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Evaluating the efficacy of environmental legislation: A case study from the US marine mammal Take Reduction Planning process

Sara L. McDonald [a,b,*], Rebecca L. Lewison [c], Andrew J. Read [d]

[a] Duke University, Division of Marine Science and Conservation, Nicholas School of the Environment, Durham, NC 27708, United States
[b] Monterey Bay Aquarium, Seafood Watch, 99 Pacific Street, Suite 100 A, Monterey, CA 93940, United States
[c] Biology Department, San Diego State University, San Diego, CA 92182, United States
[d] Duke University, Division of Marine Science and Conservation, Nicholas School of the Environment, Beaufort, NC 28516, United States

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ABSTRACT

There have been limited efforts to evaluate the efficacy of environmental management programs, in part because environmental legislation often lacks objective, quantifiable criteria to use in such assessments. Here we evaluate the ecological outcomes of an important element of one well-known environmental statute, the US Marine Mammal Protection Act (MMPA), using take reduction planning as a case study. Take reduction planning is mandated by the MMPA as a means to reduce mortality of marine mammals in US fisheries to below statutory thresholds. We used data from formal Stock Assessment Reports to assess and rank the success of five Take Reduction Plans (Harbor Porpoise, Bottlenose Dolphin, Atlantic Large Whale, Pelagic Longline, and Pacific Offshore Cetacean) in mitigating the bycatch of 15 marine mammal stocks. In general, Take Reduction Plans have had an uneven record of meeting their statutory requirements. Successful plans were characterized by straightforward regulations and high rates of compliance. Unsuccessful plans covered marine mammal–fisheries interactions in the northeastern US, had low compliance with complex regulations and sometimes focused on very small stocks. This study emphasizes the importance of requiring legally mandated, quantitative metrics and long-term monitoring programs to evaluate the efficacy of a well-known element of an established environmental management program.

1. Introduction

Government institutions have attempted to address conflicts between the conservation and allocation of natural resources, mitigate activities that harm human and environmental health, and conserve wildlife and ecosystems by enacting and implementing environmental legislation. The US alone has passed 20 major federal environmental statutes (http://www.nrdc.org/reference/laws.asp), and is a signatory or party to 162 international environmental agreements (http://sedac.ciesin.org/entri/country.jsp). It is clear that some of these laws and agreements have been successful in mitigating the effects of harmful activities and helped to conserve natural resources but, for several reasons, there have been few attempts to formally evaluate the efficacy of such environmental initiatives. First, a monitoring program is required prior to establishing any environmental intervention to provide a baseline against which to measure impacts (Brogden, 2003;

* Correspondence to: Monterey Bay Aquarium, 886 Cannery Row, Monterey, CA 93940, United States. Tel.: +1 252 732 5846.
E-mail addresses: sara.mcdonald@duke.edu, smcdonald@mbayaq.org (S.L. McDonald).

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Koontz and Thomas, 2006; Newig, 2007; Pullin and Knight, 2009). Often such baseline data do not exist, or if they do, are not readily accessible. Second, legislation must clearly define measurable objectives that can be used in future evaluation (Newig, 2007; Dukes, 2005; Weiss, 1972). Third, to account for environmental variability, monitoring must occur over long time scales, which can be expensive (Brogden, 2003; Koontz and Thomas, 2006). Finally, ecosystem complexity and the possibility of multiple, simultaneous interventions make it difficult to attribute a change in environmental conditions to environmental variability or a particular intervention (Brogden, 2003; Koontz and Thomas, 2006; Newig, 2007).

Without a formal evaluation of the efficacy of environmental interventions, however, practitioners may not only waste time and resources (in the case of ineffective measures), but the unintended consequences of such interventions may cause more harm than good (Koontz and Thomas, 2006; Pullin and Knight, 2009; Weiss, 1972). In addition, feedback regarding ecological outcomes of environmental management is the cornerstone of adaptive management. Despite these compelling reasons, ecological evaluation of conservation management remains in the very early stages (Pullin and Knight, 2009).

With regard to conservation, national and international laws and treaties seldom specify objective, measurable criteria against which we may evaluate the efficacy of protective measures. For example the European Union's Habitats Directive, the principle legislation for wildlife conservation throughout the EU (together with the Birds Directive), lists in its Annexes the protective status of species (endangered, vulnerable, rare, or endemic). It does not, however, specify any objective criteria used to classify these species or how a species' classification may be changed once it is listed (Cardoso, 2012). Similarly, the US Endangered Species Act (ESA, 16 U.S.C.1531 *et seq.*) includes five qualitative benchmarks for listing a species as endangered ("in danger of extinction", 16. U.S.C. 1532(6)) or threatened ("likely to become endangered", 16. U.S.C. 1532(20)), but does not stipulate any quantitative measures (*e.g.,* probability of extinction in a certain number of years) to assign listing status. Although the ESA requires recovery plans to incorporate "objective, measurable criteria" for removal from the list or a change in classification (16 U.S.C. 1533(f)(1)(B)(ii)), many species lack recovery plans or the specificity of the criteria for down-listing or de-listing vary considerably within and among species (Gregory et al., 2013; Gerber, 1998; Gerber and DeMaster, 1999; Gerber and Hatch, 2002). Thus it is difficult to evaluate the effectiveness of these recovery plans, or the conservation actions contained within them.

