Biological Conservation 191 (2015) 375–382

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Legislative correlates of the size and number of protected areas in Canadian jurisdictions

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ARTICLE INFO

Article history:
Received 12 November 2014
Received in revised form 4 July 2015
Accepted 12 July 2015
Available online 31 July 2015

Keywords:
Legislation
Management
Park
Policy
Reserve
Systematic conservation planning

ABSTRACT

Protected area legislation provides the statutory authority for the establishment and management of protected areas. Yet few studies have investigated the relationship between protected area legislation and those attributes of protected areas that are likely to affect their success in achieving biodiversity conservation objectives. Here we investigate the association between the size and number of protected areas within Canadian provincial, territorial and federal jurisdictions and provisions of the corresponding legislation using a Before–After/Control–Impact design. We found that jurisdictions with legislation that includes explicit provisions for donations in cash or in-kind and many types of stakeholder involvement had, on average, larger (1.01× to 29.0×) protected areas after versus before legislation enactment, compared to those without such provisions. Jurisdictions with legislation that includes provisions for protected area co-management with local or aboriginal/indigenous communities also had, on average, a higher rate of park establishment after (0.17–23.7 protected areas/year) versus before (0.17–6.34 protected areas/year) legislation enactment, compared to those without such provisions (0.09–5.00 protected areas/year; 0.21–5.30 protected areas/year after and before respectively). Similar patterns were detected for jurisdictions with legislation that includes provisions for operating and/or capital cost recovery. Our results suggest that legislative provisions that facilitate stakeholder participation and cost recovery may contribute to the establishment of more and larger protected areas. As signatories to the Convention on Biological Diversity attempt to expand protected area networks, they should consider including provisions concerning stakeholder involvement and cost recovery into protected areas legislation.

1. Introduction

Protected areas are an important vehicle for biodiversity conservation at a range of geographical scales (Chape et al., 2005; Dudley, 2008; Bertzky et al., 2012). Signatory nations to the Convention on Biological Diversity (CBD) must report on their progress in establishing terrestrial and marine protected areas as part of their efforts to reduce biodiversity loss (UNEP, 1992). The most recent CBD protected area targets call for the global protection of 17% of terrestrial and inland waters and 10% of marine and coastal areas (COP 10, 2010), which represents a substantial increase from the current global protection levels of 12.5% of land area and 3% of ocean area (Watson et al., 2014).

Legislative tools are believed to be important for protected area effectiveness (Dearden et al., 2005). Unsurprisingly then, the CBD encourages signatory nations to enact protected area legislation as part of their commitment to biodiversity conservation (UNEP, 1992). Some examples of protected area legislation include the Canada National Parks Act (Government of Canada, 2000), the Swedish Environmental Code (Government of Sweden, 2000), and the Ugandan Wildlife Act (Government of Uganda, 1996). As protected area legislation provides the legal authority for protected areas establishment and management, their success in meeting conservation goals is likely to depend upon the statutory provisions of the legislation (Dearden et al., 2005).

Here we investigate the relationship between the provisions of federal, provincial and territorial protected area legislation in Canada and the size and number of Canadian protected areas. We selected the size and number of protected areas as attributes of interest because (a) information on protected area size and number is readily available for all jurisdictions; and (b) there is substantial evidence that the ability of protected area networks to conserve biodiversity depends on both these attributes. For example, it has been argued that larger protected areas are better able to provide long-term persistence for the full complement of species and landscape-scale ecological processes (Peres,

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http://dx.doi.org/10.1016/j.biocon.2015.07.016
0006-3207/

2005; Bradshaw et al., 2009; Cantú-Salazar and Gaston, 2010; but see Coetzee et al., 2014). An analysis of 14 national parks in Western North America showed that mammal extinction rates declined with increasing park size (Newmark, 1995). More recent analyses have shown that conservation outcomes correlate positively with the size of marine protected areas (Edgar et al., 2014). Also, a global analysis showed that nations with more protected areas tended to have fewer bird, mammal, and plant species at risk of extinction (McKinney, 2002).

Although management costs per km^2 may decrease with the size of protected areas (Balmford et al., 2003; Bruner et al., 2004), we expect the absolute cost of maintenance and management to increase with size and number of protected areas (Bruner et al., 2004). Consequently, the ability to recoup capital and operational costs may influence the size and number of protected areas that can be established. Similarly, we expect that protected area legislation that enables greater stakeholder involvement in protected area planning, establishment or management will facilitate the establishment of larger and more protected areas. This may be particularly true in countries, such as Canada, where indigenous communities own or (co)manage substantial territory.

Here we investigate the association between protected area size and number and legislative provisions that pertain to (1) operating and/or capital costs recovery; and (2) opportunities for stakeholder involvement in planning and management. For our purposes, we define stakeholders as any member of the public or local communities, including aboriginal or indigenous peoples, non-governmental organizations, other levels of government (e.g. municipal) and landowners.

