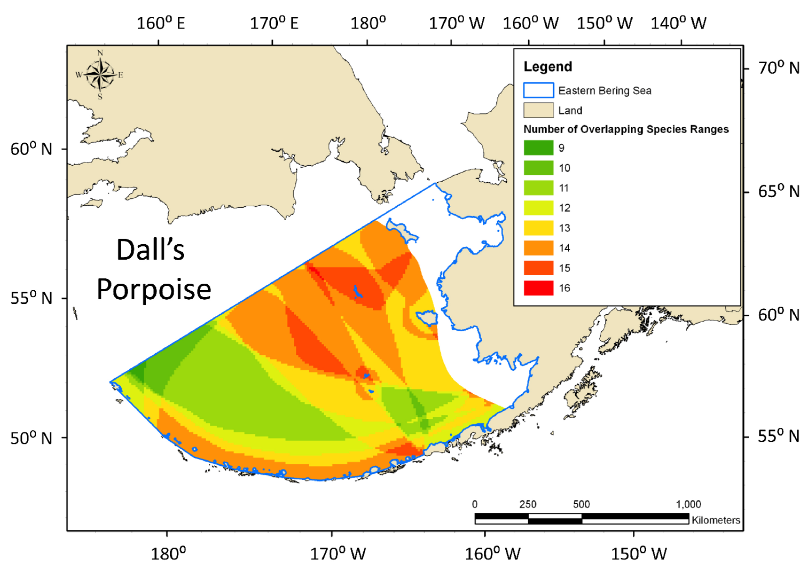

Figure A4.4. - - Map of the ecosystem (E4 of Table 4) represented by the geographic range of the Dall's porpoise (*Phocoenoides dalli*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

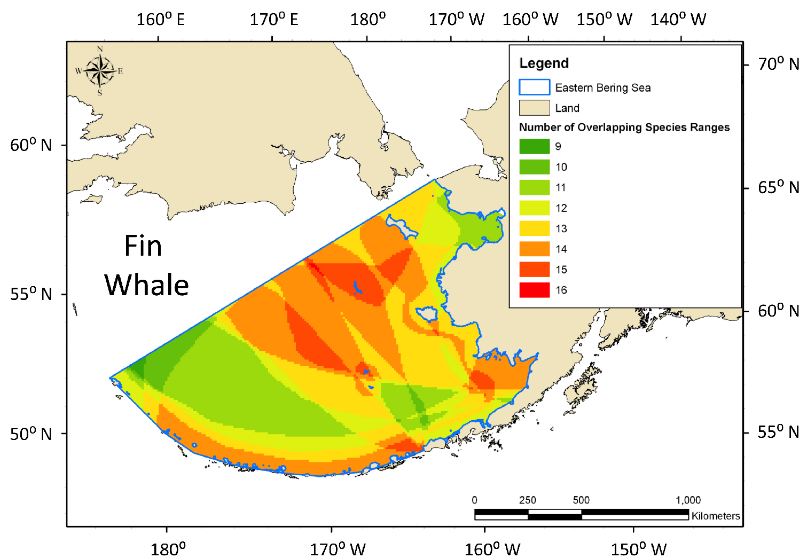

Figure A4.5. - - Map of the ecosystem (E5 of Table 4) represented by the geographic range of the fin whale (*Balaenoptera physalus*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

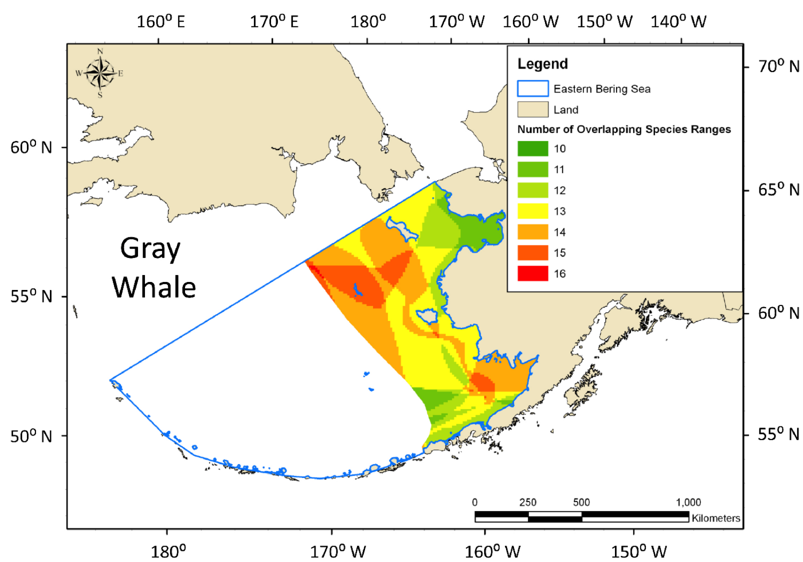

Figure A4.6. - - Map of the ecosystem (E6 of Table 4) represented by the geographic range of the gray whale (*Eschrichtius robustus*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

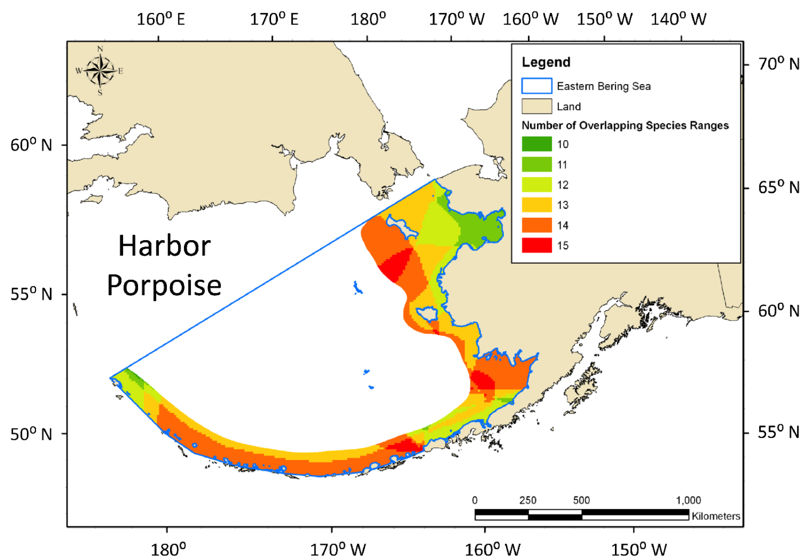

Figure A4.7. - - Map of the ecosystem (E7 of Table 4) represented by the geographic range of the harbor porpoise (*Phocoena phocoena*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

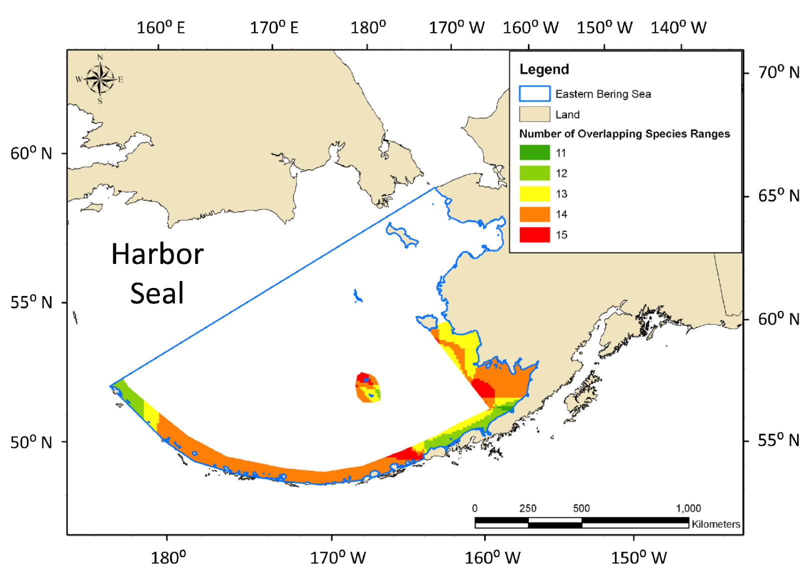

Figure A4.8. - - Map of the ecosystem (E8 of Table 4) represented by the geographic range of the harbor seal (*Phoca vitulina*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