In contrast, the International Union for the Conservation of Nature (IUCN) employs specific, quantitative criteria to evaluate the status of species on its Red List. The Canadian Species at Risk Act and the Australian Environment Protection and Biodiversity Conservation Act 1999 draw on these same, measurable criteria (Mooers et al., 2007; TSSC, 0000; COSEWIC, 0000). Unfortunately, some of the criteria are not easily applicable to some taxa. For example, it is especially difficult to measure habitat fragmentation, the extent of occurrence, and areas of occupancy of long-lived marine animals that travel over great distances (Gerber, 1998; Gerber and DeMaster, 1999; Gerber et al., 2000).

1.1. Case study

An important section of the US Marine Mammal Protection Act of 1972 (MMPA, 16 U.S.C. 1361 *et seq.*) provides a unique opportunity to evaluate its efficacy. It contains quantifiable metrics that aim to reduce the incidental mortality of marine mammals in fisheries, a process known as bycatch. Marine mammal populations are vulnerable to bycatch mortality because of their life history characteristics and demography (Lewison et al., 2004; Read, 2008; Read et al., 2006; Soykan et al., 2008). These species exhibit long lifespans, late ages of maturity, low fecundity, and high survival rates (Heppell et al., 2000, 2005) and, consequently, are vulnerable to even moderate rates of mortality (Lewison et al., 2004; Heppell et al., 2000, 2005). High bycatch rates can cause marine mammal populations to decline over very short timeframes (Lewison et al., 2004; Taylor et al., 2000; Wade, 1998).

For small populations of marine mammals, bycatch can be particularly pernicious (Lewison et al., 2004; Read, 2008). Under these circumstances, even rare bycatch events can adversely affect population viability, especially if the mortality includes reproductively active females (Read and Wade, 2000). In a large fishery that interacts with a small population of marine mammals, each fishing vessel's contact with individual animals will be extremely rare, so protective measures can be both expensive and politically unpopular (Read, 2008).

Here we present a case study in which we evaluate the ecological outcomes of a process implemented to reduce marine mammal bycatch in US waters through the development of Take Reduction Plans. Geijer and Read (2013) described an overall decline in marine mammal bycatch in the US since the implementation of these plans, suggesting that they have been generally successful in reducing the scale of bycatch in the US. This evaluation builds on the analysis of Geijer and Read (2013) by comparing ecological outcomes following the implementation of these plans to the criteria mandated under the MMPA. We create a simple, objective method to evaluate the ecological efficacy of several plans by comparing their outcomes to the mandates contained in the statute. By examining the history and attributes of each plan, we also propose a suite of factors that may contribute to their ecological outcomes.

2. Methods

2.1. Theory—case study background

In the US the National Marine Fisheries Service (Service) is charged with protecting cetaceans and most species of pinnipeds by implementing the MMPA. A unique feature of the MMPA is a formula for estimating the maximum allowable number of animals that can be removed from each stock by human-related causes without causing depletion or impeding recovery, a parameter known as the Potential Biological Removal (PBR). PBR is calculated as the product of the minimum estimate of the population size (N_{min}), one-half of the maximum potential population growth rate (R_{max}), and a recovery factor (F_r), which considers the status of a population and addresses uncertainty caused by biases in mortality, abundance, and R_{max}. If bycatch of a stock exceeds PBR, the stock is deemed "strategic" (16 U.S.C. 1361(19)). The "strategic" designation includes stocks listed as endangered or threatened under the Endangered Species Act, depleted under the MMPA, or that are declining and likely to become endangered or threatened (16 U.S.C. 1362 (19)).

The MMPA also directs the Service to compile a list of commercial fisheries each year based on the frequency and severity of their interactions with marine mammals: Category I (frequent incidental mortality or serious injury); Category II (occasional); and Category III (remote likelihood). The Service prepares Stock Assessment Reports for each stock that are required to contain information on population structure, abundance, trends, and the extent of human-caused mortality (16 U.S.C. 1387(d)). Regional scientific review groups provide peer-review of the Stock Assessment Reports and make recommendations about research priorities (Taylor et al., 2000; Read and Wade, 2000). If a "strategic" stock interacts with a Category I or II fishery, the Service must form a multi-stakeholder group of fishermen, researchers, environmentalists, and state and federal managers, known as a Take Reduction Team (TRT, 16 U.S.C. 1387(f)(6)(A)(i)).

Each TRT is required to create a consensus-based suite of regulations called a Take Reduction Plan (16 U.S.C. 1387(f)(7)(A)(ii)). The immediate goal of each plan is to reduce bycatch to below PBR within the first six months of implementation (16 U.S.C. 1387(f)(2)). The long-term goal is to reduce bycatch to levels approaching a zero mortality and serious injury rate, termed a "zero mortality rate goal" (ZMRG), which has been defined as 10% of PBR (50 CFR Section 229). If the team does not reach consensus, the Service is required to draft a plan that incorporates any consensus-based elements (16 U.S.C. 1387(f)(7)(A)(ii)).