2. Materials and methods

2.1. Protected area legislation survey

In 2006 the International Union for the Conservation of Nature (IUCN) Commission on Environmental Law (CEL) and the World Commission on Protected Areas (WCPA) established a Task Force on Protected Areas Law and Policy, which focused on analyzing existing governance in protected areas and providing advice on improving governance models (Task Force Protected Areas, 2008). As part of the task force activities, in 2009 the IUCN Academy of Environmental Law designed a global survey of legislative instruments for protected areas establishment and management. The survey included 16 sections and 69 questions that evaluated the extent to which statutory provisions address a range of issues, including protected areas establishment, governance, management and administration; scientific involvement; enforcement; and financing (see Appendix A for the complete survey). The goal of the survey was to identify provisions that, in conjunction with the IUCN protected areas management categories (Dudley, 2008), increase the chances of achieving protected area conservation objectives.

Our original goal was to explore the association between the size and number of Canadian protected areas in different jurisdictions and legislative provisions concerned with (a) cost recovery (b) stakeholder involvement; and (c) establishment of buffers around or corridors between protected areas. Consequently, we used a subset of survey questions pertaining to these issues (Table 1).

We focused on protected areas for which statutory authority derives from the Canada National Parks Act or the principal provincial or territorial protected area legislation in each province or territory (Table 2). In cases where the statute has undergone substantive amendments since coming into force (e.g. the case of the National Parks Act in 2000), we used the latest version of the statute. Several Canadian provinces and territories have multiple pieces of legislation that apply to different categories of protected areas. For example, planning and management of protected areas on public lands in Newfoundland and Labrador is, in principle, subject to provisions of the Provincial Parks Act, the Wilderness and Ecological Reserves Act, the Lands Act or the Wildlife Act. We consulted government officials for jurisdictions where we were unsure about the principal protected area legislation.

Information extraction from the final set of statutes proceeded in two steps. First, as part of a directed studies course, two senior undergraduate students independently extracted survey question data from each statute, with responses to survey questions being compared among the two raters. Second, each statute was subsequently reviewed by at least one of the study authors with expertise and knowledge in protected areas legislation both within Canada and worldwide, and compared to the two undergraduate evaluator responses. In the case of any discrepancies, the third evaluation was considered the correct interpretation. Survey questionnaires were completed for protected area legislation for 10 provinces, 3 territories, and national parks.

2.2. Protected area data

We used the Conservation Areas Reporting and Tracking System's protected areas database that includes 4090 protected areas and is the

Table 1
Questions relating to funding, stakeholder involvement, and buffers and corridors from the survey of protected area (PA) legislation (Appendix A). Levels of response are listed in parenthesis with Y = yes, N = no, D = duty, E = enabling, NE = none.

Legal question code used in figures	Question
Funding	
F1	Does the instrument include provisions for forfeiture or cost recovery (e.g. pollution clean-up or restoration of damaged ecosystems)? (Y/N)
F2	Does the instrument include provisions to collect entrance/user fees from transient vehicles? (Y/N)
F3	Does the instrument include provisions for the PA or PA agency to accept donations in cash or in-kind? (Y/N)
F4	Does the instrument include provisions to collect general entrance fees from PA visitors? (Y/N)
Stakeholder involvement	
C1	In what capacity does the instrument provide for public involvement or input for establishment of PAs? (D/E/NE)
C2	In what capacity does the instrument provide for public involvement or input for management of PAs? (D/E/NE)
C3	In the instrument, is public consultation with local stakeholders explicitly identified for the designation or establishment of PAs? (Y/N)
C4a	Does the instrument make provisions for PA establishment on land owned by indigenous or local communities? (Y/N)
C4b	Does the instrument make provisions for PA establishment on land owned by another level of government (e.g. regional, municipal, etc.)? (Y/N)
C5	Does the instrument provide for co-management with other levels of government? (Y/N)
C6	Does the instrument provide for co-management with non-governmental organizations? (Y/N)
C7	Does the instrument provide for co-management with local communities? (Y/N)
C8	Does the instrument provide for co-management with aboriginal/indigenous communities? (Y/N)
C4c	Are there provisions related to the establishment by the government of PAs on land that is not government owned? (Y/N)
Buffers and corridors	
S1 — not used	Does the instrument explicitly make reference to the creation or management of corridors connecting individual PAs? (Y/N)
S2 — not used	Does the instrument explicitly make reference to the creation or management of buffer zones around PAs? (Y/N)

Table 2
Provincial, territorial and national protected area legislation, associated dates of enactment, and the total number and median, minimum and maximum size of protected areas in each jurisdiction.

