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Review

Limitations of an optimum sustainable population or potential biological removal approach for conserving marine mammals: Pacific walrus case study

Martin D. Robards[a,*], John J. Burns[c], Chanda L. Meek[b], Annette Watson[d]

[a] Department of Biology and Wildlife, University of Alaska, Fairbanks, AK 99775, USA
[b] Department of Political Science, University of Alaska, Fairbanks, AK 99775, USA
[c] Alaska Department of Fish and Game – Retired, AK, USA
[d] College of Charleston, Charleston SC 29424, USA

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ABSTRACT

Decision rules are the agreed-upon points at which specific management interventions are initiated. For marine mammal management under the U.S. Marine Mammal Protection Act (MMPA), decision rules are usually based on either a numeric population or biological-removal approach. However, for walrus and other ice-associated pinnipeds, the inability to reliably assess population numbers or biological removals highlights a significant gap in the MMPA, particularly when the Arctic environment is rapidly changing. We describe the MMPA's ecosystem-based management goals, and why managers have bypassed these goals in favor of an approach that depends upon numerical population assessment. We then revisit the statute's primary goals in light of current knowledge about the Pacific walrus ecosystem and new developments in environmental governance. We argue that to monitor and respond to changes in the walrus ecosystem, decision rules should be based on scientific criteria that depend less on the currently-impractical goal of accurately enumerating population size and trends, or removals from that population. Rather, managers should base decisions on ecological needs and observed ecological changes. To implement this approach would require an amendment to the MMPA that supports filling the gap in management with achievable decision rules. Alternatively, walrus and other ice-associated pinnipeds will remain largely unmanaged during a period of profound environmental change.

1. Introduction

To manage wildlife populations, managers usually rely upon tools that estimate stock abundance (Caughley and Sinclair, 1994; Williams et al., 2002), despite their expense and the significant challenges to achieving adequate accuracy and precision (Morellet et al., 2007). Unfortunately, population estimates alone, absent an understanding of the wider context in which populations fluctuate (e.g., density dependence, or varying demographics), are an incomplete basis for evaluating the health, status, or specific management needs of a wildlife population (Gordon et al., 2004; Ray and McCormick-Ray, 2004; Nichols and Williams, 2006). Furthermore, if decision-making is predicated on a specific stock abundance threshold (i.e., a decision rule), but data cannot be acquired at a legally adequate precision, a management void may result (Johannes, 1998; Ruckelshaus et al., 2002). In this paper, we focus on the management goals delineated by the United States Marine Mammal Protection Act (MMPA), which mandates consideration of populations within an ecosystem context.

In 1972, the MMPA established a general moratorium on take of marine mammals, responding to the tenuous circumstances of many of the world's marine mammal species, scientific concern, and public outcry about both the high incidental take of dolphins in tuna fisheries and seal pup harvests in the North Atlantic. The MMPA provides several exemptions to the moratorium, including one recognizing federal responsibility to support Alaska Native subsistence rights, permitting the non-wasteful take of non-depleted marine mammals such as walrus for subsistence and handicrafts. Exceptions also allow a limited incidental take to accommodate industrial activities such as commercial fishing or oil and gas exploration. Thus, to address the goals of the MMPA, managers use strategies to establish if a species is depleted, or to account for an appropriate level of "take" – both assessed within the context of carrying capacity.

The numerical relationship between a population of a particular species, at a particular time and place, and their environment's carrying capacity is always in flux, and estimating carrying capacity

* Corresponding author. Marine Mammal Commission, 4340 East-West Highway, Room 700, Bethesda, MD 20814, USA.
E-mail address: mrobards@mmc.gov (M.D. Robards).

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may only be realistic when the long-term average state for an ecosystem is stable. However, for policies or managers seeking to maintain wildlife populations, or restore them to specific levels (including historical maxima), transience in carrying capacity that is directional is highly problematic (Hilborn et al., 1995; Pitcher, 2005; Marsh et al., 2005). This problem is particularly pertinent when directional change of an ecosystem leads to alternate ecosystem states, termed regime shifts (Overland et al., 2008). Because assessing carrying capacity is complex, managers have generally relied upon population abundance estimates alone to assess the status of marine mammal populations.

Recently, Taylor et al. (2007) suggested that, for several species governed by the MMPA, not only is carrying capacity problematic, but assessing population trends may also be unachievable. Specifically, a 50% decline in population size over a 15 year period could go undetected based on current survey techniques applied at 4-year intervals. Most difficult to assess were the pagophilic (ice-loving) pinnipeds, including the Pacific walrus (*Odobenus rosmarus divergens*) and four species of seal: bearded (*Erignathus barbatus*), ribbon (*Phoca fasciata*), ringed (*Phoca hispida*), and spotted (*Phoca largha*). These species are important components of the Beringian ecosystem (the combined shelf areas of the Bering, Chukchi, East Siberian, and Beaufort seas) and represent major subsistence resources for the region's Native cultures (Krupnik and Ray, 2007). Taylor et al. (2007) suggest that population assessment alone cannot currently provide a reliable decision rule for these species.

In this paper we take an interdisciplinary approach to assess the best science and management of Pacific walrus. We present the case that current trends and predicted future scenarios for the subarctic and Arctic environment will reduce the Pacific walrus population. We then describe the primary ecosystem-based goal of the MMPA, and why the MMPA's secondary goal, which is associated with numerical population status is used as the basis for management. Finding this numerical approach unable to respond to contemporary management needs of the Pacific walrus, we consider new ecological and social-science insights about ecosystem-based governance. The governance literature attempts to integrate natural and social sciences, and thereby provides not only a critique, but also new ways to augment the numerical-based approaches that dominate current marine mammal management.