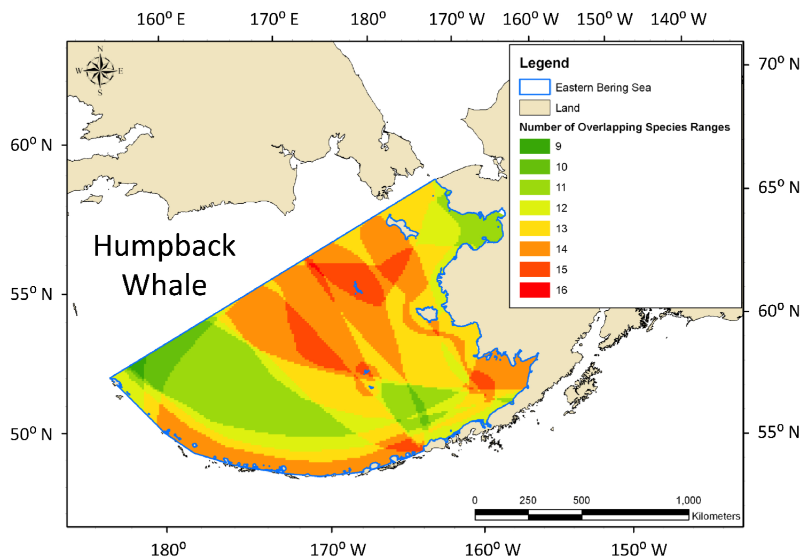

Figure A4.9. - - Map of the ecosystem (E9 of Table 4) represented by the geographic range of the humpback whale (*Megaptera novaeangliae*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

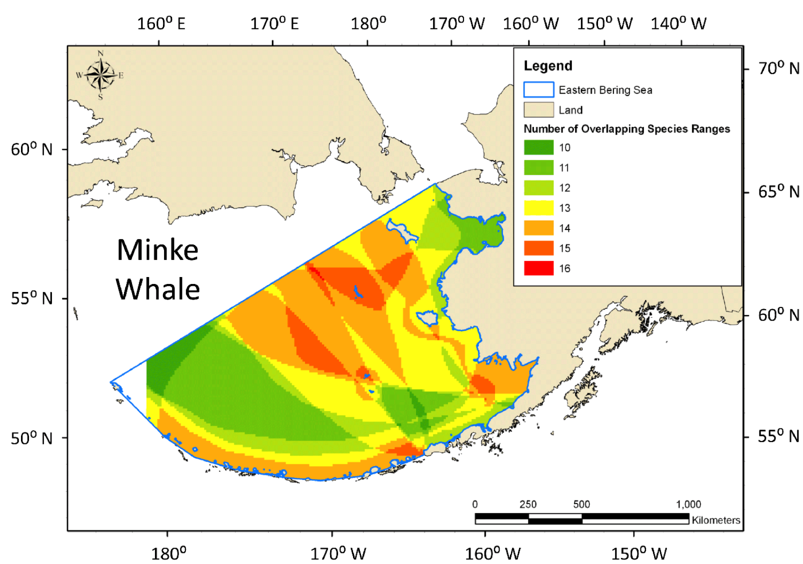

Figure A4.10. - - Map of the ecosystem (E10 of Table 4) represented by the geographic range of the minke whale (*Balaenoptera acutorostrata*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

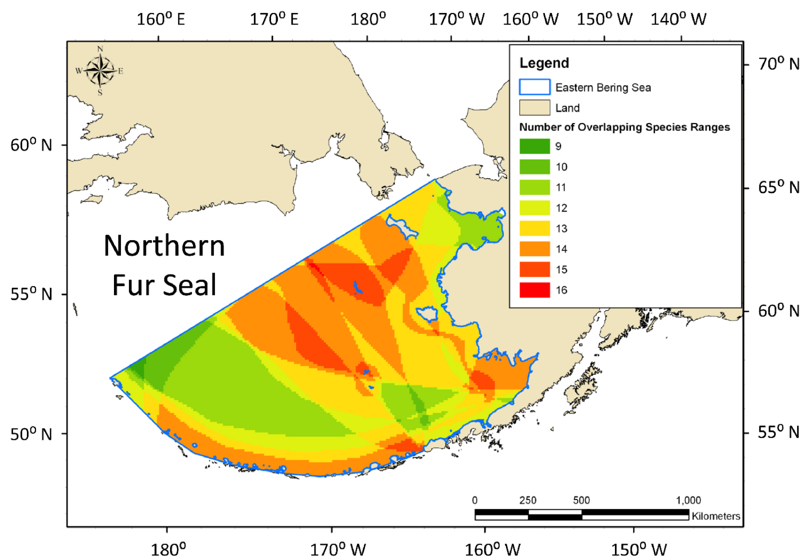

Figure A4.11. - - Map of the ecosystem (E11 of Table 4) represented by the geographic range of the northern fur seal (*Callorhinus ursinus*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

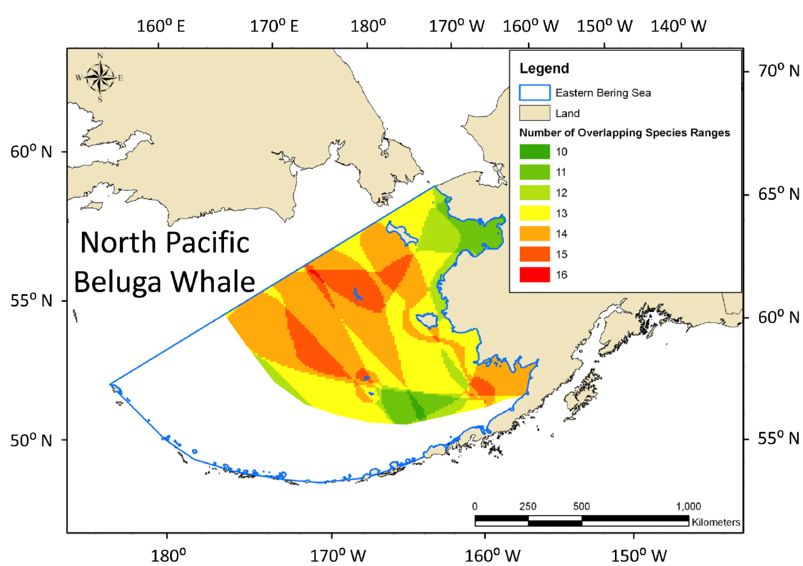

Figure A4.12. - - Map of the ecosystem (E12 of Table 4) represented by the geographic range of the North Pacific beluga whale (*Delphinapterus leucas*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

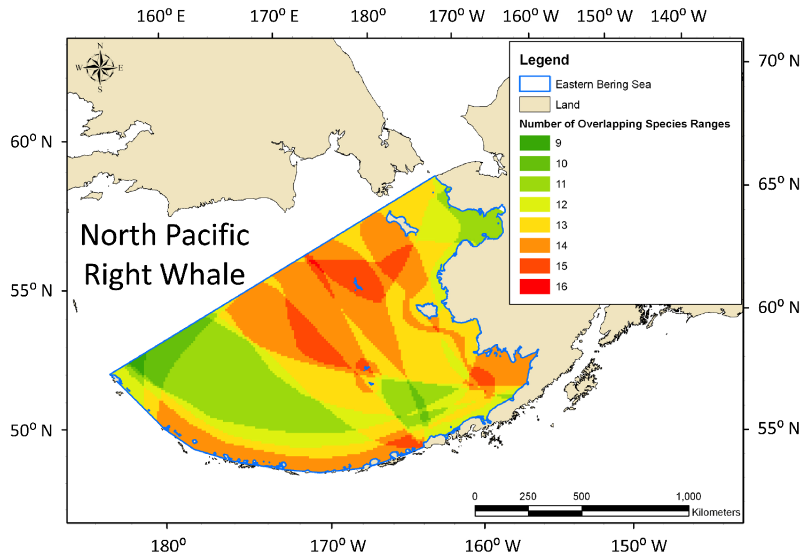

Figure A4.13. - - Map of the ecosystem (E13 of Table 4) represented by the geographic range of the North Pacific right whale (*Balaena glacialis*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