Jurisdiction	Protected area legislation	Legislation enactment date	Total number of protected areas	Median (minimum; maximum) protected area size (km^2)
Alberta	Provincial Parks Act	2000	74	7.04 (0.093; 512)
British Columbia	Parks Act	1996	895	3.37 (0.003; 9736)
Newfoundland and Labrador	Provincial Parks Act	1988	31	2.45 (0.019; 152)
Nunavut	Territorial Parks Act	1988	7	18.3 (0.104; 1421)
Ontario	Provincial Parks and Conservation Reserves Act	2006	624	10.6 (0.010; 22,633)
Saskatchewan	Parks Act	1986	58	2.84 (0.008; 3129)
Yukon	Parks and Land Certainty Act	2002	7	1998 (15.6; 5418)
Canada	Canada National Parks Act	2000	39	1376 (13.4; 45,848)

most complete such source in Canada (CCEA, 2011). In our analysis, we included all national parks and provincial or territorial protected areas subject to the main identified provincial or territorial protected area legislation. We restricted our analysis to those jurisdictions with at least two protected areas established both before and after the legislation enactment date (Table 2). This requirement substantially reduced the number of jurisdictions in the sample: the final dataset included 1735 protected areas from five provinces (Alberta, British-Columbia, Newfoundland and Labrador, Ontario, and Saskatchewan), two territories (Nunavut and Yukon), as well as Canada's National Parks. The full data set and R code used in our analyses are available on-line (Leroux et al., 2014).

2.3. Data analysis

2.3.1. Protected area size

We employed a replicated Before–After/Control–Impact (rBACI) experimental design to evaluate the association between legislative provisions and protected area size. As in any such design, we are interested in the interaction between the main effect (in our case, legislative provision) and time (in our case, before versus after legislation enactment). For example, if aboriginal consultation leads to larger protected areas, and a legislative provision explicitly requiring consultation is more likely to result in consultation (or more effective consultation), then for jurisdictions that have such a legislative provision ("Impact"), the difference between average park size before versus after enactment should be greater than the difference in those jurisdictions ("Control") without such a provision. For this analysis, individual protected areas were the unit of observation (n = 1735), with replication being provided by the multiple jurisdictions that have, versus do not have, the legislative provision in question.

We fit multiple linear regression models with $\log_{10}$ protected area size (in km^2) as our response variable and ecozone, statutory provision, and time (before or after enactment) as predictors. Protected areas that were established on or after the date of legislation enactment were classified as established "after" the date of enactment. We included ecozone (Agriculture and Agri-Food Canada, 1999) as a covariate to control for the considerable regional variation in the number and size of protected areas across Canada, and assigned each protected area to the ecozone that contained its centroid. The fitted model was:

$$\mathrm{Log}_{10}(\mathrm{PA\ \ size}) \sim \mathrm{Ecozone} + \mathrm{Time} + \mathrm{Provision}_i + \mathrm{Time} * \mathrm{Provision}_i$$

where the *i* subscript denotes a particular statutory provision. In this model, the influence of a particular provision (a fixed effect) is inferred from the interaction Time * Provision, indicating that the difference in average size before and after legislative enactment varies between those jurisdictions that have, or do not have, the provision in question. We calculated the effect size for the fitted interaction term as Cohen's f^2 (Cohen, 1988):

$$f^2 = \frac{R^2_{Full\ \ Model} - R^2_{Reduced\ \ Model}}{1 - R^2_{Full\ \ Model}}$$

where the full and reduced models are, respectively, that including and excluding the Time * Provision interaction term. We also calculated the proportional change in protected area size = (median protected area size (after) − median protected area size (before))/median protected area size (before) separately for jurisdictions whose protected area legislation does, or does not, include the provision in question. The ratio of these two values gives the proportional change in protected area size in jurisdictions with versus without the provision, with ratios greater than one indicating larger (positive) changes in median size for jurisdictions whose legislation includes the provision in question.

2.3.2. Number of protected areas

The number of protected areas is a jurisdictional attribute, not an attribute of individual protected areas. The comparatively small sample size of jurisdictions (n = 8) required a different analytic approach based on randomization (Manly, 2006).

With the exception of Nunavut, the time interval during which protected areas were established prior to legislation enactment is longer than the interval following enactment. To control for this difference in opportunity for protected area establishment, we calculated the number of protected areas established after enactment as well as the number established before legislation enactment in an equivalent time interval. To control for the difference in the duration of the interval before versus after, we used a moving window approach to obtain the distribution of the number of protected areas established before legislation enactment for all successive intervals equal to the duration of the interval following legislation enactment.