2.2. Data

Seven Take Reduction Teams (teams) are currently active: Atlantic Large Whale; Atlantic Trawl Gear; Bottlenose Dolphin; False Killer Whale; Harbor Porpoise; Pacific Offshore Cetaceans; and Pelagic Longline (http://www.nmfs.noaa.gov/pr/interactions/trt/teams.htm#gmhp). One team (Atlantic Offshore Cetaceans)disbanded because the fisheries it addressed were closed by regulation. We extracted data from marine mammal Stock Assessment Reports (SARs) from 1989 to 2013 (http://www.nmfs.noaa.gov/pr/sars/species.htm) for 15 stocks that are managed under Take Reduction Plans, and compiled information on annual bycatch, PBR, ZMRG, and abundance. The data reported in SARs are two years behind their published date, so data covered by the reports analyzed herein were from 1987 to 2011. The methods we used to collect and analyze these data are described in detail by Geijer and Read (2013). We extracted annual marine mammal serious injury and mortality estimates from the section in the SARs entitled "Annual Human Caused Mortality". When no mortality estimate was available, we used data from other sections of the SARs including observed mortality and serious injuries (see Geijer and Read, 2013 for a more detailed description).

2.3. Calculation—established plans

We used two metrics to estimate the efficacy of each plan relative to MMPA goals and to each other. The first metric was a simple determination of whether a plan was successful irrespective of statutory deadlines, *i.e.*, were mortality levels reduced and maintained below PBR or ZMRG. We chose not to use the statutory deadlines laid out in the MMPA because they have been characterized as unrealistic and as a result, several Take Reduction plans experienced delays throughout the process (GAO, 2008; RESOLVE, 1999; Young, 2001). Moreover, ecosystem unpredictability and inter-annual variation in fishing effort may cause bycatch to fluctuate annually and, although bycatch might drop below PBR within six months (or ZMRG in five years), it could exceed PBR or ZMRG in subsequent years (GAO, 2008). Thus, it is more relevant to ask whether bycatch was maintained at levels below PBR or ZMRG once achieved than to determine whether statutory deadlines were met. Metric 1 is thus a simple categorical measure of whether bycatch was reduced and maintained below PBR or ZMRG as follows:

-1 = Bycatch $>$ PBR
0 = Bycatch $\leq$ PBR and $>$ ZMRG, and remained there through 2011
1 = Bycatch $\leq$ ZMRG, and remained there through 2011.

Stocks where bycatch fluctuated above and below ZMRG were assigned a score of 0, while stocks that fluctuated above and below PBR were assigned a -1. Ranks of all stocks managed under a single plan were averaged to determine a mean rank. We excluded stocks that were below ZMRG prior to implementing a plan (Table 1).

Metric 2 was the mean of the annual difference in bycatch from PBR divided by PBR itself.

$$\text{Metric 2} = \text{mean}[(\text{PBR-Bycatch})/\text{PBR}]$$

such that: 1.00 implies No bycatch

0.90–0.99 implies $\leq$ ZMRG (because ZMRG = 10% of PBR)
0.00–0.89 implies $>$ ZMRG and $\leq$ PBR
$<$0.00 implies $>$ PBR.

Table 1
Marine mammal Take Reduction Teams and stocks analyzed herein.

Team	Stock
ALWTRT	Western North Atlantic right whale
	Gulf of Maine humpback whale
	Western North Atlantic fin whale
	Western NorthAtlantic minke whale[a]
BDTRT	Western North Atlantic Northern Migratory coastal[b]
	Western North Atlantic Southern Migratory coastal[b]
	Northern North Carolina Esturarine (NNCES)
	Southern North Carolina Estuarine (SNCES)
	Northern South Carolina Estuarine (NSCES)[c]
	Charleston Estuarine (CES)[c]
	Western North Atlantic South Carolina/Georgia[c]
	Northern Georgia/Southern South Carolina Estuarine (NGSSCES)[c]
	Southern Georgia Estuarine Stock (SGES)[c]
	Western North Atlantic Northern Florida Coast[c]
	Western North Atlantic Central Florida coast[c]
	Jacksonville Estuarine (JES)[c]
	Indian River Lagoon Estuarine (IRL)[c]
	Biscayne Bay[c]
HPTRT	Gulf of Maine/Bay of Fundy Harbor Porpoise
POCTRT	California/Oregon/Washington Baird's beaked whale[a]
	California/Oregon/Washington Cuvier's beaked whale[a]
	California/Oregon/Washington short-finned pilot whale
	California/Oregon/Washington sperm whale
	California/Oregon/Washington humpback whale
	California/Oregon/Washington pygmy sperm whale[a]
	California/Oregon/Washington short-beaked common dolphin[a]
	California/Oregon/Washington long-beaked common dolphin[b]
	California/Oregon/Washington northern right whale dolphin[b]
PLTRT	Western North Atlantic short- and long-finned pilot whales
	Western North Atlantic Risso's dolphin

[a] Not included in analyses because bycatch was $<$ ZMRG prior to the year of plan implementation and remained there post-implementation.
[b] Stock is included in analyses because although not strategic (bycatch $<$ PBR), bycatch was $>$ZMRG prior to plan implementation.
[c] Not included in analyses because of insufficient data.

Ranks of all stocks managed under a single plan were averaged to determine mean rank and, as above, we excluded stocks that were below ZMRG prior to implementation of a plan (Table 1).

