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REVIEW PAPER

A poor international standard for trap selectivity threatens carnivore conservation

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Abstract Unintentional mortality of endangered carnivores due to non-selective trapping is important for conservation and warrants urgent attention. Currently, non-selective traps are being approved and used based on trap selectivity tests conducted according to International Organization for Standardization (ISO) guidelines. We review these guidelines and find them inadequate, because: (1) the ISO definition of selectivity does not

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account for relative abundance of target and non-target species and does not therefore meaningfully reflect selectivity; (2) the guidelines methodology at best quantifies relative selectivity of one trap against another, which is of limited use unless the control trap is known to have an acceptable level of absolute selectivity for the target species; (3) information on relative trap selectivity cannot simply be extrapolated elsewhere, unless species assemblage and relative species abundances are consistent. We demonstrate that the ISO definition of trap selectivity is only a simple capture proportion and therefore does not represent trap selectivity. ISO guidelines on trap selectivity should be reviewed to reflect particular ecological scenarios and we suggest how this might be done. Policy-makers, practitioners and researchers should interpret scientific results more cautiously. Trap approval decisions should be based on scientific evidence to avoid undermining the conservation of biodiversity.

Introduction

Animal trapping is as old as humankind, and has been used as a tool for acquiring resources, such as meat or fur, among others. Wild predators are also trapped widely to protect human interests such as farming, ranching, game shooting and conservation (e.g. Reynolds and Tapper 1996; Lozano et al. 2013). However, non-selective trapping can have serious impacts on non-target populations (e.g. Virgós and Travaini 2005), by causing population decline and regional/national extinction (in for example bears, lynxes, wolves, mustelids and wild cats; see Council of Europe 1993; Breitenmoser 1998; Cabezas-Díaz et al. 2009; Lozano and Malo 2012; Ripple et al. 2014). Since the 1970s, because of population declines and threats associated with predator control programs (Lozano et al. 2013), vulnerable predator species have been protected by international and national laws (as, for example, by the Washington Convention or CITES in 1975, and the Spanish Law 4/1989 for nature protection) and non-selective trapping devices have been banned in Europe (Bern Convention in 1979, and the European Birds and Habitats Directives, approved in 1979 and 1992, respectively). Despite the widespread ban on non-selective traps, they continue to be used in most European countries (e.g. Council of Europe 1993; Virgós and Travaini 2005; Lozano and Malo 2012), as well as many other areas around the world (see Iossa et al. 2007), and consequently remain a threat to the conservation of predators and other non-target animals (Lozano et al. 2013). Likewise, non-selective traps remain a potential threat to overall biodiversity due to the demonstrated role of carnivores in maintaining healthy ecosystems (reviewed by Ripple et al. 2014).

In 1999, the International Organization for Standardization (ISO) produced internationally-adopted methods for testing various aspects of the performance of both killing and restraining traps for mammals, including trap selectivity (ISO 1999a, b). Traps are being tested and approved based on these ISO standards worldwide. We review the ISO trap standards and, in particular, the definition of selectivity used, showing that those standards are flawed and present a serious threat to the conservation of endangered carnivore species.

Measuring trap selectivity

The stated principle of the ISO trap selectivity tests is to evaluate, in the field, the capability of a trap to capture target rather than non-target animals, by recording the number of both that are captured by the test trap, and by a control trap. ISO specify that experimental and control traps should be placed "*in the same substrate and/or vegetation type in pairs, with appropriate separation for the target animals, or alternatively within the trap layout using random assignment and the bait or lure recommended by the manufacturer*". For killing traps, ISO define a control trap as the "*most commonly used trap (of the killing, or submersion restraining type) for the target animal which is used in accordance with the killing-trap system established through most commonly used practice. This will be determined by the authority using this part of ISO 10990, such as a nationally recognized certification body*" (ISO 1999a, see also ISO 1999b for similar wording regarding restraining traps). According to the ISO methods, trap 'selectivity' is calculated as follows:

Selectivity = Number of captured target animals/total number of captured animals

However, this definition clearly does not accommodate selectivity as currently understood in ecology (reviewed by Manly et al. 2002). According to Manly et al. (2002), 'when resources (i.e. animals) are observed disproportionately to their availability, use (i.e. trapping) is said to be selective'. Unfortunately, the ISO definition does not consider the availability of animals in the environment (see also below). Nevertheless, the ISO guidelines are intended for testing the suitability of new traps for general use, by allowing aspects of a new trap to be compared with those of an established (control) trap (ISO 1999a, b; Iossa et al. 2007). Such a comparison would be expected to indicate whether or not the test trap is more or less selective for the target species than the control trap. At best, this would provide a measure of the relative selectivity of one type of trap compared to that of another, but not of the absolute selectivity. The ISO definition of selectivity (1999a, b), should be readdressed for three reasons:

(1)   The ISO definition of selectivity does not take into account the relative abundance of target and non-target species and represents only a simple rate or capture proportion (as defined above), which is not the same than a true selectivity index (Manly et al. 2002). If traps are completely non-selective, and capture individuals of different species (including the target species) at random, then this metric will simply reflect the relative abundance of the target species in test areas. At worst, it could disguise selectivity for a (potentially endangered) non-target species, resulting in unpredictable (and potentially deleterious and irreversible) consequences. Although the ISO methodology specifies evaluating test traps and control traps alongside each other, presumably to determine whether one is relatively more selective than the other, it is not stated explicitly that they need to be tested where the species assemblage and relative species abundances are similar.

(2)   The ISO guidelines do not consider measuring absolute selectivity for the target species. Information about the relative selectivity of one trap compared to another will be useful only if the control trap is already known to have an acceptable level of absolute selectivity. Moreover, no threshold value of trap selectivity is provided.

(3) The ISO method does not account for the fact that the species assemblage and relative species abundance in the test area may not be representative of those elsewhere. The results of a comparison of two trap types in one area (even where species assemblage and relative species abundance are similar for testing both traps) cannot simply be extrapolated elsewhere.

The habitat selection and dietary preference literature has already dealt with and discussed widely the issues arising from not considering relative species abundance (reviewed in Manly et al. 2002). It is generally agreed that no conclusions can be drawn about habitat or resource selection (i.e. selectivity) without a robust estimate of the relative availability of habitats or resources in the study area. Likewise, indices of trap selectivity should be based on algorithms which use estimates of species availability (Manly et al. 2002). An example of an appropriate index of trap selectivity is Savage's W index, a selectivity index used in different ecological applications related to the selection of resources (see Manly et al. 2002), which can be expressed for our purposes as:

$$W = Capture\ proportion/population\ proportion$$

where the numerator alone (capture proportion) corresponds to the current ISO index for trap selectivity. The denominator (population proportion) is that proportion of the entire population of possible trapped animals (of all species) made up of members of the target species. A value of 1.0 for W indicates no selectivity.

Comparing selectivity measures

To demonstrate the inadequacy of the ISO selectivity index to quantify selectivity we compared results obtained using the ISO index with those derived from Savage's index (W; Manly et al. 2002). We considered five hypothetical scenarios using different capture proportions (as mentioned before, capture proportion equates to the ISO selectivity index) and realistic values for relative species abundance, and capture sample sizes (we considered a total sample of twenty captured animals for each scenario). The captures were hypothesised to be of four common carnivore species in Mediterranean environments, as derived from the literature (data for red foxes *Vulpes vulpes*, Cavallini and Lovari 1994; stone martens *Martes foina*, Genovesi et al. 1997; Eurasian badgers *Meles meles*, Rosalino et al. 2004; and European wildcats *Felis silvestris*, Monterroso et al. 2009). It is realistic to visualise that foxes are the target species while the others are non-target species. Expected capture frequencies for each scenario were calculated according to relative species abundance (if individuals of each had equal likelihood of capture). Results are shown in Table 1.