For example, British Columbia's first Provincial Park (Strathcona) was established in 1911 and British Columbia's Parks Act was enacted in 1996. So in British Columbia, there are 85 and 15 years before and after legislation enactment respectively. We calculated the number of protected areas established in the 15 years post-enactment interval, as well as the number of protected areas established during every possible (n = 70) continuous 15 year interval beginning in 1911. Thus, for every jurisdiction, we obtain: (1) the number of protected areas established after the legislation was enacted over an interval of *T* years; and (2) the set of all possible numbers of protected area establishments before enactment based on successive time intervals of duration *T*.

We used $\mathrm{PA}_{\mathrm{number\ \ observed}}$ = (number of protected areas established after legislation enactment − number of protected areas established before legislation enactment) divided by the total number of protected areas as our measure of the effect of protected area legislation on the number of protected areas. For each

jurisdiction j, the moving window approach results in a set of N_j possible $PA_{number\ observed}$ values. For each jurisdiction, we randomly selected one observation from the corresponding set of N_j observations, fit the general model $PA_{number\ observed} \sim Provision_i$, where i represents a particular statutory provision (see Table 1), and repeated this procedure 5000 times. The result is a distribution of model coefficients for each provision, one for each trial.

To evaluate the association between provision and number of protected areas, we used the same 5000 $PA_{number\ observed}$ observations, reshuffled (randomized) the provision assignments among jurisdictions, and refitted the model. In this way, we obtained, for each trial and each provision, two sets of model coefficients, one observed, the other based on the reshuffled data (i.e. null model). The set of 5000 trials then allowed us to estimate both the average difference and the associated 95% confidence intervals, with a positive difference indicating that the rate of protected area establishment was greater after enactment than before, for a given provision.

3. Results

The date of provincial, territorial or National protected area legislation enactment ranged from 1986 (Saskatchewan) to 2006 (Ontario) (Table 2).

The IUCN survey included two questions pertaining to provisions for establishment of buffers and corridors, four questions pertaining to provisions for the funding of protected areas, and ten questions pertaining to provisions concerned with stakeholder involvement (Tables 1, B.2–B.4). As three questions related to stakeholder involvement (C4a, C4b, C4c) had virtually identical responses, we combined them into a single question for analysis. In this case, a jurisdiction that included provisions for stakeholder involvement defined in questions C4a, C4b or C4c was classified as a "yes" and the remaining jurisdictions were classified as a "no" in the combined question (see jurisdictional responses to all legal questions in Tables B.2–B.4). Moreover, no reviewed legislation included explicit provisions pertaining to the establishment of buffer zones or corridors on adjacent lands. As variation in size and number of protected areas among jurisdictions cannot therefore be attributed to variation in legislative provisions pertaining to buffers and corridors, these survey questions were eliminated from further analysis. Our final sample of questions included four questions pertaining to funding and eight questions pertaining to stakeholder involvement (Tables 1, B.2–B.4).

Size of protected areas spanned seven orders of magnitude. On average, the smallest protected areas occur in Newfoundland and Labrador (median = 2.4 km^2) and Saskatchewan (median = 2.8 km^2), while the largest occur in National Parks (median = 1376 km^2) and the Yukon (median = 1 998 km^2, Tables B.1, Figs. 1, B.1). British Columbia and Ontario have the most protected areas (Table B.5). Although the cumulative number of parks increased comparatively steadily through time in British Columbia, Ontario shows a large increase in the number of parks in the late 1990s and early 2000s (Fig. 1b) associated with the