For both metrics, higher ranks indicated greater success. We calculated ranks for the following plans: Harbor Porpoise, Atlantic Large Whale, Pelagic Longline, and some stocks managed under the Bottlenose Dolphin and Pacific Offshore Cetaceans plans. Unfortunately, we were unable to rank several stocks and teams. For example, bycatch levels for all stocks considered by the Atlantic Trawl Gear team are below PBR, none of the stocks are strategic, nor do they interact with any Category I fisheries. This team was created as the result of a lawsuit brought by environmental groups (Stipulated Settlement Agreement, 2003). This team created a Take Reduction Strategy rather than a Plan, which is restricted to voluntary measures involving education, outreach, and research (National Marine Fisheries Service, 2008, 2012). Secondly, the stocks considered by the Bottlenose Dolphin Team were redefined in 2010 and data were available for only a few of the newly defined stocks. The Northern and Southern Coastal Migratory Stocks of bottlenose dolphins are not strategic but were included in the analyses because bycatch exceeded ZMRG when the plan was created. Moreover, these stocks are susceptible to periodic, large-scale, unusual mortality events that can decrease abundance and lower PBR. In addition, the Stock Assessment Reports for the these stocks described bycatch levels in terms of minimum and maximum potential values due to uncertainty regarding the stock identity of individual dolphins killed in gillnet fisheries. Thus, we conducted separate rankings with these minimum and maximum values. The primary fisheries considered by the Atlantic Offshore Cetaceans Team have been closed, making the plan irrelevant. Finally, the False Killer Whale plan had not been implemented long enough to calculate ranks for its stocks.

2.4. Calculation—covariates

We gathered information about each team that we hypothesized might influence the ecological outcome for each stock. These included the following (Table 2): team size (members plus alternates); team age (months); PBR in 2011 for each stock (averaged for each covered by a plan); the number of amendments to each plan; and geographic region of the team/stocks.

Table 2
Covariates of Take Reduction Teams and marine mammals stocks that may contribute to their ecological success.

Take Reduction Team and Affiliated marine mammal stock	PBR in 2011	BC/PBR	Team size (number of members + alternates)	Team Age (Years)	Number of Take Reduction Plan Amendments	US Geographic Region
Atlantic Large Whale	**3.1** (**average of team stocks**)	**3.0**	**82**	**18.4**	**28**	**Northeast**
Western North Atlantic Right Whale	0.9	5.6				
Gulf of Maine Humpback Whale	2.7	3.1				
Western North Atlantic Fin Whale	5.6	0.4				
Bottlenose Dolphin	**39.6** (**average of team stocks**)	**0.03–0.27**	**60**	**13.1**	**2**	**Southeast**
Western North Atlantic, Coastal, Northern Migratory[a]	86	0–0.01				
Western North Atlantic, Coastal, Southern Migratory[a]	63	0–0.06				
Northern North Carolina Estuarine System	7.9	0.13–0.38				
Southern North Carolina Estuarine System	1.6	0–0.63				
Harbor Porpoise	**625**	**0.35**	**42**	**18.9**	**2**	**Northeast**
Gulf of Maine-Bay of Fundy Harbor Porpoise						
Pacific Offshore Cetacean	**45.8** (**average of team stocks**)	**2.26**	**17**	**18.9**	**2**	**West**
California/Oregon/Washington Sperm Whale	1.5	10.7				
California/Oregon/Washington Short-finned Pilot Whale	4.6	0				
California/Oregon/Washington Humpback Whale	11	0.4				
California/Oregon/Washington Northern Right Whale Dolphin	48	0.15				
California/Oregon/Washington Long-beaked Common Dolphin	164	0.04				
Pelagic Longline	**143** (**average of team stocks**)	**1.39**	**26**	**9.6**	**0**	**Southeast**
Western North Atlantic Risso's Dolphin	126	1.88				
Western North Atlantic Long- and Short-finned Pilot Whale	159	0.89				

[a] Stocks not strategic.

Team sizes were used as a proxy for the number of fisheries involved in a Take Reduction Plan and were similar relative to each other with or without the inclusion of alternates. We chose to include alternates because this research was part of a broader study in which alternates were an important part of the dataset (McDonald and Rigling Gallagher, 2015b; McDonald and Rigling-Gallagher, 2015a). We chose to look at groups size because as group size increases, trust among participants in a negotiation and the likelihood of achieving consensus decreases, participant perceptions of outcome efficiency and equity also decreases, as well as the likelihood of compliance with a consensus-based agreement (Dukes, 2005; Floyd et al., 1996; Leach, 2006; Holmes and Scoones, 2000; Leach and Sabatier, 2005; Sipe, 1998). Regarding team age, we hypothesized that older teams have built trust and social capital and thus have more buy-in and compliance with the plan. We chose to look at PBR because it is much more challenging to reduce bycatch below a PBR that is already extremely low (less than five) than one that is very high. This could affect the success of a plan. The number of times a plan has been amended could make it more difficult to implement and enforce, and geographic region could affect myriad ecological variables as well as socio-economic and cultural norms that might influence fishing effort or compliance with plan requirements. To determine whether any covariates significantly affected these results, we conducted a multiple regression analysis of the ecological ranks (metrics 1 and 2) on the independent variables of PBR, US geographic region, and Take Reduction Team size and age using Mplus (Muthén and Muthén, 1998–2010).