W, Savage's index, is not constrained and can range numerically between zero and infinity. For all scenarios considered we visualised that foxes were 64 % of the community while the other species represented 36 %. In scenarios in which fox capture proportions were 0.6, 0.7 and 0.8 with the other captures being non-target, W for foxes ranged between 0.94 and 1.25, where 1.0 indicates capture of foxes consistent with no selectivity (Table 1). If W values differing from 1 indicate selective capture of foxes, a W of statistically significantly less than 1 indicates fewer fox captures than expected and a W of significantly greater than 1 indicates more fox captures than consistent with no selectivity (see Manly et al. 2002). At the higher fox capture proportions in our analysis (≥0.9), W exceeded 1 by a larger margin than in the scenarios where it was <0.90 (it was 1.41 and 1.48

Table 1 Illustration of the lack of selectivity represented by the ISO selectivity index, using five hypothetical scenarios for trapping foxes and sympatric species in Mediterranean environments

| Species	W	B	Relative species abundance	Expected (based on relative species abundance)	Capture proportion (ISO selectivity index)	Observed (based on ISO selectivity index)	χ^2	P
Scenario 1								
Red fox	0.94	0.2	0.64	12.8	0.6	12		
Wildcat	1.25	0.27	0.12	2.4	0.15	3		
Badger	0.62	0.13	0.16	3.2	0.10	2		
Stone marten	1.87	0.4	0.08	1.6	0.15	3		
Total	4.69	1.00	1.00	20	1.00	20	0.139	0.71
Scenario 2								
Red fox	1.09	0.30	0.64	12.8	0.7	14		
Wildcat	1.25	0.35	0.12	2.4	0.15	3		
Badger	0.62	0.17	0.16	3.2	0.1	2		
Stone marten	0.62	0.17	0.08	1.6	0.05	1		
Total	3.59	1.00	1.00	20	1.00	20	0.313	0.58
Scenario 3								
Red fox	1.25	0.41	0.64	12.8	0.80	16		
Wildcat	0.83	0.27	0.12	2.4	0.1	2		
Badger	0.31	0.10	0.16	3.2	0.05	1		
Stone marten	0.63	0.21	0.08	1.6	0.05	1		
Total	3.02	1.00	1.00	20	1.00	20	2.222	0.14
Scenario 4								
Red fox	1.41	0.66	0.64	12.8	0.9	18		
Wildcat	0.42	0.19	0.12	2.4	0.05	1		
Badger	0.31	0.15	0.16	3.2	0.05	1		
Stone marten	0	0	0.08	1.6	0	0		
Total	2.13	1.00	1.00	20	1.00	20	5.87	**0.02**
Scenario 5								
Red fox	1.48	0.78	0.64	12.8	0.95	19		
Wildcat	0.42	0.22	0.12	2.4	0.05	1		
Badger	0	0	0.16	3.2	0	0		
Stone marten	0	0	0.08	1.6	0	0		
Total	1.90	1.00	1.00	20	1.00	20	8.34	**0.004**

The table shows the Savage selectivity index (W = capture proportion/population proportion), B (values of W, standardised such that they sum to 1.0, and can therefore be compared across scenarios), relative species abundance, expected capture frequencies according to relative species abundance (if species captured at random, i.e. no selectivity), capture proportion under the H_0 of no selectivity (number of captured target animals/total number of captured animals, this equates to the ISO index), observed capture frequencies under five scenarios (representing the proportion of species captured) and χ^2 and P values associated with differences between expected and observed frequencies. Data for non-fox captures were combined for statistical purposes (assumptions of the χ^2 test depend on expected values being sufficiently large; a convention that they are not ≤5 is widely used). Statistically significant selectivity in capture frequencies for fox and non-fox species compared with that based on relative species abundance were demonstrated only where ≥90 % of animals captured were foxes (scenarios 4 and 5, see P values in bold). W for foxes approximates to 1 where the proportion of foxes captured is close to the relative abundance of foxes, this indicates random capture of (no selectivity for) this species; see scenarios 1, 2 and 3. Where W is significantly greater than 1 for foxes, trapping is selective for this species (see scenarios 4 and 5). Selectivity (W) is greater for wildcats than foxes under scenarios 1 and 2