2. Pacific walrus and their changing environment

Evidence from satellite data, field research, and Native communities' observations in the Beringian region over the past decade suggest profound alterations in sea ice as a result of a changing climate, including a shortened ice season, lower ice concentrations, and greater summer recession (ACIA, 2005; Grebmeier et al., 2006; Ray et al., 2006). Pacific walrus rely on ice for much of the year, so changes in ice affect walrus ecology. Ice is a platform for walrus during the winter for resting, feeding, and breeding. Subsequently, during spring and summer, walrus become increasingly gender/age segregated. While male Pacific walrus largely remain associated with land, large numbers of females and calves have normally stayed with the ice, using it as a rafting platform on which they rest and nurse, and from which they feed as ice cover seasonally retreats. Some females and calves utilize terrestrial haulouts, particularly in the western Bering and Chukchi seas, although recent use of terrestrial habitat by females and calves in Alaska (eastern Bering and Chukchi seas) was limited prior to 2007.

Walrus reliance on sea-ice or land differs with respect to feeding ecology. From ice, ocean currents carry walrus over new areas of benthos, limiting depletion in any one spot (Fay, 1982). In contrast, while foraging from land, walrus become central place foragers as they feed, and return to specific haulouts. Pacific walrus historically consumed an estimated three million metric tons of benthos per year, an amount that Ray et al. (2006) equates to the total extraction by Bering Sea commercial fisheries. Consequently, prey depletion around terrestrial haulouts may be significant, and lead to redistributions of walrus population components as they seek new feeding areas (Ray et al., 2006).

Recent climate change has impacted female walruses and their calves as they travel north with the sea ice in summer. Walrus effectively feed in water depths up to about 110 m (Fay and Burns, 1988). Once sea ice retreats north past the shelf break into deep waters of the Arctic basin, walrus are progressively less able to feed themselves and their calves from ice and need to relocate to land to rest and feed until the ice advances again. In recent years as sea-ice receded past the shelf break into the deep Arctic basin, both researchers and hunters observed poor condition of females at haulouts early in fall and evidence of abandoned calves (Cooper et al., 2006). Nevertheless, walrus have survived profound environmental changes in the past, and we expect that a summer redistribution of females and calves to land is a realistic adaptive scenario for current and predicted environmental conditions. Recent increases in terrestrial haulout use in summer and fall in both Alaska and Chukotka support this hypothesis.[1] With increasing use of terrestrial haulouts, females and especially calves are more vulnerable to localized prey depletion and a variety of mortality factors – including being crushed or injured by overcrowding and panic stampedes (including as a result of human disturbance), from predation by polar bears similarly driven to land, and by hunting from Alaska and Chukotka Natives.

In conjunction with reductions in summer sea ice and the potential for walrus redistribution, their prey abundance may also be in decline. Grebmeier et al. (2006) offer two potentially complementary hypotheses for observed reductions in benthic biomass; first that predators such as walrus have exceeded the carrying capacity of their prey, and second that ecosystem changes have led to declines in benthic productivity. Both hypotheses are problematic for calculating what constitutes a healthy walrus population; in either case a population decline is expected unless walrus are already below or at their carrying capacity.

In summary, a specific spatial and temporal configuration of sea ice is required to maintain high walrus populations, deviations from which will reduce the Beringian region's capacity to support walrus. The continued deterioration of sea ice is a widely accepted future trend (Wang and Overland, 2009), and presents great uncertainty about the future ecological characteristics of the Beringian ecosystem, of how many walrus that ecosystem can support, of how current levels of subsistence harvest affect the walrus population, or how these combined changes will impact Native subsistence. In conjunction with ecosystem changes, decreasing ice cover and broadening of the open-water season present new opportunities for development. Three primary examples are the oil and gas industry in the Chukchi Sea, increased shipping through the Bering Strait, and expansion of commercial fishing into the northern Bering and Chukchi seas. Collectively, these potential, new or expanding activities in the Arctic pose additional uncertainties and thus additional challenges to walrus management, if managers wish to act conservatively in the face of change (Ragen et al., 2008).

[1] Personal Communication with Joel Garlich-Miller, U.S. Fish and Wildlife Service; and Anatoly Kochnev, Chukotka TINRO; September 2007.

3. Current knowledge about the size of the Pacific walrus population

The Pacific walrus population appeared to increase rapidly (approximately 9% per year) during the 1960s and 1970s as a result of a significant reduction in harvests (Fay et al., 1989). Population increases led to concerns that density-dependent mechanisms might cause the population to surpass carrying capacity (Fay et al., 1989). However, the rate of increase was surprising for a reproductively *K*-selected species. Walrus are presumed to have an annual rate of increase of 3–6%, leading Ray and McCormick-Ray (2004) to hypothesize that variable and imperfect survey methods may have underestimated the original walrus population size, or overestimated the 1980 figure of about 300,000 animals.

Since inception of the MMPA, biologists have attempted to estimate the total Pacific walrus population in 1975, 1980, 1985, 1990, and 2006 using aerial survey techniques. Prior to 2006, surveys suffered from persistent biases and imprecision and used inconsistent methods for integrating data from the United States and former USSR. However, they were continued because of a perceived lack of alternate methods for population assessment or different approaches for management (Hills and Gilbert, 1994). By 1990, researchers concluded that the surveys produced data unsuitable for accurately estimating population size or quantifying trends and no new surveys were conducted until 2006 (Hills and Gilbert, 1994). The attempted full population survey in spring 2006 used newly developed methods (Burn et al., 2006; Jay et al., 2006), but the results are still pending in 2009 after three-years of data analysis.