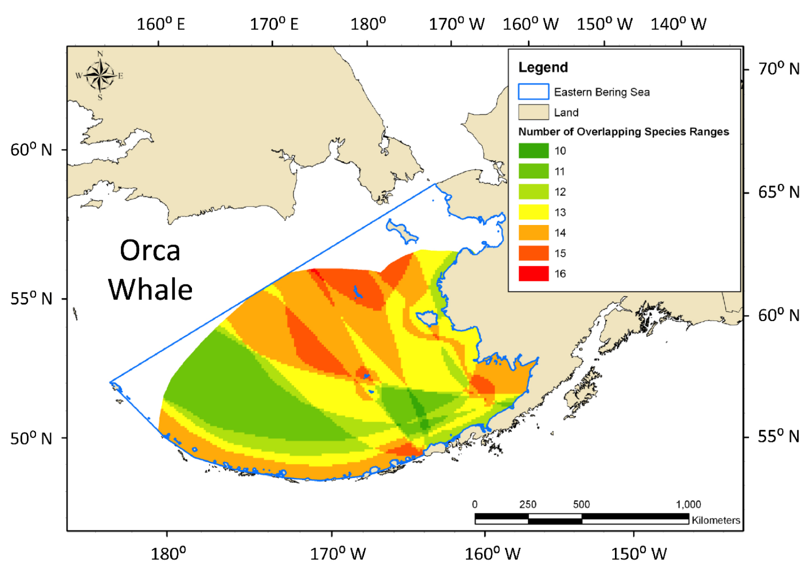

Figure A4.14. - - Map of the ecosystem (E14 of Table 4) represented by the geographic range of the orca whale (*Orcinus orca*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

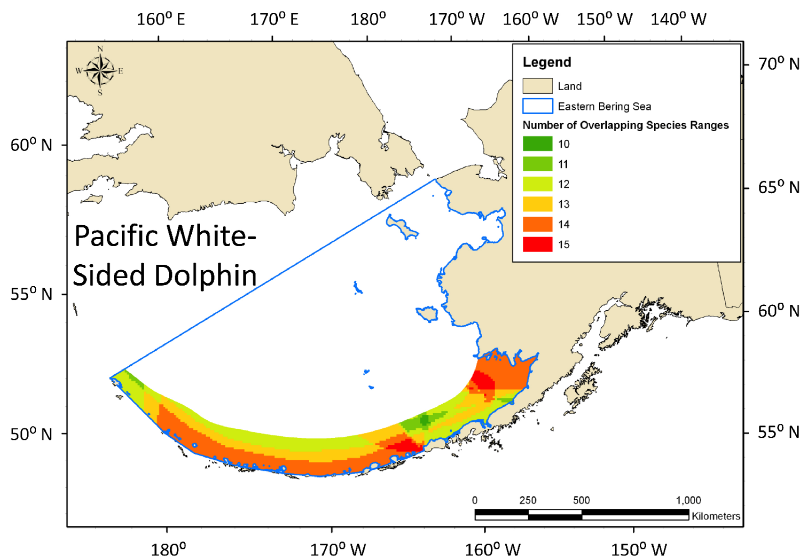

Figure A4.15. - - Map of the ecosystem (E15 of Table 4) represented by the geographic range of the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

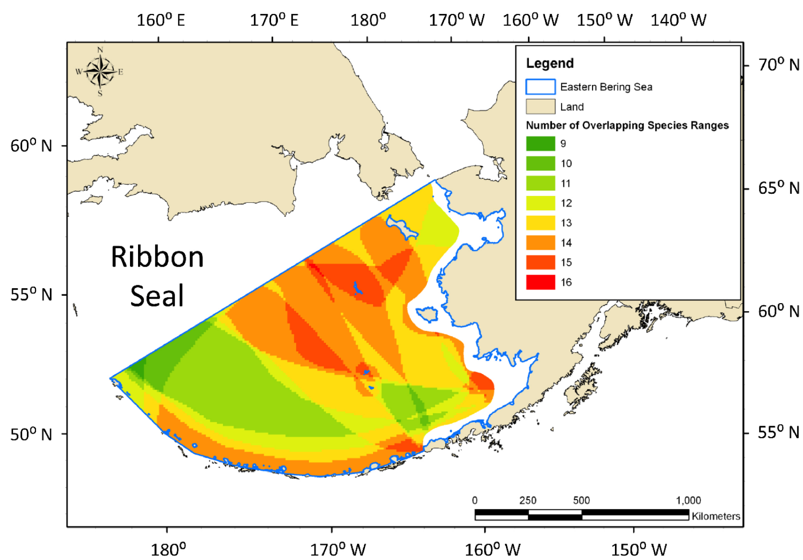

Figure A4.16. - - Map of the ecosystem (E16 of Table 4) represented by the geographic range of the ribbon seal (*Histriophoca fasciata*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

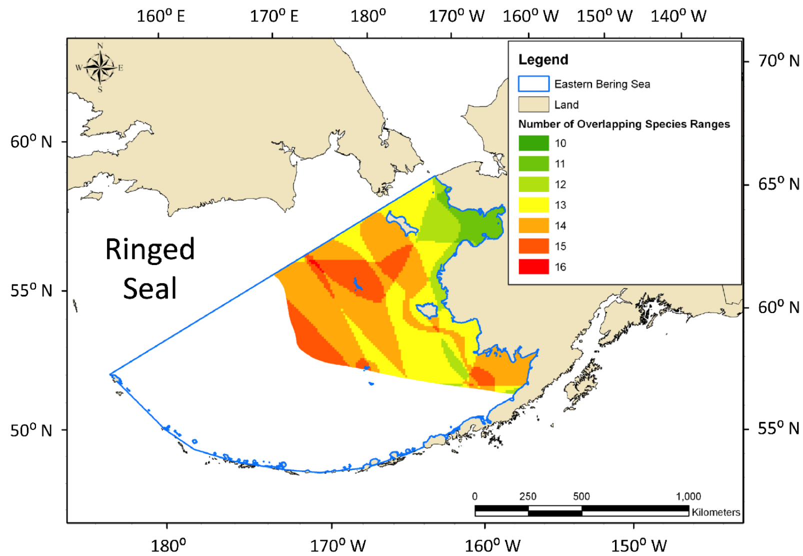

Figure A4.17. - - Map of the ecosystem (E17 of Table 4) represented by the geographic range of the ringed seal (*Pusa hispida*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

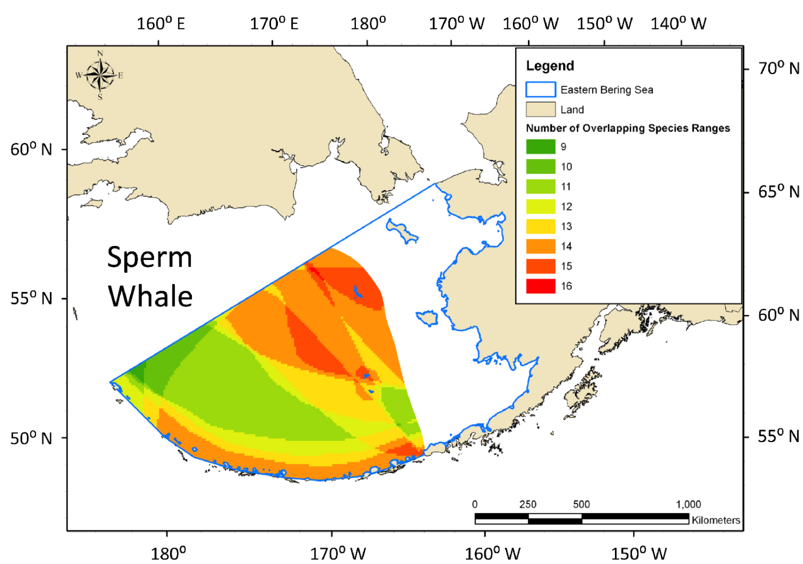

Figure A4.18. - - Map of the ecosystem (E18 of Table 4) represented by the geographic range of the sperm whale (*Physeter macrocephalus*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

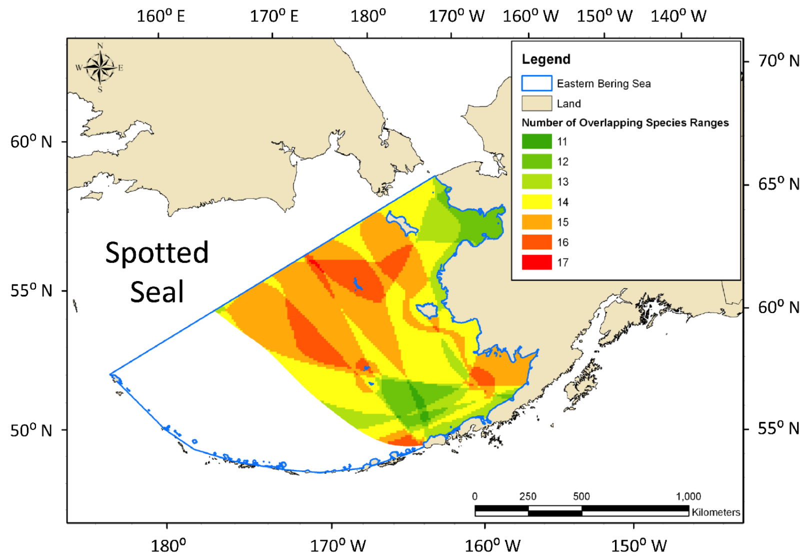

Figure A4.19. - - Map of the ecosystem (E19 of Table 4) represented by the geographic range of the spotted seal (*Phoca largha*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