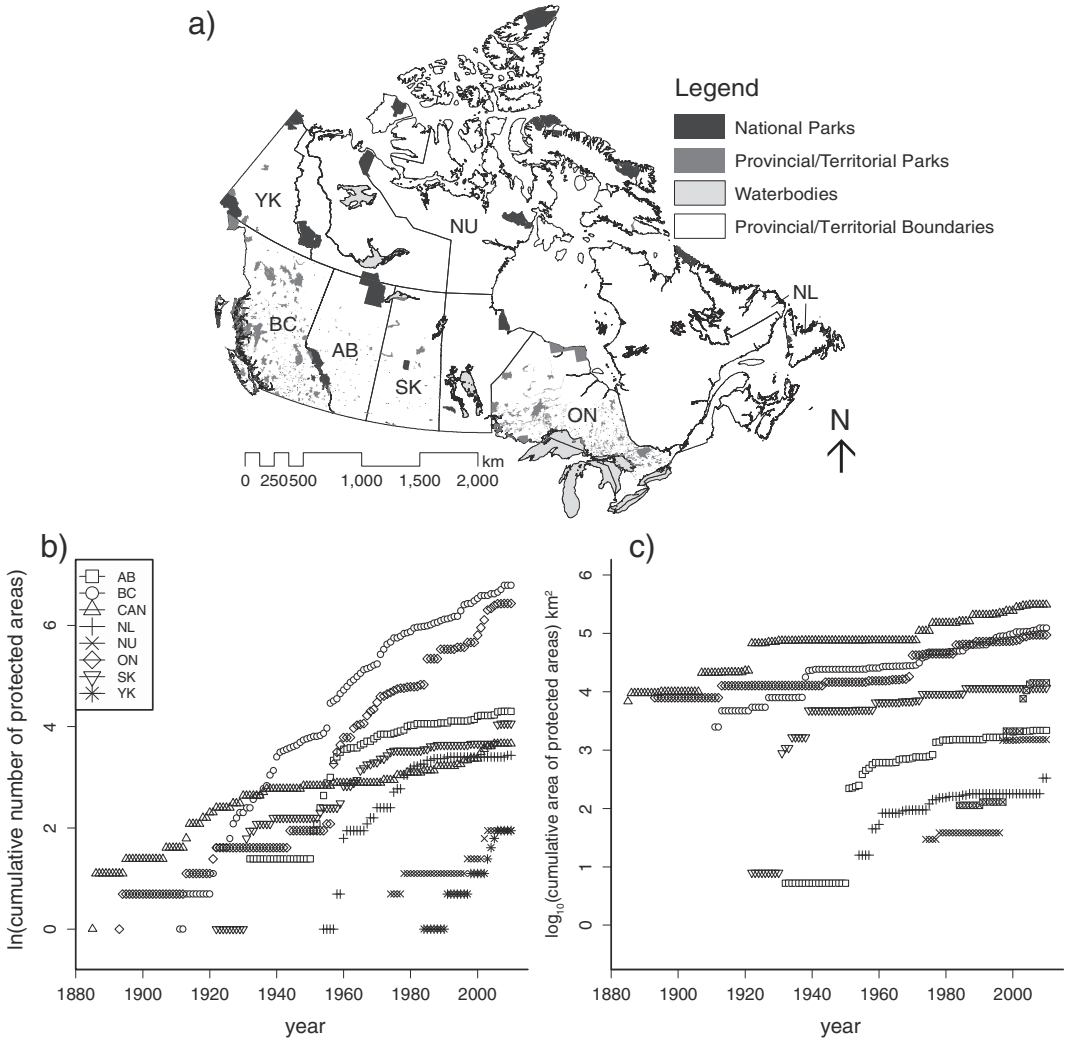

Fig. 1. Map of Canadian provincial, territorial and national protected areas (a) along with the cumulative number (b) and area (c) of protected areas established in each jurisdiction over time. Jurisdictions are: AB = Alberta, BC = British Columbia, CAN = Canada, NL = Newfoundland and Labrador, NU = Nunavut, ON = Ontario, SK = Saskatchewan, YT = Yukon.

Table 3
Statistical summary of the effect size (Cohen's f^2); the coefficient of determination of the full model (R^2), and the type I error associated with the null hypothesis that the difference between average protected area size before versus after legislation enactment is the same for jurisdictions with legislation that included the provision in question compared to those which did not. In addition to the interaction term, each model includes covariates for ecozone, time, and the statutory provision (F1–F4; C1–C8) in question. We also report the mean proportional change in median protected area size for jurisdictions that included the provision in question compared to those which did not (see main text for details). See Table 1 for survey questions associated with each legislative provision.

Legislative provision	Effect size	R^2	p	Proportional change in median PA size (SE)	
Funding				Included	Not included
F1	0.01	0.18	<0.001	5.27 (4.99)	11.6 (9.35)
F2	0.00	0.14	0.283	1.16 (0.73)	9.80 (5.73)
F3	0.01	0.17	<0.001	14.8 (7.56)	0.51 (0.64)
F4	0.01	0.16	<0.001	6.39 (4.71)	9.72 (10.3)
Stakeholder involvement					
C1	0.00	0.19	0.295	8.74 (8.21)	6.98 (5.86)
C2	0.00	0.18	0.229	6.66 (6.16)	8.61 (7.26)
C3	0.00	0.19	0.295	8.74 (8.21)	6.98 (5.86)
C4	0.01	0.15	<0.001	7.68 (5.85)	7.60 (7.56)
C5	0.01	0.17	<0.001	9.87 (7.65)	6.30 (6.00)
C6	0.02	0.19	<0.001	7.88 (5.77)	7.40 (7.62)
C7	0.01	0.15	<0.001	7.37 (5.96)	7.91 (7.47)
C8	0.01	0.15	<0.001	9.41 (7.92)	6.57 (5.94)

"Lands for Life" initiative of the provincial government at that time. National Parks have the largest cumulative area of any jurisdiction (Fig. 1b, c). Although the Yukon has comparatively few protected areas, they nonetheless cover a large area (Fig. 1b, c).