The 2006 survey came at significant expenditure of time and money, including years of preparation and post-analysis, and a $1 million U.S. Congressional appropriation. As is normal with population surveys of vast areas in remote regions, significant uncertainty will remain, associated with the variables and correction factors required to calculate the resultant population estimate (e.g., Burn et al., 2006). Cost and personnel time will also limit regular future surveys, supporting Taylor et al.'s (2007) conclusion that population trends will not be detected in a timely manner. Even assuming that an accurate and precise count is obtained, population size alone does not provide information on the relationship between walrus numbers and their changing environment: for example, whether population changes reflect trends in reproductive rate, mortality, carrying capacity, or a combination of the three.

An alternative survey could use counts of walrus on land. However, here too, observational errors can be significant (Udevitz et al., 2005), and dynamic regional distributions of walrus can thwart understanding how abundance at specific census sites relate to overall population numbers (Hills, 1992). Decreased numbers at specific haulouts could just reflect animal movements to more suitable habitat, at least temporally, rather than a changing population. At Round Island, Alaska, counts are predominantly of males, also limiting inferences about the status of females, which more directly determine population growth rate.

Given no reliable population estimates, a long-term tissue collection program (teeth and reproductive tracts) begun by the State of Alaska during the 1960s, and partially continued by U.S. Fish and Wildlife Service, provides the most recent indications of change in age structure, productivity, and status of Pacific walrus. However, lack of data on walrus (e.g., recruitment rates or age/gender-specific survival), environmental health and conditions, biases in hunter preferences, and different harvest management regimes were acknowledged to limit conclusions about the relationship between life history parameters, population size, and the dynamic carrying capacity of the Beringian region (Garlich-Miller et al., 2006).

4. Ecosystems and the Marine Mammal Protection Act (MMPA)

The intense focus on numerical counts of marine mammal populations comes at the expense of the primary intent of the MMPA. The Congressional findings and declaration of policy in the MMPA emphasize goals of ecosystem function over those of absolute numbers of marine mammals:

> Marine mammals have proven themselves to be resources of great international significance, esthetic and recreational as well as economic, and it is the sense of the Congress that they should be protected and encouraged to develop to the greatest extent feasible commensurate with sound policies of resource management and that the primary objective of their management should be to <u>maintain the health and stability of the marine ecosystem</u>. Whenever consistent with this primary objective, it should be the goal <u>to obtain an optimum sustainable population keeping in mind the carrying capacity of the habitat</u>. (Emphasis added. 16 USCS § 1361(6)).

This statement instructs managers to attend to the "health and stability" of marine ecosystems. Ecosystems are in a balance between negative and positive feedbacks that tend to stabilize or destabilize a particular and potentially transient state (Link, 2002; Levin and Lubchenco, 2008). Currently, positive feedbacks are destabilizing the multi-year ice-dominated summer Arctic Ocean, favoring a new summer ice-free state. We use the term '*resilience*' as synonymous with the intent of 'health and stability' within the MMPA. Resilience in this context denotes the capacity of an ecosystem state to retain the characteristics necessary to support marine mammal populations such as walrus as significant functioning elements, while maintaining the capacity of the walrus population to absorb a spectrum of endogenous and exogenous perturbations (Folke, 2006). From our perspective, the MMPA calls for actions that seek to stabilize those ecosystem states that encompass marine mammals as significant functional elements.

Programs considered or implemented under the MMPA that focus on *secondary* population objectives, rather than the primary ecosystem objective of the Act have been considered both troubling (Kareiva et al., 2006) and tragic (Fay et al., 1989). However, although ecosystem-based management is a logical response to the MMPA's goal of maintaining ecosystem-based resilience, the fundamentals of ecosystem management were not well articulated until the 1990s (Christensen et al., 1996), well after the implementation of the MMPA. Nevertheless, Eberhardt (1977), and much earlier Aldo Leopold (1933) and George Perkins Marsh (1864) described similar concepts.

5. Population-based approach to marine mammal management

Many consider population status and trends as requisite for effective management and conservation of marine mammal populations. This has resulted in few management approaches not requiring a primary focus on numerical validation of population size (e.g., Garner et al., 1999; Small et al., 2003; Taylor et al., 2007). The general focus on population numbers rather than the broad ecosystem-based intent of the MMPA is a consequence of management history, implementation of goals, and path-dependent action. In its original findings (MMPA §2(1)), Congress stated that certain marine mammals had been depleted or were in danger of extinction due to adverse human actions. Congress further declared that:

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> …such species and population stocks should not be permitted to diminish beyond the point at which they cease to be a significant functioning element in the ecosystem of which they are a part, and, consistent with this major objective, they should not be permitted to diminish below their optimum sustainable population. Further measures should be immediately taken to replenish any species or population stock which has already diminished below that population. In particular, efforts should be made to protect essential habitats, including the rookeries, mating grounds, and areas of similar significance for each species of marine mammal from the adverse effect of man's actions (MMPA §2 (2)).