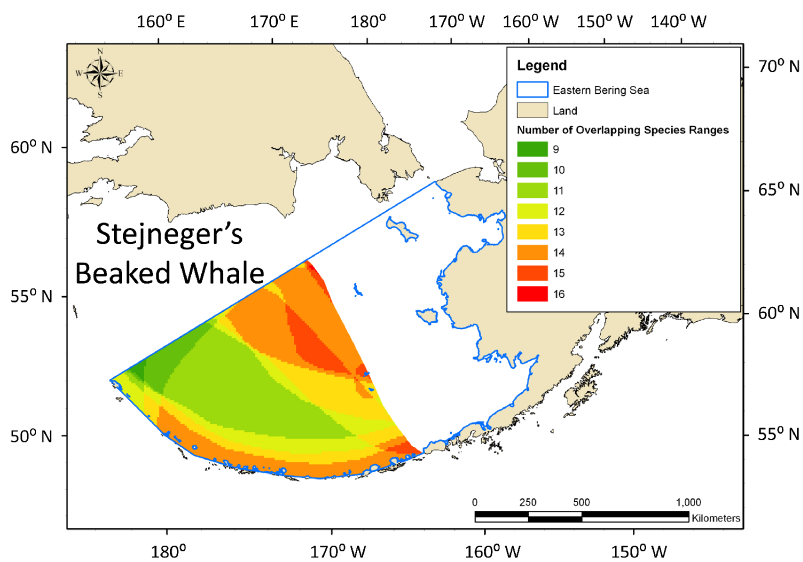

Figure A4.20. - - Map of the ecosystem (E20 of Table 4) represented by the geographic range of Stejneger's beaked whale (*Mesoplodon stejnegeri*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

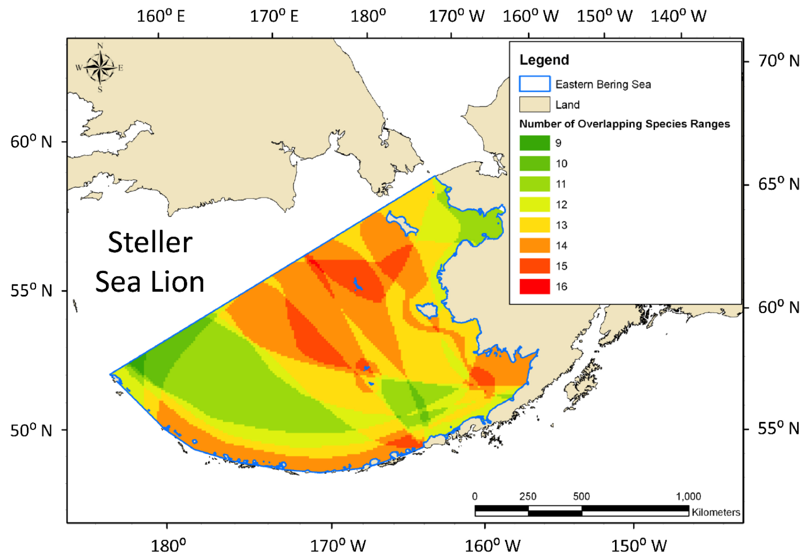

Figure A4.21. - - Map of the ecosystem (E21 of Table 4) represented by the geographic range of the Steller sea lion (*Eumetopias jubatus*) in the EBS showing the number and location of overlapping geographic ranges of the other species of marine mammals.

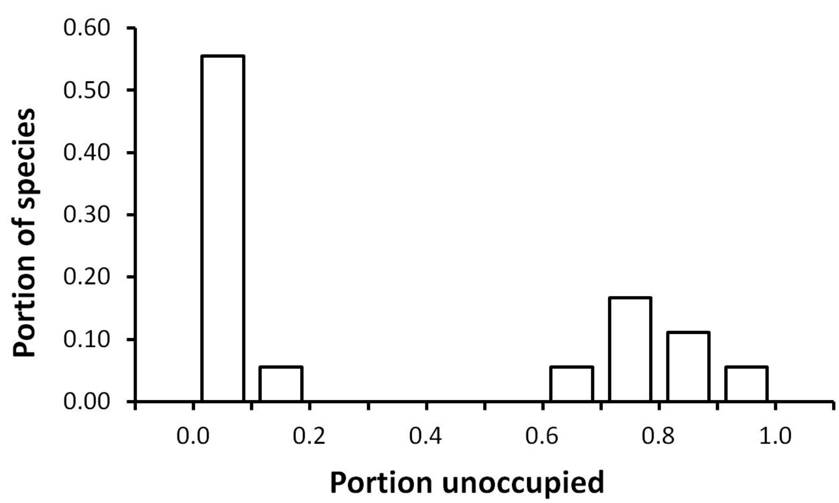

Figure A4.22. - - The frequency distribution of the portions of the geographic range of Baird's beaked whale (*B. bairdii*) that are not occupied by each of 18 other species of marine mammals within the EBS (see ecosystem E1 of Table 4 for ecosystem size and mean portion unoccupied).

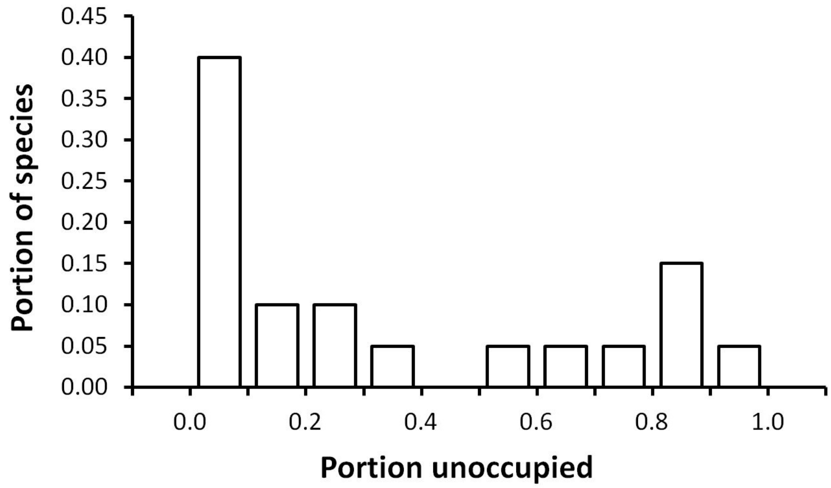

Figure A4.23. - - The frequency distribution of the portions of the geographic range of the bearded seal (*E. barbatus*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E2 of Table 4 for ecosystem size and mean portion unoccupied).

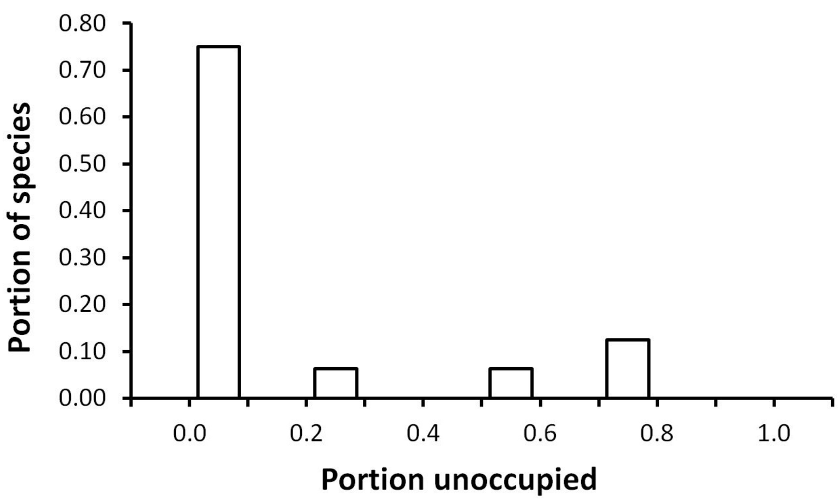

Figure A4.24. - - The frequency distribution of the portions of the geographic range of the bowhead whale (*B. mysticetus*) that are not occupied by each of 16 other species of marine mammals within the EBS (see ecosystem E3 of Table 4 for ecosystem size and mean portion unoccupied).