3. Results

3.1. Existing plans

The five plans we assessed deal with 15 marine mammal stocks. Ranks for Metric 1 ranged from −1 to 0.75, while ranks for Metric 2 ranged from −0.5 to 0.89 (Figs. 1 and 2, Table 3). The two lowest ranking plans (Harbor Porpoise and Atlantic Large

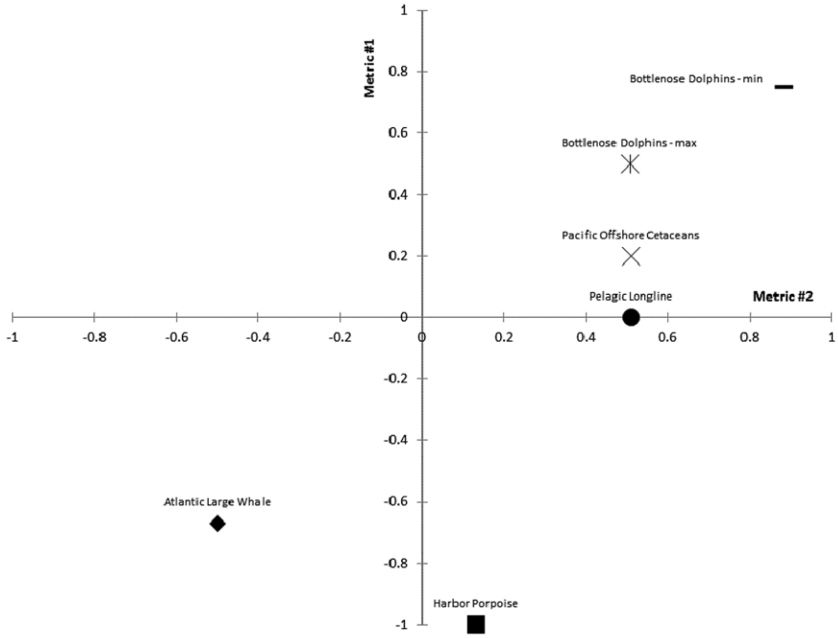

Fig. 1. Rank scores of marine mammal Take Reduction Plans, Metric 1 by Metric 2.

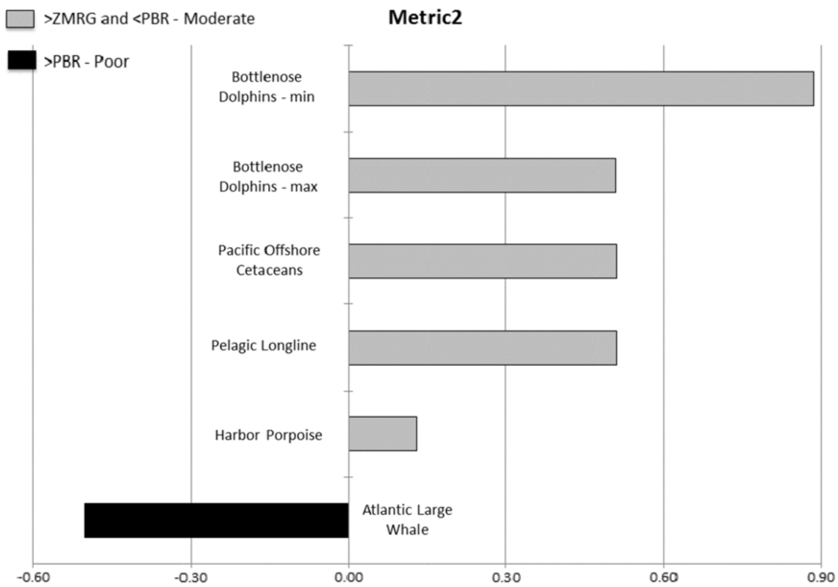

Fig. 2. Ranks for Metric 2 of marine mammal Take Reduction Plans. Black (<0) = high bycatch (>PBR) and gray (0–0.89) = moderate bycatch (>ZMRG and <PBR).

Whale) had Metric 1 scores below zero, and the latter had a negative value for Metric 2 (Figs. 1 and 2, Table 3), indicating that average annual bycatch fluctuated above and below PBR and far exceeded ZMRG. The most successful plans (Bottlenose Dolphin and Pacific Offshore Cetaceans) had positive values for the first Metric and scored above 0.5 for Metric 2 (Figs. 1 and 2, Table 3). These plans reduced and sustained bycatch across stocks to below PBR, and at least two stocks from each maintained bycatch below ZMRG. The high, positive Metric 2 values indicate average annual bycatch was below PBR, and one was nearly at ZMRG (Fig. 2).

For individual stocks, values for Metric 2 ranged from −1.41 to 0.96 (Fig. 3, Table 3). Five stocks (Gulf of Maine humpback and North Atlantic right whales, California/Oregon/Washington sperm whales, Gulf of Maine-Bay of Fundy harbor porpoises, and Western North Atlantic long- and short-fin pilot whales) scored −1 for Metric 1, indicating they were above PBR or fluctuated above and below PBR. Three of those stocks (humpback, right, and sperm whales) had negative values for Metric 2, indicating that average annual bycatch exceeded PBR. The Northern North Carolina Estuarine Stock of bottlenose dolphins

Table 3
Metric 1 and 2 ranks of marine mammal Take Reduction Plans and stocks.