The National Marine Fisheries Service and U.S. Fish and Wildlife Service jointly administer the MMPA (U.S. Fish and Wildlife Service oversees walrus). When adopting implementing regulations, National Marine Fisheries Service defined operational goals relating to maintaining or restoring stock size in relation to carrying capacity (Federal Register, 21 December 1976, 41 FR 55536). U.S. Fish and Wildlife Service accepted the same ''optimum sustainable population'' (OSP) operational goal. National Marine Fisheries Service interpreted the management goals of the MMPA (perhaps due to the then unresolved scope of ecosystem management) as to ensure marine mammal species were a part of ecosystems in sufficient numbers, and not that their ecosystems were maintained or enhanced to achieve optimum numbers (such as by protecting essential habitats). Nevertheless, OSP for a species incorporates habitat, and thus, from a theoretical perspective, is inextricably linked to ecosystem goals. OSP is defined with respect to any population stock as:

> the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element (16 U.S.C. §1362(9)).

Emphasis on the ''maximum productivity'' component of OSP, mimics problematic aspects of maximum sustainable yield approaches (Bean and Rowland, 1997). Conversely, too much focus on habitat may be incompatible with other ecosystem or socio-economic objectives. Confounding these challenges, OSP may also ''call for subjective value judgments that are not amenable to quantification on the basis of available data'' (citing the Marine Mammal Commission; Bean and Rowland, 1997). Irrespective of the confusion and subjectivity over how to effectively implement an OSP approach, National Marine Fisheries Service accepted the dynamic nature of OSP and by regulation defined populations to be at OSP when they were between carrying capacity and the maximum net productivity level (MNPL; Gerrodette and DeMaster, 1990), recognizing that the MNPL would exist at a point below carrying capacity. U.S. Fish and Wildlife Service subsequently endorsed the National Marine Fisheries Service definition (USFWS, 1994):

> Optimum sustainable population is a population size which falls within a range from the population level of a given species or stock which is the largest supportable within the ecosystem to the population level that results in maximum net productivity. Maximum net productivity is the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality. 50 CFR § 403.02.

Three numbers are required to ascertain population status under an OSP assessment; population size at carrying capacity, population size producing the maximum net productivity, and current population size. Managers have only established these numbers for a few marine mammal populations (for which OSP provides a useful decision rule), but for many of these populations the estimates contain significant uncertainty (Taylor et al., 2000). Nevertheless, an administrative law judge in 1977 determined that the maximum net productivity level of Pacific walrus was at least 170,000 animals, and in 1994, U.S. Fish and Wildlife Service correspondingly indicated that walrus populations would be regarded as at or above OSP if subsequent surveys indicate that their population was 170,000 or more (USFWS, 1994).

In addition to the difficulties of assessing population, assessing carrying capacity is problematic and remains a significant ''loose end'' in implementation of the MMPA (Goodman, 2005). Currently, the correct temporal dimension of carrying capacity (historical, current, or dynamic) is unresolved. Furthermore, decreasing carrying capacity in OSP calculations when habitat has been degraded by humans is regarded by Gerrodette and DeMaster (1990) as contrary to the spirit of the MMPA. Nevertheless, using historical carrying capacity as a standard may be unreasonable or even unachievable (Marsh et al., 2005). Clearly, in directionally changing environments, carrying capacities may be transient and not reflective of past or contemporary ecosystem conditions.

6. Potential Biological Removal (PBR) approach to marine mammal management

In 1994, National Marine Fisheries Service made a significant departure from the exclusive use of OSP after Congress authorized the potential biological removal (PBR) concept as an MMPA amendment (Wade, 1998). The PBR approach provides an additional management tool that is designed for those species where anthropogenic mortality, such as the incidental take in fisheries, is assumed to be the primary population threat (Taylor et al., 2000, 2007). PBR is:

> …the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population (MMPA§3(20))

The PBR concept originated in proposals submitted by National Marine Fisheries Service, Marine Mammal Commission, fishing groups and environmental organizations seeking to: (1) explicitly consider uncertainty in management, (2) base management on parameters that could be estimated, and (3) provide incentives to gather better data (Taylor et al., 2000). The last objective sets in motion management path-dependence. If managers seek better data to assess stocks, more resources are shifted in the organizational budget to accommodate that goal. Thus primacy of population assessment becomes institutionalized over other potential management goals, such as habitat.

PBR, by definition, relies on OSP for context, although PBR does not resolve what OSP should be for a particular species. Practically, PBR takes a precautionary approach that legally limits direct anthropogenic take of marine mammals to levels that support the minimum estimated population maintaining at least half a population's carrying capacity in a given environment. However, even a conservative focus on direct anthropogenic mortality negates other sources of mortality such as those that result from prey depletion, ecosystem changes, predation, habitat degradation, and disease. Although PBR has proven to be an effective tool under some circumstances (where direct anthropogenic mortality of marine mammals is a primary concern), it does not in itself foster a precautionary ecosystem-based approach, deferring ecosystem-oriented factors (that were implicit to the primary objective of the

MMPA and to the definition of PBR through the context of OSP) to post-depletion attention. The challenges of the OSP approach, where non-direct anthropogenic factors are impacting a marine mammal population, are still problematic for the PBR approach. Pacific walrus illustrate this issue well.