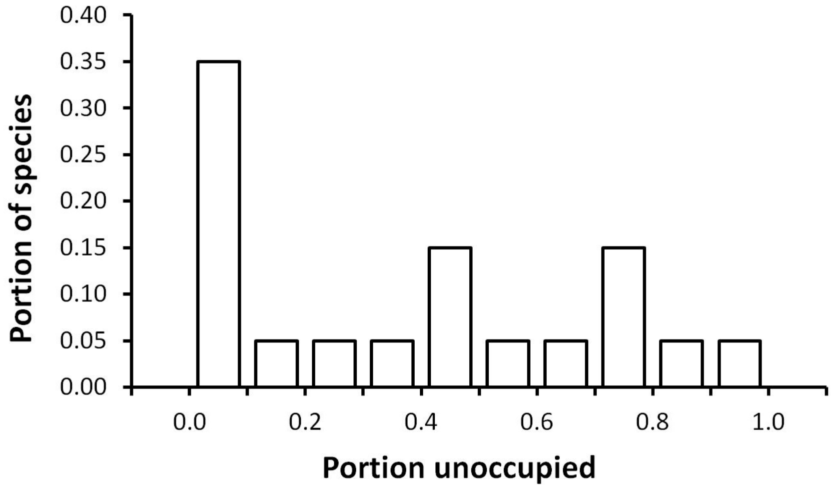

Figure A4.25. - - The frequency distribution of the portions of the geographic range of Dalls's porpoise (*P. dalli*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E4 of Table 4 for ecosystem size and mean portion unoccupied).

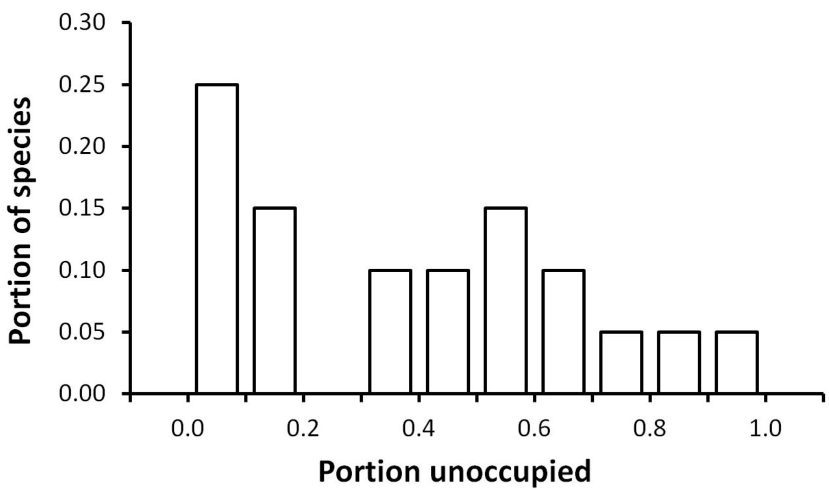

Figure A4.26. - - The frequency distribution of the portions of the geographic range of the fin whale (*B. physalus*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E5 of Table 4 for ecosystem size and mean portion unoccupied).

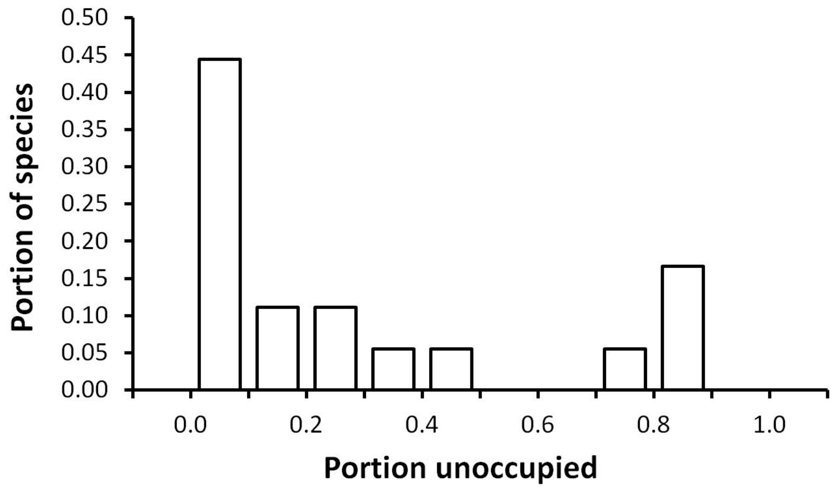

Figure A4.27. - - The frequency distribution of the portions of the geographic range of the gray whale (*E. robustus*) that are not occupied by each of 18 other species of marine mammals within the EBS (see ecosystem E6 of Table 4 for ecosystem size and mean portion unoccupied).

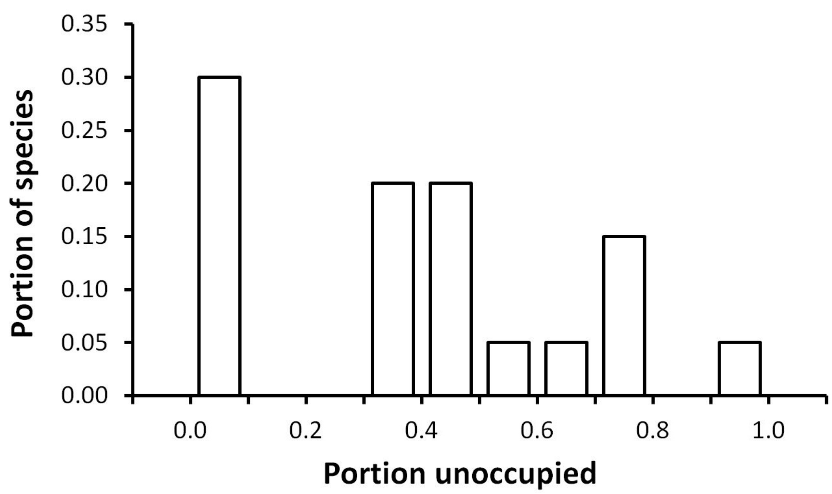

Figure A4.28. - - The frequency distribution of the portions of the geographic range of the harbor porpoise (*P. phocoena*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E7 of Table 4 for ecosystem size and mean portion unoccupied).

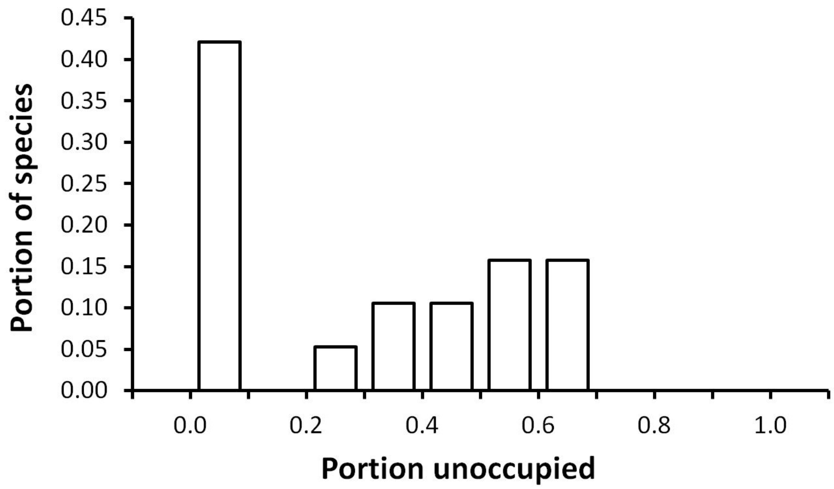

Figure A4.29. - - The frequency distribution of the portions of the geographic range of the harbor seal (*P. vitulina*) that are not occupied by each of 19 other species of marine mammals within the EBS (see ecosystem E8 of Table 4 for ecosystem size and mean portion unoccupied).

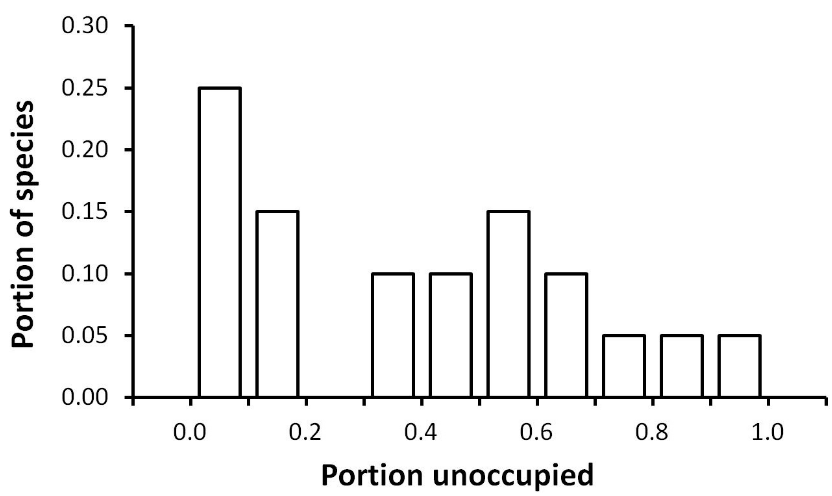

Figure A4.30. - - The frequency distribution of the portions of the geographic range of the humpback whale (*M. novaeangliae*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E9 of Table 4 for ecosystem size and mean portion unoccupied).