Statutory provisions pertaining to stakeholder involvement had the strongest association with protected area size (Table 3, Fig. 2). The difference in average size prior to and following enactment was greater for jurisdictions with legislation that provides for co-management with non-governmental organization (C6), aboriginal/indigenous communities (C8), other levels of government (C5), or local communities (C7) compared to jurisdictions with legislation that does not (Table 3, Figs. 2, B.2). Similarly, jurisdictions with legislation that includes provisions for protected area establishment on lands owned or managed by

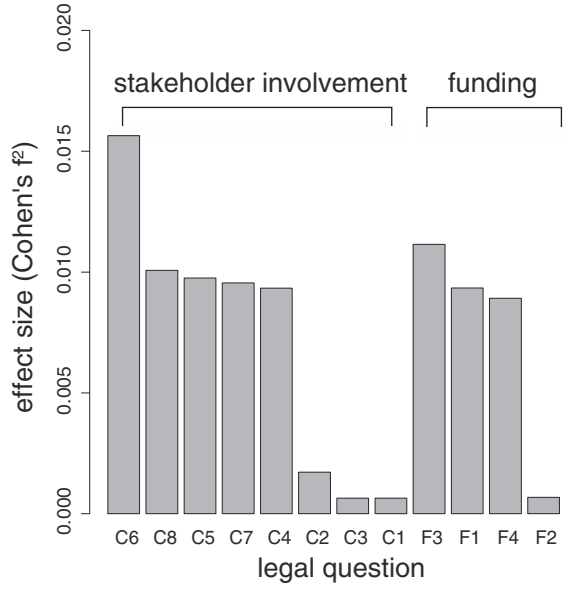

Fig. 2. The effect size (Cohen's f^2) for protected area size associated with statutory provisions concerning stakeholder involvement (C) or funding (F), as measured by the size of the interaction between time of establishment of protected areas (i.e. before versus after legislation enactment) and whether the protected areas legislation in question includes the provision in question. See Table 1 for survey questions associated with each legislative provision.

institutions other than provincial or territorial governments (C4) had a larger difference in average size pre–post enactment compared to jurisdictions with legislation that does not (Table 3, Figs. 2, B.2). The before–after enactment difference in average size was also greater for jurisdictions with provisions that allow for direct donations (F3), for forfeiture or cost recovery (F1) or the collection of park entrance fees (F4) compared to those that did not (Table 3, Figs. 2, B.2).

The median size of protected areas in all jurisdictions except Saskatchewan and National Parks was larger after than before legislation enactment (Fig. B.1). Jurisdictions that had provisions for donations in cash or in-kind (F3), and most types of stakeholder involvement (C1, C3, C4, C5, C6, C8) had, on average, larger (range 1.01–29.0 times larger) protected areas after legislation enactment than before legislation enactment, compared to jurisdictions with legislation without these provisions (Table 3). The largest differences occurred in jurisdictions that had provisions for donations in cash or in-kind (F3), co-management with other levels of government (C5), and co-management with aboriginal/indigenous communities (C8).

All jurisdictions except the Yukon had more protected areas established before than after legislation enactment (Table B.5). Provisions pertaining to stakeholder involvement had the largest association with the difference in the number of protected areas after compared to before legislation enactment (Fig. 3a). For jurisdictions with legislation that provides for co-management with local communities (C7) or aboriginal/indigenous communities (C8), the average rate of protected area establishment was greater after (0.17–23.7 protected areas/year) than before (0.17–6.34 protected areas/year) enactment compared to those jurisdictions which did not have these provisions (0.09–5.00 protected areas/year, 0.21–5.30 protected areas/year after and before respectively Fig. 3 a, b). There was also some evidence that jurisdictions with legislation that provides for other types of stakeholder involvement (C2) showed the same trend (Fig. 3a). Similarly, jurisdictions that allowed for the collection of general park entrance fees from visitors (F4) or forfeiture or cost recovery (F1) had a higher rate of protected area establishment after than before enactment compared to those without such provisions. Conversely, jurisdictions that allowed for the collection of entrance/user fees (F2) or the collection of donations (F3) had a lower rate of protected area establishment after than before legislation enactment compared to those without such provisions (Fig. 3a).

4. Discussion

We provide the first large-scale (i.e. country or continental) study of the relationship between legislative provisions of the statutes under which protected areas are established or managed, and those attributes of protected areas that are expected to influence their effectiveness in biodiversity conservation (but see smaller-scale studies in Keough and Quinn, 2000; Pressey et al., 2002). We found that, in Canada at least, the increase in average size of protected areas after enactment is greater in jurisdictions with protected areas legislation that provides for co-management with other stakeholders compared to those with legislation that does not include such provisions. The same is true for the rate at which protected areas are established. Our results may reflect patterns observed in other countries as some of the largest protected areas in Canada (Leroux et al., 2007), Australia (Farrier and Adams, 2009), and Brazil (Rylands and Brandon, 2005) are on indigenous lands. In these instances, stakeholder consultations are required if governments want to expand protected areas into territories for which other stakeholders retain legal or fiduciary rights or responsibilities.