Take Reduction Team	Marine Mammal Stock	Metric 1	Metric 2	
		Rank	**average[(PBR-BC)/PBR]**	**Interpretation of M2**
Harbor Porpoise	Gulf of Maine-Bay of Fundy Harbor Porpoise	**−1**	**0.13**	**<PBR and >ZMRG**
Atlantic Large Whale	–	**−0.67**	**−0.50**	**>PBR**
	Western North Atlantic Right Whale	−1	−0.94	>PBR
	Gulf of Maine Humpback Whale	−1	−1.41	>PBR
	Western North Atlantic Fin Whale	0	0.84	<PBR and >ZMRG
Pacific Offshore Cetaceans	–	**0.20**	**0.51**	**<PBR and >ZMRG**
	California/Oregon/Washington Short-finned Pilot Whale	1	0.54	<PBR and >ZMRG
	California/Oregon/Washington Sperm Whale	−1	−0.28	>PBR
	California/Oregon/Washington Humpback Whale	0	0.51	<PBR and >ZMRG
	California/Oregon/Washington Long-beaked Common Dolphin	1	0.87	<PBR and >ZMRG
	California/Oregon/Washington Northern Right Whale Dolphin	0	0.90	=ZMRG
Bottlenose Dolphin—minimum bycatch estimate	–	**0.75**	**0.89**	**<PBR and >ZMRG**
	Western North Atlantic, Coastal, Northern Migratory[a]	1	0.96	<ZMRG
	Western North Atlantic, Coastal, Southern Migratory[a]	1	0.96	<ZMRG
	Northern North Carolina Estuarine System	0	0.76	<PBR and >ZMRG
	Southern North Carolina Estuarine System	1	0.86	<PBR and >ZMRG
Bottlenose Dolphin—maximum bycatch estimate	–	**0.50**	**0.51**	
	Western North Atlantic, Coastal, Northern Migratory[a]	1	0.93	<ZMRG
	Western North Atlantic, Coastal, Southern Migratory[a]	1	0.74	<PBR and >ZMRG
	Northern North Carolina Estuarine System	0	−0.15	>PBR
	Southern North Carolina Estuarine System	0	0.51	<PBR and >ZMRG
Pelagic Longline	–	**0.00**	**0.51**	**<PBR and >ZMRG**
	Western North Atlantic Long- and Short-finned Pilot Whale[a]	−1	0.07	<PBR and >ZMRG
	Western North Atlantic Risso's Dolphin[a]	1	0.94	<ZMRG

[a] Stocks NOT strategic prior to TRT.

(maximum bycatch estimate) also scored negatively for Metric 2 (Fig. 3). Harbor porpoises and pilot whales, meanwhile scored under 0.5 for Metric 2. Sperm whale bycatch was below ZMRG for nine of 13 years. However, in 2010, it experienced very high bycatch (16 animals), dramatically affecting its average annual difference from PBR.

Based on Metric 1, management of four stocks can be considered a success, with scores of 1 (bycatch below ZMRG). Two of these four are managed under the Pacific Offshore Cetaceans plan and two are covered under the Bottlenose Dolphin plan (Table 3). Bycatch of Pacific short-finned pilot whales was below PBR and ZMRG for all but one-implementation years. Bycatch of the two-bottlenose dolphin stocks also was below ZMRG for all years but one, while that of long-beaked common dolphins was below ZMRG for more than 70% of the years following implementation. Five stocks scored 0.9 or above for Metric 2, indicating their average annual bycatch was at or below ZMRG (Fig. 3). Bycatch of all five stocks was below PBR when their plans were implemented and for all stocks except the Northern right whale dolphin, was below ZMRG for more than half of the implementation period.

3.2. Covariates

Team size ranged from 17 to 82 members plus alternates, including alternates (Table 2). The Atlantic Large Whale Team is the largest and Pacific Offshore Cetaceans the smallest. The youngest team was established in June 2005 and the oldest two teams were formed in February 1996. Most plans have been amended a few times; the Atlantic Large Whale plan has been amended 28 times. Mean PBR of each team also varies greatly, ranging from 3.1 to 625. The Western North Atlantic