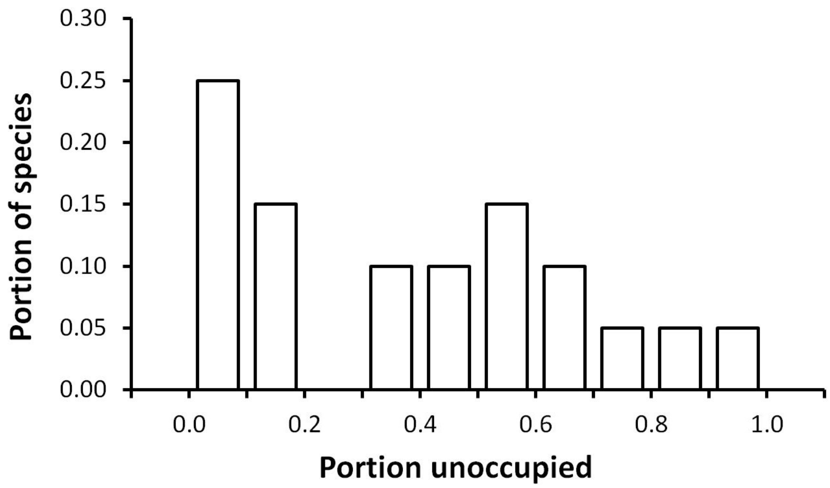

Figure A4.31. - - The frequency distribution of the portions of the geographic range of the minke whale (*B. acutorostrata*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E10 of Table 4 for ecosystem size and mean portion unoccupied).

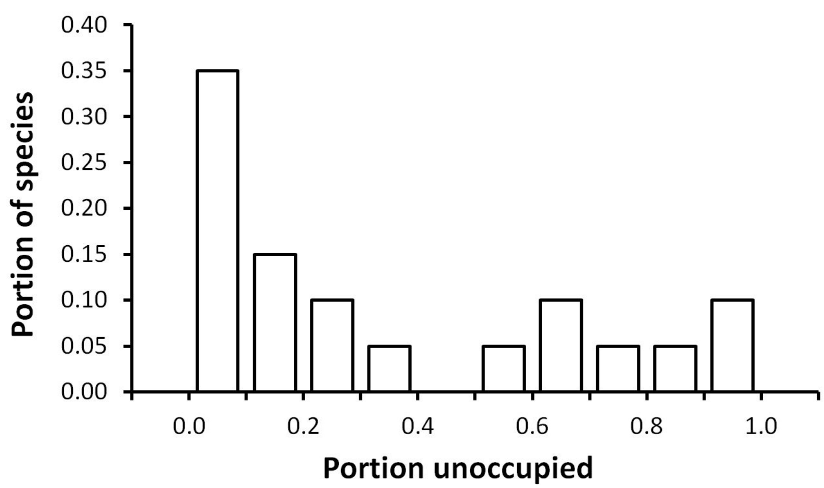

Figure A4.32. - - The frequency distribution of the portions of the geographic range of the North Pacific beluga whale (*D. leucas*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E12 of Table 4 for ecosystem size and mean portion unoccupied).

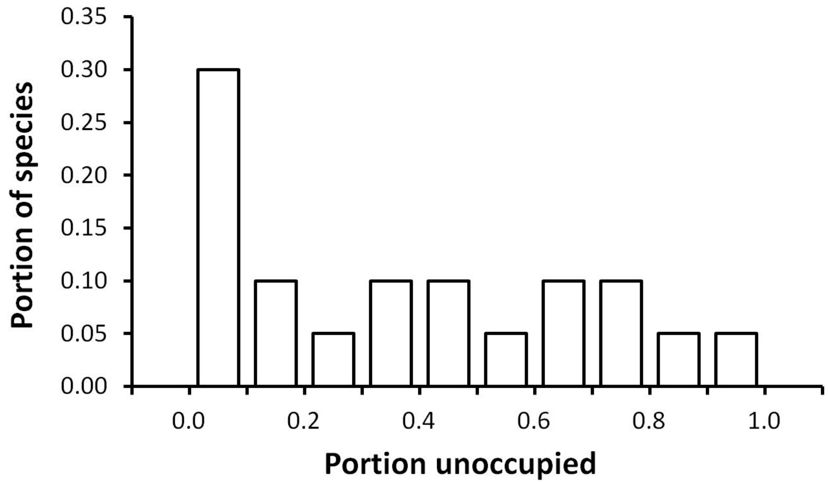

Figure A4.33. - - The frequency distribution of the portions of the geographic range of the orca whale (*O. orca*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E14 of Table 4 for ecosystem size and mean portion unoccupied).

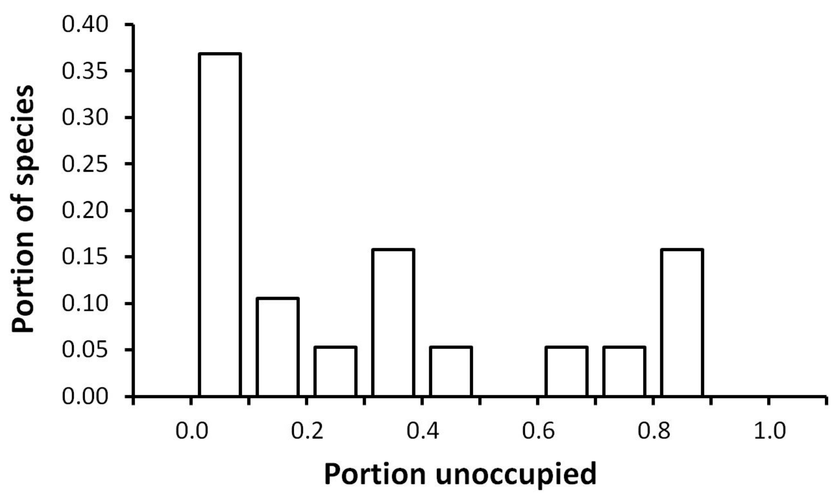

Figure A4.34. - - The frequency distribution of the portions of the geographic range of the Pacific white-sided dolphin (*L. obliquidens*) that are not occupied by each of 19 other species of marine mammals within the EBS (see ecosystem E15 of Table 4 for ecosystem size and mean portion unoccupied).

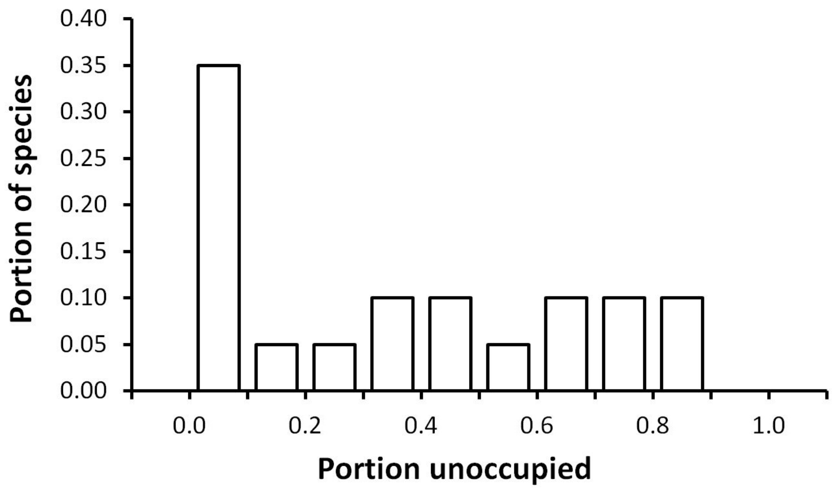

Figure A4.35. - - The frequency distribution of the portions of the geographic range of the ribbon seal (*H. fasciata*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E16 of Table 4 for ecosystem size and mean portion unoccupied).