Stakeholder involvement can take a variety of forms, ranging from pre-establishment planning to participatory management (Dearden et al., 2005; Berkes, 2009). Although there is widespread belief that local stakeholder involvement is critical to both effective protected area governance (e.g. Dearden et al., 2005) and management (e.g. Lockwood, 2010), a recent global assessment of protected areas

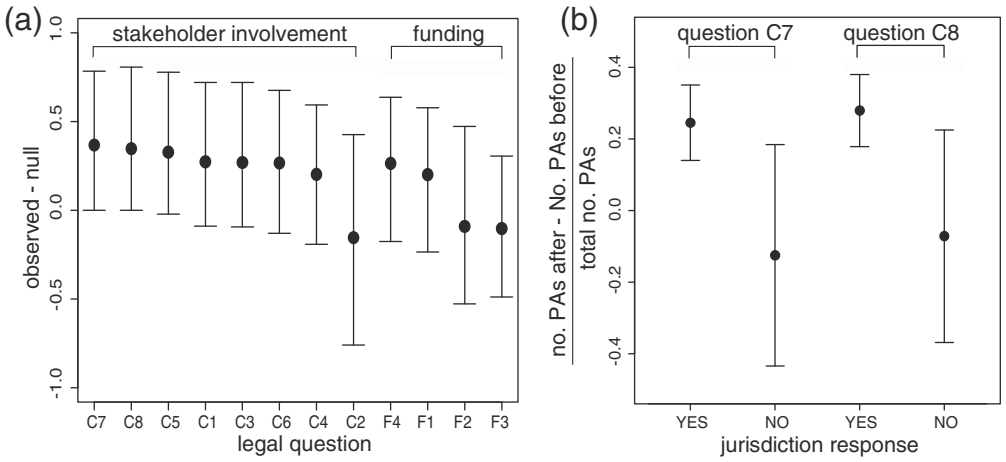

Fig. 3. The association between legislation provisions and the number of protected areas. a) The mean difference (+/−95% confidence intervals) between coefficients obtained from fitting a linear model relating the difference in the rate of protected area establishment after versus before legislation enactment to particular legislative provisions. Positive values indicate a greater rate after versus before enactment. b) standardized metric for the rate of protected area establishment after versus before legislation enactment grouped by jurisdictional response for the two provisions (C7, C8) for which an effect was detected. For further explanation, see text.

management (Leverington et al., 2010) found communication and local stakeholder involvement to be generally inadequate. Local stakeholder involvement in protected areas planning or management may be important in part because protected areas influence surrounding lands and communities (Ewers and Rodrigues, 2008; Leroux and Kerr, 2013). For example, human population growth rates are higher around a sample of protected areas in Africa and Latin America compared to other rural areas (Wittemyer et al., 2008). Although this may indicate a benefit of protected areas for local peoples (i.e. people congregate near protected areas), it may also pose a future threat to protected areas due to the contagious nature of land use (Boakes et al., 2010). The important role that protected areas play in local economies and livelihoods is a fundamental reason for local stakeholder involvement in protected areas planning and management.

However, stakeholder involvement in protected area management does not necessarily lead to gains in biodiversity conservation (Dearden et al., 2005). For example, Fox et al. (1996) note that collective agreements with local villagers concerning land-use in Lantang National Park in Nepal is in direct conflict with critical habitat protection for red panda (*Ailurus fulgens*) inside the park boundary.

We also found evidence that larger post–pre increases in average protected area size are associated with legislative provisions that facilitate internal revenue generation or cost recovery. In their global survey of protected area governance, Dearden et al. (2005) found secure funding to be a key concern for protected area managers. Our data suggests that legal mechanisms for funding securement, such as entrance fees and donations, may contribute to the establishment of larger protected areas. On the other hand, greater internal revenue generation may be a result of increasing human use of a protected area, and this larger human footprint may have negative effects on biodiversity (e.g. Fahrig, 2003). In addition, statutory provisions that in principle enhance internal revenue generation or cost recovery may not do so in practice (Buckley, 2003). Consequently, protected area managers should consider carefully the potential costs, benefits, and allocation of different revenue generation strategies for biodiversity conservation.

Although we have shown that jurisdictions with protected area legislation that includes provisions for stakeholder involvement and cost recovery have more and larger protected areas than jurisdictions without these provisions, the observed patterns may reflect the presence of correlated confounding variables rather than any causal relationship. This problem is reduced, but not eliminated, in BACI designs: confounding may occur if there exists one or more latent causal variables that are correlated with legislative provisions across jurisdictions, and for which changes within jurisdictions over time correlate with the timing of legislation enactment.