respectively), indicating greater selectivity for this species. The selectivity present where fox capture proportion was <0.9 did not result in statistically significant selectivity ($\chi^2 \leq 2.22$, $P \geq 0.14$). In scenarios where fox capture proportion was ≥ 0.9, selectivity for foxes was statistically significant ($\chi^2 \geq 5.87$ $P \leq 0.02$). These results relate to the exact (and realistic) sample sizes used here. Of course, if sample sizes were large enough there would be sufficient statistical power to detect effect sizes of the magnitudes illustrated in Table 1 for all scenarios. For example, for the effect size in scenarios where fox captures are 0.6, 0.7 and 0.8 of the total, statistical power does not reach 0.90 (that is, the incorrect null hypothesis is rejected with a probability of 0.90), until total sample sizes reach 2391, 1055, and 149 respectively (calculated with GPower; Faul et al. 2009).

Interestingly, in scenarios 1 and 2, W was greater for wildcats than for foxes (Table 1). This demonstrates that where species availability is taken into account, it is quite possible to detect greater selectivity for a non-target endangered species than for the target species. In other words, this simple simulation demonstrates how different estimates of selectivity can result from the same capture data, depending on whether a simple rate (capture proportion) or a true selectivity index is used.

Using a simple graphical model we show that the capture proportion is not an appropriate index of trap selectivity (Fig. 1). We show how the selectivity index, B (W, standardised to constrain values between 0 and 1, e.g. W for one species/sum of W for all species, with values close to 0 and 0.5 indicating non selectivity and only values close to 1 indicating selectivity), changes according to the relative abundance of two species in a community, when the capture proportion for the two species remains constant. Where relative abundance for species 1 is high and that for species 2 is low, the standardised index

Fig. 1 The true selectivity index, B (standardised W), changes according to the relative abundance of two species in a community when the capture proportion for the two species remains constant (species 1, 0.7 and species 2, 0.3). Where relative abundance for species 1 is high (0.8, Fig. 1 point A_1) and that for species 2 is low (0.2, Fig. 1 point A_2), the standardised index of selectivity, B, for species 1 is small (0.37) and that for species 2 is large (0.63). Where species 1 is present at low relative abundance (B_1) and species 2 at high relative abundance (point B_2 on Fig. 1), the relative value for B is reversed: large for species 1 (0.90) and small for species 2 (0.10)
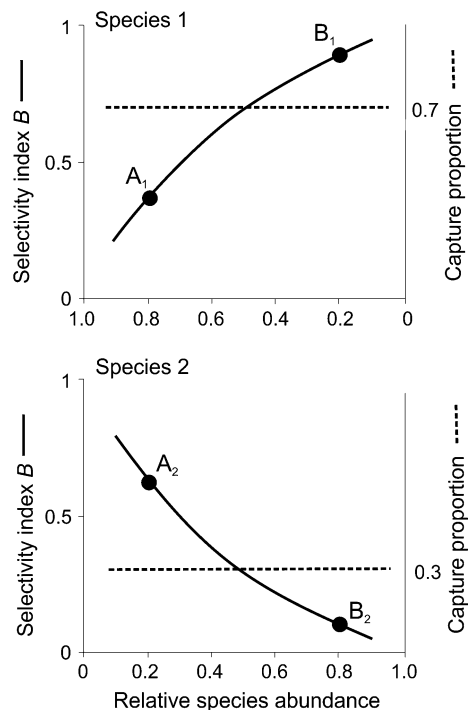
of selectivity (B), for species 1 is small and that for species 2 is large. Where species 1 is present at low relative abundance and species 2 at high relative abundance, the relative values for B are reversed: large for species 1 and small for species 2 (Fig. 1). These two simple examples using identical capture proportions demonstrate clearly the importance of considering relative species abundance in determining the selectivity of a trap, and that raw capture proportions can overestimate or underestimate selectivity.