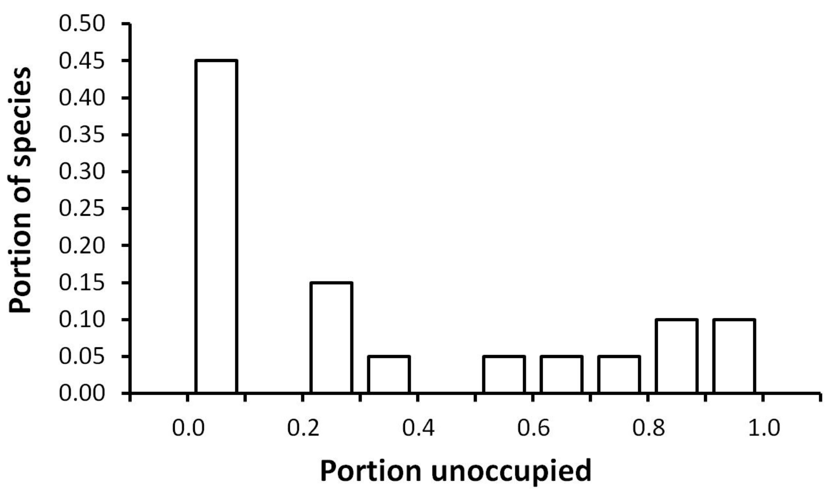

Figure A4.36. - - The frequency distribution of the portions of the geographic range of the ringed seal (*P. hispida*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E17 of Table 4 for ecosystem size and mean portion unoccupied).

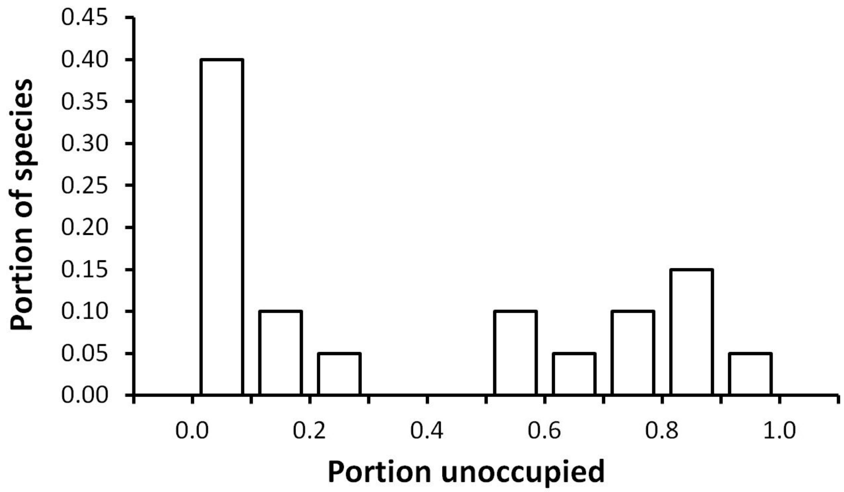

Figure A4.37. - - The frequency distribution of the portions of the geographic range of the sperm whale (*P. macrocephalus*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E18 of Table 4 for ecosystem size and mean portion unoccupied).

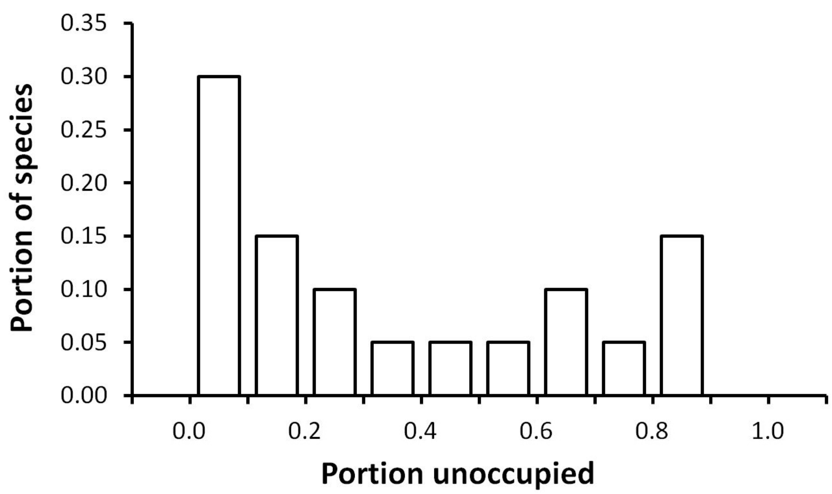

Figure A4.38. - - The frequency distribution of the portions of the geographic range of the spotted seal (*P. largha*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E19 of Table 4 for ecosystem size and mean portion unoccupied).

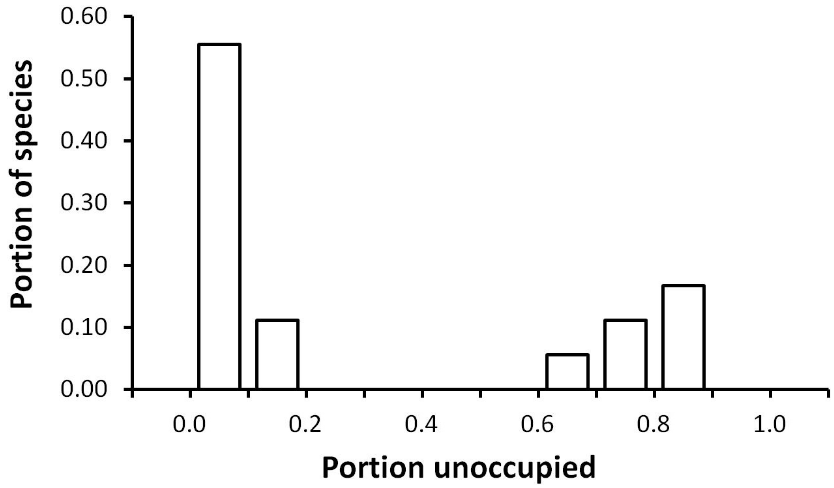

Figure A4.39. - - The frequency distribution of the portions of the geographic range of Stejneger's beaked whale (*M. stejnegeri*) that are not occupied by each of 20 other species of marine mammals within the EBS (see ecosystem E20 of Table 4 for ecosystem size and mean portion unoccupied).

Appendix V

Current Protected Areas and Distribution of Fishing Effort in the Eastern Bering Sea

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Introduction

It is instructive to compare the distribution of current fishing effort and the location (and nature) of current protected areas in the eastern Bering Sea to the corresponding empirically observed natural patterns presented in this paper. Albeit very superficially, this appendix presents information sufficient to get a first impression of what is being done in current management and how the location and size of areas that are not subjected to fishing compare to the patterns in areas likewise free of resource consumption among marine mammals—especially with respect to the numbers and kinds of marine protected areas.

Areas Currently Subjected to Fishing Effort

Figure A5.1 illustrates the location of areas where fishing was observed to occur during the period 2004-2013 based on data from the observation of groundfish fisheries and records maintained by the State of Alaska (for fisheries involving, for example, salmon, herring and shellfish; Carroll 2014). Of note here is the relative lack of fishing in the area north of the Aleutian Islands in the western part of the eastern Bering Sea ecosystem. This is also an area where there is a relative low occurrence of overlap among the geographic ranges of the marine mammal species occurring in this ecosystem (Fig. 4). In other words, if we were to make recommendations based on the pattern illustrated in Figure 4, it could easily result in locating a protected area in this region (based on guidance to mimic what other mammalian species are observed to be doing as holistic examples of sustainability). Thus, in this regard, what is bing done now in fisheries management is not obviously abnormal in comparison to what the marine mammals appear to be doing.

Although Figure A5.1 shows that a large part of the eastern Bering Sea is subject to the direct effects of fishing, such effects clearly do not involve the entire ecosystem (P_2 for humans is clearly much less than 1.0 as measured on the basis of observed fishing). Again, there is little abnormality observed in the distribution of current fishing effort or areas left free of the direct effects of fishing.

Similar maps are found in publications such as that of Fritz et al. (1998; see, in particular, Figure 39 of Fritz' work) and Zador (2013).