6.1. PBR as a subsistence management tool

PBR establishes a maximum annual removal limit for specific stocks, focusing management solutions under the MMPA on take reduction. Thus, for species with a subsistence harvest, PBR became the default for assessing appropriate harvest levels. The Alaska Native harvest of Pacific walrus was recently regarded as reasonable by U.S. Fish and Wildlife Service (Ray and McCormick-Ray, 2004), and until recently was thought to be the primary *known* source of walrus mortality. Past estimates of natural mortality were 1.5% annually (Fay et al., 1997), which based on a historical population estimate of approximately 250,000 walrus, represents about 3750 walrus, about half the range-wide harvests of 6000–9000 walrus in the mid 1980s (Fay et al., 1997). Current range-wide reported harvests have halved to 2400–4700 walrus since the 1990s (Garlich-Miller et al., 2006). In contrast, large-scale environmental changes are expected to increase natural mortality. Recent mortality of walrus on haulouts in northern Chukotka during the extreme ice retreat of 2007 suggests that 3000–4000 walruses died; mostly young animals.[2] Non-harvest mortality (not implicit in PBR) could now equal or exceed direct removals by native hunters (see similar arguments for whales in Burns, 2001).

6.2. The gap in management for Pacific walrus

Although the PBR scheme regards non-anthropogenic factors as less significant than direct human-caused mortality of marine mammals (Taylor et al., 2000), many of these factors are indirectly related to anthropogenic environmental change. For example, climate changes have an anthropogenic component (ACIA, 2005), but because they occur globally, are difficult to attribute to a specific human group that the MMPA can manage. Furthermore, some marine mammal species continue to decline for reasons apparently separate from direct human-caused mortality (e.g., western stock of Steller sea lion, several harbor seal stocks, southwest stock of sea otter, and the Hawaiian monk seal). For this latter group of species, PBR is an ineffective tool for addressing their decline.

PBR as a subsistence management tool also needs to reliably document the number of animals removed from a population during harvest activities. Recent annual estimates of the landed harvest of Pacific walrus by Native hunters have relied on direct observations from U.S. Fish and Wildlife Service harvest monitoring programs, and more recently on a statutorily-required marking, tagging, and reporting program that registers walrus ivory. Discrepancies between the two U.S. Fish and Wildlife Service programs, and with other household subsistence surveys, confound harvest estimates, as they require correction factors (Garlich-Miller and Burn, 1999). In addition, some walrus are lost during harvesting (termed struck-and-loss), which contribute to the total number of walrus removed from the population by hunting, on an annual basis. Struck-and-loss of walrus was most recently reported in the scientific literature for the period 1952–1972 in Alaska (42%), and the 1960s in Chukotka (40%) by Fay et al. (1994). We expect struck-and-lost rates to have changed in the subsequent 35 years as hunting methods and practices change among communities, and with deteriorating sea ice conditions that hamper securing wounded animals and butchering carcasses.

Effective use of OSP and PBR approaches by managers require data of sufficient resolution, confidence, and frequency to justify effective management action rather than inaction (Taylor et al., 2007). Court rulings have pointed to lack of precision and accuracy of parameters used in marine mammal stock assessments (NOAA, 2004). However, this reinforces the perceived need to define numeric parameters more precisely, rather than focus on other MMPA goals, despite Taylor et al.'s (2007) argument that this is currently unattainable for some species. National Marine Fisheries Service expressed a desire to shift from a stock assessment to ecosystem-based management of marine mammals (which U.S. Fish and Wildlife Service would presumably support), but have insufficient staff to do so, and are lacking key data that would support such a shift (NOAA, 2004). Currently, National Marine Fisheries Service is striving to achieve the basic level of data necessary to comply with mandates of the MMPA and ESA, which again focus on reducing take to support an OSP or PBR approach, while largely avoiding ecosystem-based approaches (NOAA, 2004). The 1994 U.S. Fish and Wildlife Service Walrus Conservation Plan (USFWS, 1994) also recognized the difficulties associated with an OSP approach for walrus:

> OSP for walruses cannot be defined in a statistically rigorous manner since carrying capacity (K) is not known and MNPL can not be calculated with precision. Estimates of four critical values – current population size, annual female harvest rates over the last 150 years, K, and where MNPL occurs relative to K currently are insufficient for precise calculation of OSP range….Regardless of funding levels, precise determination of MNPL relative to K is very unlikely in the foreseeable future…. Despite, or perhaps because of this recognition of difficulty, U.S. Fish and Wildlife Service ranked assessing walrus stock parameters as one of its top priorities in the coming years (USFWS, 1994). Subsequently, in 1999, Deputy Director of the U.S. Fish and Wildlife Service, Marshall Jones continued to prioritize stock assessment parameters, but indicated the need for "development of alternative population indices."[3] Nevertheless, there is still no program in place to address *K* and MNPL within a dynamic ecosystem-based context.

7. Waiting for a crisis in walrus management?

An exclusive focus on population enumeration significantly differs from the MMPA's primary ecosystem-based intent. Under such circumstances, even where alternative scientific evidence indicates that degradation of stocks or their habitats are occurring, managers are left to monitor a species or stock's decline rather than doing something about it. We contend that current management practices for Pacific walrus do not support ecosystem management, the maintenance of Pacific walrus or other pagophilic-based species at OSP (a secondary goal of the MMPA), or promote trust and collaboration with Native communities (a tertiary goal of the MMPA). Consequently, we turn to Ray (2006: 1825) who asks what information is required to reduce uncertainty to a point where "decision makers and the public will accept the conservation practices that are already apparent from knowledge at hand?" Johannes (1998: 245) also suggests that "the key management

[2] Personal communication with Anatoly Kochnev, Chukotka TINRO.

[3] Testimony of Marshall Jones, acting deputy director, U.S. Fish and Wildlife Service before the House Resources Subcommittee on Fisheries Conservation, Wildlife and Oceans, oversight hearing on the implementation of the 1994 Amendments to the Marine Mammal Protection Act. June 29, 1999.

question should not be what data do we need to make sound management decisions, [but rather,] what are the best management decisions to make when such data are unobtainable?"