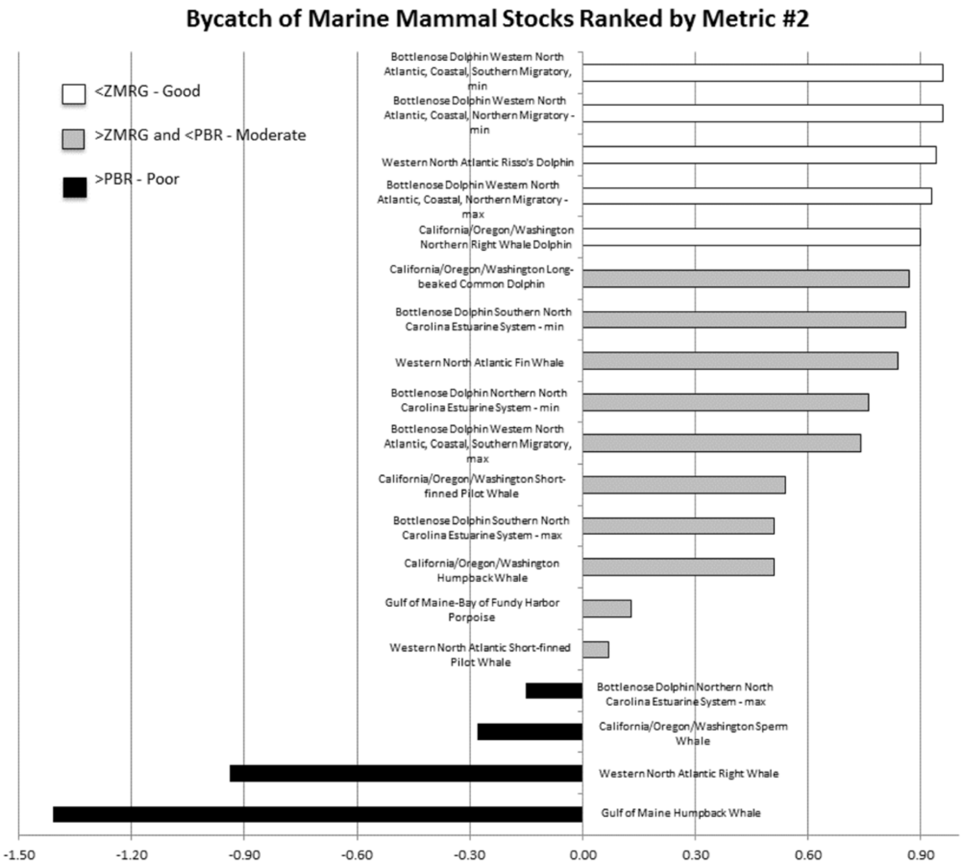

Fig. 3. Ranks for Metric 2 of 15 marine mammal stocks managed by Take Reduction Plans. Black (<0)= high bycatch (>PBR) gray (0–0.89) = moderate bycatch (> ZMRG and < PBR), and white (≥0.9) = low bycatch (≤ZMRG).

Table 4
Regression coefficients for the covariate predictor (northeast US) of Metrics 1 and 2.

Dependent variable	Covariate	Estimate	*P*-value	R^2
Metric 1	NE US	−1.11	<0.001	0.85
Metric 2		−0.76	<0.001	0.76

right whale has the lowest individual PBR (0.9) and the Gulf of Maine-Bay of Fundy harbor porpoise stock has the highest (625).

US region was a significant covariate of Metrics 1 and 2 with the northeastern US being the least successful (Table 4), which indicates that plans to regulate stocks in this region of the US (Maine to North Carolina) were less successful at reducing bycatch than plans created by teams in other regions (Table 4). The northeast accounted for 85% of the variance in Metric 1 and 76% of the variance in Metric 2.

4. Discussion

Our analysis, which uses data from a long-term monitoring program evaluated against objective, measurable criteria, suggests that performance of the marine mammal Take Reduction Planning process has been uneven. Only two of the five plans, the Pacific Offshore Cetaceans and Bottlenose Dolphin plans were successful in meeting at least one statutory goal (reducing bycatch below PBR or ZMRG) and maintaining these reduced bycatch levels. Following implementation, their average annual bycatch was consistently below PBR and periodically below ZMRG. By contrast, the Harbor Porpoise and Atlantic Large Whale plans did not result in reduced bycatch levels. For both plans, bycatch was below PBR for only half of the years following implementation and was rarely below ZMRG. This variability in ecological success (reduction in bycatch relative to PBR) also was reflected in the rankings of individual stocks. Nine of the 15 stocks analyzed for this study (Table 1) can be considered successfully managed, with Metric 1 scores $\geq$ 0 and high ranks for Metric 2. Five of these stocks had average annual bycatch levels below ZMRG (Metric 2 $\geq$ 0.9). Management of bycatch was unsuccessful for five stocks because average bycatch for four of these five stocks was above PBR (Metric 2 < 0). Average bycatch of the remaining three stocks ranged between PBR and ZMRG (Metric 2 ≥ 0 and < 0.9).

4.1. Covariates

The longevity of a plan affected the availability of data for this analysis, but did not affect success. Three plans were formulated in the mid-1990s but had widely varying degrees of success (Tables 2 and 3).

Teams in the northeastern US were less successful than those in other regions. This likely underscores the importance of compliance with and enforceability of regulations. For example, the Harbor Porpoise plan (in the northeastern US) requires the use of acoustic alarms, called pingers, in certain times and areas. When used properly, these devices can reduce harbor porpoise bycatch by more than 90% (Bache, 2001; Cox et al., 2007; Hardy et al., 2012; Palka et al., 2008). Fisheries observers monitor compliance with plan measures by recording information about the gear, catch, and bycatch when nets are retrieved. In 2010 and 2011, Orphanides and Palka (2012) estimated that only 41% of observed hauls were in compliance with pinger regulations in the Gulf of Maine. Moreover, Palka et al. (2012) documented that the fishery was only 19% in compliance with other gear requirements in the mid-Atlantic between 2010 and 2012. Geijer and Read (2013) found that harbor porpoise bycatch prior to implementation of the plan was directly correlated with cod landings in the northeast sink gillnet fishery. There was a partial de-coupling of the two parameters after the plan was implemented until 2007, indicating that measures in the plan were successful in reducing harbor porpoise bycatch (Geijer and Read, 2013). However, we found that from 2008–2012, once again, there was a high correlation between cod landings and bycatch ($r = 0.96$, $p = 0.008$). This suggests that a lack of compliance with pinger requirements rendered the plan less effective and that variation in fishing effort was driving recent bycatch levels. Moreover, efforts by fishing industry members to lobby a National Marine Fisheries Service political appointee were successful in altering plan regulations and thus undermined the negotiation process (Safina and Read, 2012; McDonald and Rigling-Gallagher, 2015a).

In contrast to the plans implemented in the northeastern US, compliance with the Pacific Offshore Cetaceans plan (western US) was excellent. Between 1998 and 2009, Carretta and Barlow (2011) documented that more than 99% of observed sets in the California drift gillnet fishery used pingers correctly. In addition, there is a high degree of observer coverage (20% of sets) in the California/Oregon drift gillnet fishery and at least 50% of unobservable vessels are boarded at sea each year (Long and Fahy, 2012). This high level of observer coverage allows precise estimates of bycatch and provides a conspicuous enforcement presence that deters violations of plan regulations. The reasons for the large difference in compliance between the two plans are not understood and worthy of further study.