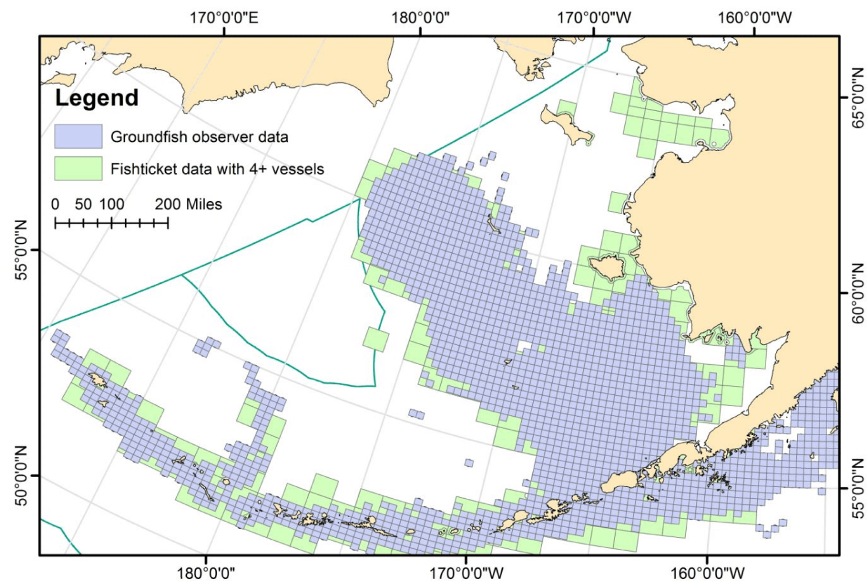

Figure A5.1. -- Map of the eastern Bering Sea showing the location of domestic fishing as recorded from 2004 to 2013, showing records maintained by both the observer program of the National Marine Fisheries Service (grey-blue squares) as well as records maintained by the State of Alaska (light green squares).

Number of protected areas

One of the management questions facing the management of fisheries in regard to marine protected areas (MPAs) involves the number of areas to be established. *How many separate areas in the eastern Bering Sea should be established as marine protected areas where fishing is prohibited year-round.* Based on the information from Appendix II, we see that only one species, the orca (*Orcinus orca*, Fig. A2.15), involves more than one area that is not occupied within the full ecosystem; it involves 2. For the eastern Bering Sea ecosystem, all other nonhuman species have only one part that is not occupied. This pattern among the nonhuman species indicates that the number of protected areas advisable (sustainable) for the eastern Bering Sea is quite limited.

The same pattern is apparent for the smaller ecosystems (Table A5.1; Fig. A5.2); no species of marine mammal has a geographic range within which more than two parts are not occupied (overlapped) by the geographic ranges of each of the other species (determined as explained below). The mean number of areas left unoccupied within the smaller ecosystems is 0.78.

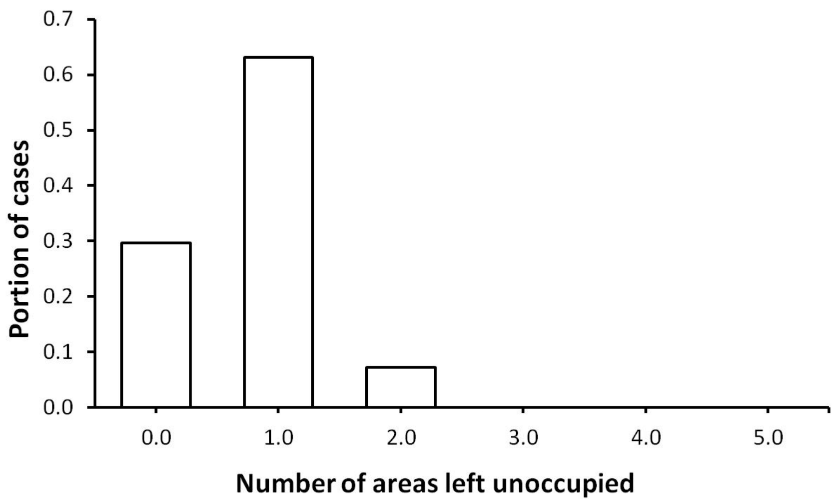

Figure A5.2. -- Frequency distribution of the count of areas left unoccupied by the 21 species of marine mammals of the eastern Bering Sea, as listed in Table A5.1, for the 21 ecosystems defined as the portion of the geographic range of each species that overlaps with the full eastern Bering Sea ecosystem (see Fig. 1).

Table A5.1. - - Number of areas left unoccupied by the marine mammal species of the eastern Bering Sea (indicated by row) for the geographic range of the other species of marine mammal (indicated by column). For both rows and columns, the species are identified by the symbols shown in Table 1 of the main text. The symbol “no” indicates no overlap; see text for details.

	Species with geographic range occupied																				
Occupying species	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**
S1		1	no	1	1	no	1	2	1	1	1	1	1	2	1	1	1	1	1	2	1
S2	1		0	1	1	1	1	2	1	1	1	1	1	1	1	1	0	1	1	1	1
S3	no	1		1	1	1	1	no	1	1	1	1	1	1	no	1	1	1	0	1	1
S4	0	1	1		1	1	1	1	1	2	1	1	1	1	1	2	1	1	1	0	1
S5	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	no	1	0	1	1		1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
S7	1	1	1	1	1	1		2	1	1	1	1	1	1	2	1	1	1	1	1	1
S8	1	1	no	1	1	1	2		1	1	1	1	1	1	1	1	1	1	1	1	1
S9	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
S10	1	0	0	1	1	0	1	1	1		1	1	1	0	1	1	0	1	0	0	1
S11	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0
S12	1	1	0	1	1	1	1	1	1	1	1		1	1	1	1	1	1	2	1	1
S13	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
S14	1	2	1	2	2	1	2	1	2	2	2	2	2		1	2	1	2	2	2	2
S15	1	1	no	1	1	1	1	2	1	1	1	1	1	1		1	1	1	1	1	1
S16	0	1	1	2	1	1	1	1	1	1	1	1	1	1	1		1	1	1	0	1
S17	1	2	0	1	1	1	1	2	1	1	1	1	1	1	1	1		1	1	1	1
S18	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1		1	0	1
S19	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1		1	1
S20	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1		1
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Figure A5.3 is helpful in explaining the data in Table A5.1. This map shows the origin of two data points: a) the count of parts of the geographic range of the Dall's porpoise (S4 in Table 1 and Table A5.1) left unoccupied by the ringed seal (S17) and b) the count of parts of the geographic range of the ringed seal (S17 in Table 1 and Table A5.1) left unoccupied by the Dall's porpoise (S4). Because, in each case, there is only one part left unoccupied there is a 1 in the corresponding rows and columns (row S4, column S17 and row S17 and column S4).

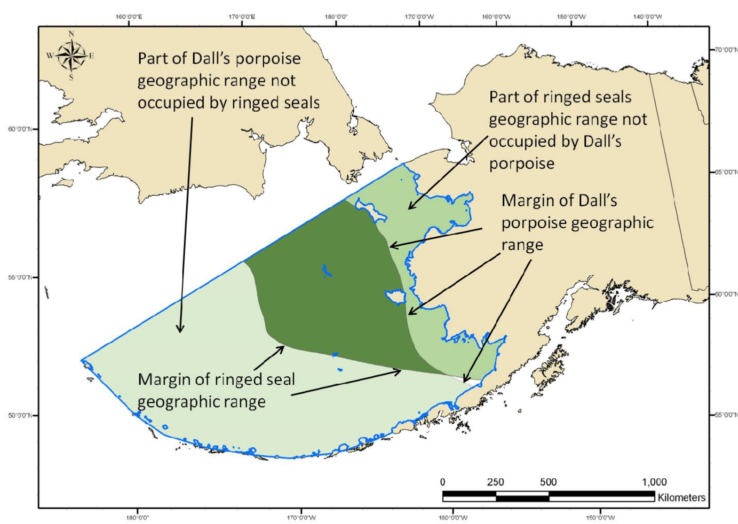

Figure A5.3. -- Map of the eastern Bering Sea showing the part of the geographic range of the Dall's porpoise (Fig. A2.5) not occupied (light green) by the ringed seal and that of the ringed seal (Fig. A2.18) not occupied (intermediate green) by the Dall's porpoise. The mutual overlap is shown in dark green.

At present, it appears that there is only one area in the eastern Bering Sea that is closed to fishing of any kind year round. That is the Walrus Islands State Game Sanctuary (Weiss and Morrill 2014). Even in this case, however, subsistence harvesting of Walrus is allowed. All other areas set aside as MPAs are managed with reference to restrictions on specific kinds of fish that cannot be harvested and/or are closed to fishing only part of the year. In such cases, there were over 20 areas subject to limited fishing in 2007 (National Marine Protected Areas Center/ National System of Marine Protected Areas 2009). Although this is an abnormally large number of areas compared to those left unoccupied by the marine mammals in the eastern Bering Sea, we have to be careful of making a fallacious comparison. These are not areas in which the consumption of resources of any kind are prohibited year round.

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