OSP and PBR provide valuable tools for managing some marine mammals. However, PBR added direct anthropogenic mortality to the definition of OSP, requiring from an ecosystem perspective a more data-intensive parameter that leaves a gap in management for species such as the Pacific walrus. The numeric focus has perpetuated management intransigence associated with debates over methods and means of assessing and statistically analyzing the Pacific walrus population, rather than how desired conservation outcomes can be fostered through more comprehensive attention to other factors known to impact the walrus population's status (Fig. 1).

Several authors (e.g., Harwood and Stokes, 2003; Goodman, 2005; Brandon et al., 2007; Taylor et al., 2007) focus attention on alternative numeric approaches, such as likelihood, information theory, and Bayesian analyses. However, we argue that if ecosystem management seeks to "capture the essential dynamics with minimum increase of complexity" (Garcia and Charles, 2007: 585), then even a few statistically valid numbers collected in isolation from their ecosystem context may complicate relatively clear situations. Best available numbers (or the best available technology to collect those numbers) are not necessarily consistent with the best available science mandate of the MMPA. Our focus therefore is toward alternative methods that augment OSP and PBR approaches.

8. A fresh approach

In theory, ecosystem-based approaches seek to account for knowledge and uncertainty about biotic and abiotic components, interactions within ecosystems, and apply management actions at scales that are meaningful to ecological functions (e.g., Christensen et al., 1996; Garcia and Cochrane, 2005; Pikitch et al., 2004; Pitcher, 2008). Link (2002) describes a continuum (rather than a dichotomy) that runs from single-species approaches to full ecosystem approaches. The greater the focus on single-species management (seeking to maximize multiple but separate objectives), the fewer ecosystem factors can be incorporated (that explicitly consider trade-offs among objectives). An ecosystem approach fosters consideration of how to resolve and allocate trade-offs among stakeholders (Mangel et al., 1996; Rosenberg and McLeod, 2005; Garcia and Charles, 2007). Such approaches are expected to avoid the reactive and "frenetic, lawsuit-driven response to crisis" that currently exists (Reynolds, 2005: 2). From a scientific perspective, the wider purview of an ecosystem-based approach to Pacific walrus management requires an interdisciplinary focus that includes among other things, a complex array of anthropocentric factors such as economics, cultural values, and social conditions across scales and cultures (Mangel et al., 1996; Berkes et al., 2007).

A promising line of interdisciplinary literature with respect to managing the complexities of marine resource systems has been the concept of governance, which includes the broader social contexts that are required for effective ecosystem-based management (Folke et al., 2005; Berkes et al., 2007). Governance is a "set of regulatory processes, mechanisms and organizations through which political actors influence environmental actions and outcomes" (Lemos and Agrawal, 2006: 298). Mangel et al. (1996) in their review of principles for conserving wild living resources, highlight the need to incorporate multiple stakeholders in two of their seven principles. Accordingly, Co-management structures, encouraged under Section 119 of the MMPA, explicitly seek meaningful and equitable inclusion of Alaska Natives in resource management. Nevertheless, governance may be challenged by two "catch-22" conditions (Holt, 2005): first, changes in governance are most likely under conditions of controversy such as a depletion (Folke et al., 2005); and second, a legal finding of depletion can lead to greater top-down government control, which can inhibit local participation in conservation efforts.

9. Potential elements of ecosystem-based management for Pacific walrus

Our primary suggestion is that we know enough to adaptively govern Pacific walrus in a manner that minimizes anthropogenic degradation of the walrus population, and if possible, increases their resilience to ongoing changes. To frame this suggestion, we expect that ecosystem-based governance of marine mammals will have to consider factors similar to fisheries management (Pikitch et al., 2004). These include: (1) avoiding habitat degradation; (2) minimizing risk of irreversible anthropogenic change to natural assemblages of species and ecosystem processes; (3) acquiring and perpetuating long-term socioeconomic benefits without compromising ecosystems; (4) generating knowledge about ecosystem

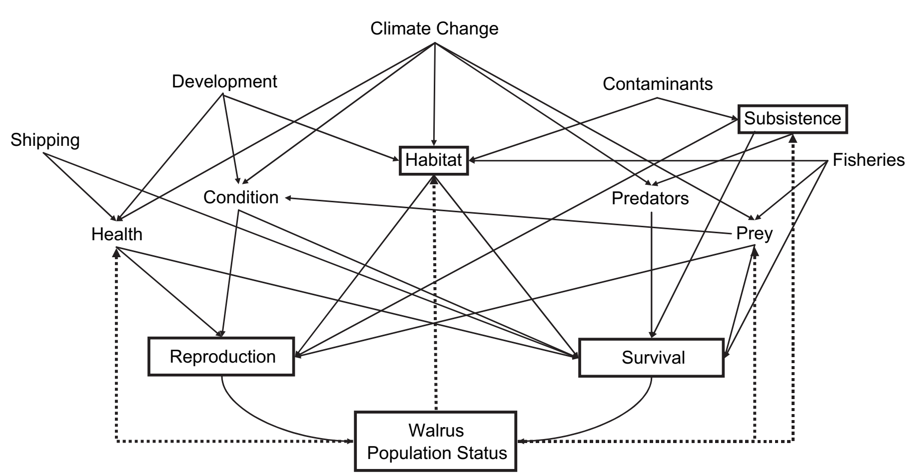

Fig. 1. Conceptual Pacific walrus social-ecological system, locating walrus population status within the context of a suite of biological, ecological, and anthropogenic factors. We have not shown social factors and other resources that affect motivations of subsistence hunters, but recognize their importance. Boxed terms represent key concepts within the text. Dotted arrows represent feedbacks from the walrus population to the social-ecological system as a whole. Graphic adapted from an original provided by Dr. T. Ragen, U.S. Marine Mammal Commission.