In summary, Table 1 and Fig. 1 show that: (1) the ISO selectivity index is a defective index of selectivity; (2) for a community comprising foxes, wildcats, badgers and stone martens, in the relative species abundances shown, trap selectivity for red foxes could be demonstrated only for the realistic sample size considered when capture proportions are 0.9 or greater (where the proportion is lower, the statistical test fails to reject the H_0 of 'no selectivity' a type 2 error); and (3) good quality information, on species occurrence and their relative abundance, is required to determine the selectivity of a trapping device (according to arguments by Manly et al. 2002).

Potential risks for carnivore conservation

Our approach illustrates how deriving indices using concepts not supported by ecological theory can generate spurious results (see Anderson et al. 2001). The effects can be damaging for conservation if, for example, environmental authorities base decisions regarding the legality of traps upon them. Defective ISO-like indices of selectivity (in the sense that they are merely capture rates) are being used worldwide for testing traps, e.g., in Australia (Fleming et al. 1998), South America (Luengos-Vidal et al. 2003), USA (e.g. Shivik et al. 2005), Canada, Europe and Africa (see 15 studies reviewed by Iossa et al. 2007). In the study case of Spain, authorities are encouraging both the testing of trap selectivity specifically using the ISO guidelines, and the participation of administration technical staff in the scientific teams carrying out the studies—the results thus obtain the formal support of the authorities. As a consequence, the Ministry of Agriculture, Food and the Environment in Spain (MAGRAMA) has decided that a number of traps are selective for red foxes (MAGRAMA 2011), based on studies conducted by Muñoz-Igualada et al. (2008, 2010). The impact of this is that regional Spanish authorities are now widely considering granting legal approval for the use of certain traps on hunting grounds, including Spanish traditional snares (allegedly selective, according to Muñoz-Igualada et al. 2008, 2010, and the ISO standards). However, this type of snare accounts for the largest proportion of recorded mortality of the most endangered Iberian predator, the Iberian lynx *Lynx pardinus* (Rodríguez and Delibes 2004; Cabezas-Díaz et al. 2009), clearly showing that these traps are not selective. Following guidelines produced by MAGRAMA (2011), the Autonomous government of Castilla La Mancha region approved Order 18/06/2013, which allows the use of several purportedly selective traps for foxes, including both traditional and new designs of snare. Following this Order, the deployment of 1207 snares was approved in two provinces bordering the critically endangered population of Iberian lynx, jeopardising the survival of dispersers and colonisation of new areas, hence putting at serious risk the survival of the most threatened felid in the world (in fact, an Iberian lynx was captured in one of these approved snares in May 2015; see Iberlince 2015).

Likewise, non-selective trapping (due to the use of putative selective devices according to ISO index or similar) of red foxes in Europe may jeopardize other endangered species, such as the European wildcat (Lozano and Malo 2012), and populations of two key species for

maintaining ecosystem function, the Eurasian lynx *Lynx lynx* and the grey wolf *Canis lupus* (Breitenmoser 1998; Ripple et al. 2014). Snares designed to capture coyotes *Canis latrans* in North America (e.g. Shivik et al. 2005) could also catch wolves and other species. Furthermore, trapping of South American foxes, such as the pampas fox *Pseudalopex gymnocercus*, could lead to the depletion of endangered neotropical felids (Luengos-Vidal et al. 2003). Therefore, similar studies are needed in these regions, dealing with these carnivores and others, to test if the pattern found in Spain is being repeated elsewhere.