In addition, poor performance of Take Reduction Plans in the northeastern US also may result from low stock sizes, broad scope of the plan, difficulty reaching consensus, and participants who undermined negotiations (McDonald and Rigling Gallagher, 2015b; McDonald and Rigling-Gallagher, 2015a). The small sample size of this analysis may not have detected the influence of these variable statistically, but they are factors that affect the creation and implementation of the plans. For example, the enormous scope and scale of the Atlantic Large Whale Team makes it impractical to monitor compliance using an observer program. Moreover, the team has never reached consensus, which has confounded the purpose of consensus-based negotiation and increased the likelihood that the negotiating parties would go outside of the process to achieve their goals (McDonald and Rigling Gallagher, 2015b; McDonald and Rigling-Gallagher, 2015a; Coglianese, 1997; Funk, 1997). This plan has spawned five lawsuits and Congressional intervention (Asmustis-Silvia, 2009; Asmutis-Silvia and Young, 2010). Moreover, the Atlantic Large Whale plan focuses on bycatch from very small, endangered stocks that have very low PBR values. Perhaps as a result, the team has produced myriad, convoluted amendments to the plan that, so far, have been unsuccessful in meeting statutory goals.

The MMPA defines conservation targets that scale directly with abundance, so stock size is an important driver of the likelihood that a plan will meet those targets. Three of the four lowest-ranking stocks had abundance estimates of less than 1000 individuals, resulting in very low PBRs (values < 10). The PBR for right whales is often less than one individual per year (Table 2). Even under ideal circumstances, reducing bycatch to ZMRG becomes practically impossible for such stocks.

4.2. Caveats

Our method provides an objective means of evaluating the efficacy of Take Reduction Plans, but data limitations presented significant challenges to the approach. The data contained in US marine mammal stock assessments vary in amount, precision, and age (Lewison et al., 2004; Read et al., 2006; Geijer and Read, 2013; GAO, 2008). Abundance estimates older than eight years are considered unusable because stocks size may have changed over the intervening period. In such cases, PBR is undefined (Moore and Merrick, 2011). Bycatch estimates are extrapolated from observer programs, when such data are available, but are negatively biased when derived from logbook and stranding data (Lewison et al., 2004; Read et al., 2006; Geijer and Read, 2013; National Marine Fisheries Service, 2011). Observer and stock assessment survey programs are costly and their implementation varies greatly among stocks. Only half of US fisheries are observed, which limits estimation of bycatch levels and their associated uncertainty (GAO, 2008; National Marine Fisheries Service, 2011). Defining stock structure also can be challenging, making estimates of abundance, PBR, and bycatch imprecise or biased (Read et al., 2006; Geijer and Read, 2013). Uncertainty regarding stock boundaries can lead to multiple reconfigurations of stock structure over time, as evidenced by bottlenose dolphins in the Atlantic (http://www.nmfs.noaa.gov/pr/sars/species.htm). Moreover, stocks that cross international boundaries may be subject to fishing related threats outside of the jurisdiction of the US. Take Reduction planning process, which could affect abundance that is used to calculate PBR. Finally, our evaluation was limited by the number of years of data available following implementation of a plan; due to this limitation, we were unable to evaluate the False Killer Whale plan altogether.

5. Conclusions

Using the Take Reduction Planning process as a case study, we assessed the conservation effectiveness of a well-known element of an established US environmental management program under the MMPA. We were able to conduct this research only because of the existence of data from long-term monitoring of marine mammal stocks contained (and made publicly available) in the Stock Assessment Reports (http://www.nmfs.noaa.gov/pr/sars/species.htm), as well as objective, measurable criteria that were integrated into the statute. Despite their flaws and inconsistencies, the Stock Assessment Reports allowed us to assess the conservation efficacy of these plans. This underscores the importance of creating and maintaining long-term, ecological monitoring programs. Prior to implementation, managers should consider and plan for the challenges associated with such evaluations. Moreover, this study underscores the value of incorporating objective, measurable criteria into environmental legislation or agreements that provide goals against which to compare the results. Other such agreements and legislation like the IUCN redlist, Canadian Species at Risk Act, and the Australian Environment Protection and Biodiversity Conservation Act 1999 also contain measurable criteria that lend themselves to evaluation of their conservation efficacy.

Take Reduction Plans have had an uneven record of meeting their statutory requirements. Successful plans were typically drafted by small teams and produced regulations that were readily monitored and enforced, which facilitated compliance. Unsuccessful plans were produced by large, unwieldy teams, usually in the northeastern US, addressed small stocks and crafted regulations that were difficult to enforce or were not enforced at all. A comprehensive evaluation of the elements contributing to the success or failure of Take Reduction Plans will require investigation of the negotiation process, outputs, socio-political outcomes, and explorations of participant attitudes (McDonald and Rigling Gallagher, 2015b). A comparison of these social factors with the ecological outcomes presented here is critical to creating a comprehensive evaluation of this process and for suggesting improvements to this negotiated rulemaking process. Very limited evaluation of such consensus-based rulemaking processes has been conducted to date and more research is needed to explore whether the factors associated with ecological effectiveness of this participatory, environmental management process hold in other cases both within and outside the US.

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