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processes; and (5) adopting robust and precautionary management measures based on the best available information. We differentiate the logic of this precautionary ecosystem-based management approach from one that demands unattainable data. Data as yet unattained may provide future opportunities to assess and improve management, but in our view, should not trump the precautionary implementation of interventions based on existing knowledge.

9.1. Avoiding habitat degradation

Walrus, predominantly males, are protected at the Round Island Walrus Sanctuary in Bristol Bay and are annually counted there. Yet, there is a dearth of information about how walruses use haulouts elsewhere in the State of Alaska and Chukotka, where both males and females haul out in large numbers. Proposals made in Alaska during the early 1900s for protecting walrus habitat on the northwest Alaska coastline never came to fruition (Bernard, 1923). Therefore in 2007, when female walrus hauled out in the thousands along this northwest Alaskan coast, due to a complete absence of sea ice over the Chukchi sea shelf, they had little protection from disturbance or hunting. Likewise these terrestrial haulouts are not currently protected from future degradation.

Rapid changes in economic and social conditions throughout the Arctic and sub-Arctic regions put pressure on current and potential walrus habitat. Companies involved in transportation, commercial fishing, and hydrocarbon exploration/extraction are increasingly interested in the northern Bering and Chukchi seas, the ocean floor, and adjacent coastlines. If our summer scenario for female walrus and their calves manifests (they will routinely use land when the ice retreats far enough past the shelf break), protections or contingencies for walrus habitat on parts of Alaska's coast would provide a proactive approach to avoiding critical habitat degradation. This could be accomplished through protected areas along coastlines that are likely to be used by walrus. Decision rules may also be developed based on the availability and areal extent of ice over shelf areas in a particular year.

9.2. Minimize the risk of irreversible change within ecosystems

Current impacts of global climate change on sea ice in the Beringian region are expected to be long-term, with a predicted ice-free summer by 2037 (Wang and Overland, 2009). Loss of summer sea ice over the continental shelf represents an irreversible change at the scale of current management needs. However, we expect walrus can continue to be supported as functioning elements of the arctic and subarctic ecosystems by minimizing the risk of compounding sea ice loss with other ecosystem changes. Such approaches could seek to proactively limit impacts to known benthic feeding habitat, by minimizing industrial activity or fishing in those areas.

9.3. Obtain and maintain long-term socioeconomic benefits without compromising the ecosystem

Pacific walrus are not legally considered as depleted so there have been no subsistence harvest limits under the MMPA in Alaska, except during a short return of management to the State of Alaska during the 1970s. Since 1979, regulations only mandate walrus are harvested in a "non-wasteful" manner, and that products can only be used for specific purposes (Robards and Joly, 2008). Little flexibility exists for Native communities to explore better ways of utilizing fewer walrus to fit contemporary needs, even where efforts might reduce overall harvests (Robards and Joly, 2008).

Co-management as envisioned in the Section 119 amendment to the MMPA is both a means to support subsistence activities, while also encouraging conservation of the walrus population and habitat[4]. Management efforts might look to ways to support subsistence through experimentation on how to increase the value of a smaller harvest. Alternatively, managers might seek to conserve the reproductive potential of the walrus population through encouraging a reduced harvest of females and reducing struck-and-loss (Burns, 1965; Robards and Joly, 2008).

Although not providing a decision rule for managers, an empowered Native community may also act as an advocate of MMPA goals in remote regions, which is clearly represented in the experience of the Alaska Eskimo Whaling Commission. Whalers currently collaborate with a diverse range of stakeholders to ensure that development is done in a manner that respects the needs of hunters (e.g., timing), migrating whales (e.g., spatial restrictions), and the developers who bring significant economic benefits to many communities. Communities may also focus their advocacy broadly across agency jurisdictions not easily accomplished by the responsible federal agency alone.

9.4. Generate knowledge of ecosystem processes

Considering that Taylor et al. (2007) do not expect that a population depletion or increase can be detected on the basis of current survey techniques for pinnipeds counted on ice, that both OSP and PBR require multiple counts, and that K is particularly nebulous under current conditions, repeated population surveys can currently only be part of a continued and expensive endeavor that provides little understanding of ecosystem processes. In contrast, a suite of ecological indicators could be used to describe the interaction between animals and their habitat, while still providing a basis for management decisions to attain specific predefined goals (Eberhardt, 1977; Lentfer, 1988; Fay et al., 1990; Dale and Beyeler, 2001; Morellet et al., 2007). A suite of indicators sensitive to changes in key variables could be used to assess responses of walrus and their habitat to changes in population abundance and harvest pressure, as well as how walrus are affected by changes in the range and quality of their prey or habitat. Demographic indices have been used to address walrus population status elsewhere (Chivers, 1999), but we recommend augmenting these with a suite of indicators that are more fully representative of the structure, function, and composition of the Pacific walrus ecosystem (Fay et al., 1990).

From a biological perspective, population demographics, condition, reproductive status, distribution, range, and behavior (e.g., foraging times) are all potential indices. From an ecological perspective, prey composition and abundance, walrus population health and distribution, as well as sea ice conditions may all be practical indices. Methods exist to accomplish biological goals using sophisticated tags attached to free-ranging animals that are deployed without having to capture walrus (Jay et al., 2006). Physiological and histological samples, as well as dietary assessments, can also be obtained from subsistence harvested animals throughout their hunted range, where effective management relationships exist with Alaska Native communities (see Wikelski and Cooke, 2006 for a review of physiological applications to species conservation).