The large residual variation of the fitted models is a clear indication that variation in size and number of protected areas is determined by factors other than the provisions of the statutes under which they are established. Including ecozone in the fitted models allows for some statistical control of purely physical constraints, e.g. that larger ecozones can, at least in principle, support larger and more protected areas. Other factors that appear correlated with protected areas establishment, such as topography (e.g. Joppa and Pfaff, 2009) are fixed over time and, as such, cannot explain the detected interaction, but are nonetheless likely to affect size. On the other hand, if indeed larger parks tend to be established in areas remote from large urban populations (Joppa and Pfaff, 2009), and urban expansion is proceeding more slowly in jurisdictions with, e.g. legislative provisions for stakeholder involvement, this may result in a misinferred legislative effect.

Potential confounders notwithstanding, our results illustrate how researchers can begin to undertake meaningful analyses of the extent to which the substantive elements of policy and legal instruments influence the effectiveness of various biodiversity conservation approaches, including protected areas. For the attributes examined here, qualitatively stronger evidence of causal influences is probably best obtained by a detailed forensic analysis of the process by which protected areas in different jurisdictions were established and, in particular, of the precise role played by stakeholder consultation and considerations of cost recovery in the setting of park boundaries and the associated size of protected areas.

Whatever their nature, statutory provisions must be implemented to have any effect. Implementation is invariably achieved either through policy or regulatory enforcement. It is, therefore, unsurprising that the health (Laurance et al., 2012) or effectiveness (Edgar et al., 2014) of protected areas in biodiversity conservation increases with the level of investment in on-the-ground/in-the-water threat protection. This implies that decreasing investment by governments in the resources required to deliver such protections will erode the ability of protected areas to fulfill conservation objectives. Moreover, the potential protection afforded through legislative tools need not be static; in the face of escalating competition for natural resources, protected areas may be subject to downgrading, downsizing, and degazettement (PADDD sensu Mascia and Pailler, 2011) as a consequence of legislative, policy or regulatory changes.

Our results suggest two fruitful avenues for future research. First, here we have used park size and number as a proxy for biodiversity conservation, presuming that larger and more protected areas will enhance

biodiversity conservation. Although a recent meta-analysis of protected area performance failed to detect any effect of protected area size on the difference between various estimates of biodiversity inside and outside park boundaries (Coetzee et al., 2014), it did not consider the legislative provisions that govern the 57 parks included in the analysis. There is, here and elsewhere, an obvious opportunity to examine associations between the legislative framework under which protected areas come into existence or are currently managed, on their ability to conserve biological diversity using, for example, estimates of changes in wildlife abundance within versus outside protected areas.

Second, protected areas established under the same legislation may nonetheless be managed very differently (Dearden et al., 2005), and there is considerable interest in determining the relationship – if any – between management on the one hand, and biodiversity conservation on the other (e.g. Carranza et al., 2014; Nolte et al., 2013; Henschel et al., 2014). An obvious question then is the extent to which variation in management regimes – and in particular, measures of management effectiveness (see Hockings et al., 2000; Leverington et al., 2010; Nolte and Agrawal, 2013) – are associated with variation in the substantive content and intent of the legislation under which protected areas are established and managed. This type of analysis would then allow one to trace potential causal effects from legislative provisions through management regimes to the effectiveness of protected areas in achieving biodiversity conservation (and other) objectives (e.g. Ewers and Rodrigues, 2008; Gaston et al., 2008; Geldmann et al., 2013).

Signatory nations to the CBD are making progress towards meeting the 2020 Aichi protected area targets (Tittensor et al., 2014). As Canada and other signatory nations to the CBD work toward the expansion of their protected areas network, our results suggest that provisions for stakeholder involvement and cost recovery should be incorporated into the legislative tools that provide the legal authority for protected areas planning, establishment or management.

Acknowledgments

SJL and CSF are supported by the Natural Sciences and Engineering Research Council of Canada (#RGPIN 435372-2013 and 48216-2008, respectively). We thank L. Hermanutz, P. Marino, J. Ebel, C. Hammill, the Hermanutz lab, B. Coetzee and anonymous reviewers for constructive comments on this work. J. Graham, N. Morehouse, R. Vanderkam, J. Perron, M. Klassen provided invaluable information on protected area legislation in their jurisdiction. We thank the following students in the course BIO 3115 Conservation Biology (2012) for assisting with evaluation of the protected areas legislation: E. Fisher, D. Liu, M. Mullet, M. Snudden, and A. Valin.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.biocon.2015.07.016.

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