We emphasize the need to frame monitoring within models that allow for hypotheses to be tested. For example, to adaptively learn how management interventions achieve specific goals, actions should be tied to achievable research objectives. Management

[4] We acknowledge that many scholars of co-management do not see co-management as a panacea due to issues such as unequal power sharing and lack of mutual understanding about partner goals.

interventions prior to population depletion may also fundamentally differ from those required within a population recovery plan, necessitating that co-managers fully consider what goals are desired (Nichols and Williams, 2006).

9.5. Use robust and precautionary management measures that favor the ecosystem

The ability of scientists to conclusively establish causal relationships between management actions and population level processes may be limited. Consequently, Pikitch et al. (2004) recommend incorporating natural history parameters when developing precautionary management policies, such as we have suggested for protecting terrestrial habitat for walrus. However, some natural history changes, such as distribution, productivity, health, and behavior, may be subtle and difficult to detect by scientists alone. Nevertheless, evidence supports a meaningful role of hunters to help provide early and nuanced observations of marine mammal status and behavior (e.g., Huntington, 2000; Garcia and Charles, 2007; Moore, 2005; Berkes et al., 2007). These immediate and first-hand observations can be dovetailed with other scientific observations (e.g., satellite imagery of sea ice, tracking of animal movements, or physiological parameters), resulting in a more mutual understanding of a population's status and trend. Subsequently, using a deliberative process to establish decision rules among stakeholders, based on observed changes in natural history parameters (e.g., spring cow/calf ratios or fall mortality estimates) can provide a mutually legitimate and potentially robust governance approach.

Although analyzing costs is beyond the scope of this manuscript, we expect that preventing populations of marine mammals from becoming depleted (legally and biologically), based on preemptive management actions is fiscally beneficial (among other ecological and moral benefits). Divisive experiences among stakeholders elsewhere led to costly crisis management of Cook Inlet beluga (Moore and DeMaster, 2000) and Steller sea lion (Mansfield and Haas, 2006). Furthermore, an ecosystem approach offers opportunities for greater integration of studies on species groups (for example ice seals in conjunction with walrus), perhaps providing economies of scale in addressing specific common issues for those species not well addressed by OSP or PBR approaches.

10. Conclusion

We have argued that the MMPA's primary mandate is ecosystem-based. However, it has been assumed that an effective management strategy will naturally flow from repetitive population counts. For species such as walrus, which are difficult or currently impractical to accurately count, population assessments are a costly and largely ineffective management tool. This is because the approach does not provide a decision rule responsive to biological, ecological, or anthropogenic change. By making rigorous population estimates a primary goal, biologists and managers have changed the focus of discussions toward statistical methods and numbers, while neglecting the important and necessary discussions about values associated with different ecosystem properties and functions at different scales.

The most recent population survey of Pacific walruses, although laudable for its technological innovation and ingenuity, has little ecological relevance to current management challenges. We do not dispute the utility of population-based approaches to wildlife managers, or on the value that the PBR approach made to addressing concerns over the take of marine mammals in fisheries. However, where numbers are not practically attainable (for either fiscal or practical reasons), we think that use of *best available, but unreliable* numbers in lieu of other inputs that would urge precautionary management actions is unlikely to foster the MMPA's goals. Even with an accurate estimate of the walrus population, and if harvest size and struck-and-loss could be fully and accurately determined, the challenge of managing walrus as a functioning element of the rapidly changing Beringian ecosystem would remain unresolved.

The MMPA calls for management to use the best available scientific evidence toward maintaining the role of marine mammals in healthy ecosystems, maintaining an optimum sustainable population of particular species, and for respecting the rights of Native hunters. But the best scientific evidence available today is not the same as envisioned when the MMPA was first drafted. Evidence today crosses a range of disciplines, cultures, and scales that point toward different approaches to managing marine mammals. Like proponents of ecosystem-based approaches in fisheries with poor or non-existent data, we propose a move away from the exclusive reliance on just one or two numerical parameters – such as population size (akin to spawning-stock biomass), and PBR (akin to fishing mortality rate).

Folke et al. (2005) in their review of natural resource governance conclude that it is "not detailed knowledge of the parts of the system but improved understanding of the dynamics of the whole system" that managers should strive for. Accordingly, we suggest using a suite of indicators. The challenge requires improving knowledge about a marine mammal's dynamic biology (e.g., demographics, age-specific survival, reproductive rates, age at first reproduction), ecology (e.g., carrying capacity, density dependence, prey quality and availability, habitat availability), anthropogenic mortality (e.g., demographic bias in harvest, relation of actual to estimated harvests, incidental take), and other factors shaping their ecosystems like increased development and contaminants.

To monitor and respond to changes in marine mammal ecosystems, an amendment to the MMPA that recognizes the gap in management for species not easily counted, and thus not well covered by the OSP or PBR scheme is needed. We have suggested accomplishing this by incorporating scientific and other natural history criteria that depend less on enumerating population size, and more on evaluating a suite of environmental and biological factors. Avoiding post-crisis assessment and management of walrus and their interactions with humans provides opportunities for governance as envisioned in the MMPA. Such a framework would bring together all stakeholders with diverse interests and needs, over multiple scales (both spatial and temporal), around the common goal of ensuring a continued and pluralistic human-walrus relationship.

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