Although many devices are designed to capture mainly carnivores, many taxa are also negatively affected by non-selective trapping. For example, they often catch substantial numbers of non-target mammals, e.g. ungulates and lagomorphs, endangered birds (eagles, hawks, owls, vultures, etc.) and even reptiles (see Fleming et al. 1998; Luengos-Vidal et al. 2003; Shivik et al. 2005; Iossa et al. 2007; Garrido 2008; Muñoz-Igualada et al. 2008, 2010). Furthermore, it is logical to expect that changes in populations of large carnivores, such as wolves, dingoes *Canis dingo* and big cats, including lynxes and pumas *Puma concolor*, might cause profound changes to ecosystem structure and function, due to negative cascading effects, which can potentially affect plant, bird, mammal, herpetofauna, and invertebrate richness or abundance, as well as soil erosion and stream morphology (see Ripple et al. 2014). So, the urgent study of the effect of the ISO standards-based trapping (wherever this is performed) upon structure and function of ecosystems, is also of the major importance.

ISO standards in general are internationally respected and authorities would be willing to adhere to them as a sign of good practice. But if the ill-defined concept of ISO selectivity remains unchanged, the approval of non-selective traps based on capture proportion data will be extended elsewhere in Europe and beyond, further undermining attempts to conserve carnivore communities and, in the worst case, overall biodiversity (Lozano et al. 2013; Ripple et al. 2014).

The source of the ISO problem

One might wonder how the ISO guidelines could prove so inadequate for their apparent intended purpose. The most likely reason is that the committees that approve ISO guidelines consist not only of scientists, but of different and often opposing stakeholders (Harrop 1998; Iossa et al. 2007). ISO guidelines tend to be the result of negotiation among conflicting interest groups, often based on little more than incomplete minimum agreements (e.g. Harrop 1998, 2000; Iossa et al. 2007). As a result, some ISO definitions and methodologies may not be consistent with scientific knowledge (as it is the case considering the concept of selectivity, Manly et al. 2002) and/or sufficiently accurate (Powell and Proulx 2003; Harris et al. 2005; Iossa et al. 2007; Proulx et al. 2012).

We highlight the weakness of the ISO guidelines generation process (see also Bialous and Yach 2001), and call for independent tests of scientific consistency as a condition for validating ISO guidelines.

Conclusions and recommendations

Trap selectivity is an important issue with potentially wide implications for the conservation of endangered carnivores. It is essential that trap selectivity is properly assessed (i.e. according to scientific methodology), by accounting for relative species abundance, before

traps are approved for widespread use. However, field trials with predators are extremely labour-intensive and we certainly do not under-estimate the scale of additional effort required to account for relative species abundance in calculating absolute trap selectivity.

The definition of trap selectivity used in the current ISO guidelines is flawed, as demonstrated here, and approving traps using these guidelines poses a threat to the conservation of endangered species, such as, for example the Iberian lynx in Spain. Policymakers should redraft the ISO guidelines, which are inadequate. Importantly, trap selectivity should be redefined, to incorporate the relative abundance of species; for example, Savage's W index (with a threshold value ≥ 1.4 indicating selectivity) or similar could be used (see Manly et al. 2002). Traps in current use should be reassessed according to the new definition. The ISO guidelines should clarify the difference between relative and absolute selectivity. The guidelines also need to specify how the two measures of selectivity can be legitimately used, and clarify that measures of selectivity cannot simply be extrapolated elsewhere.

In field tests, trap setting and checking should be done consistently (the basic design indicated by ISO standards being correct). Tests should be conducted under comparable ecological conditions (considering not only vegetation type, but also weather, season, species assemblage, etc.), and accounting for temporal variation in selectivity. To take into account population proportion (in order to consider animal availability), and calculate correct values of the W index (or similar), previous estimates of animal populations should be obtained, by applying standard census techniques (e.g. Sutherland 2006; Long et al. 2008; O'Connell et al. 2011).

Furthermore, wildlife researchers with experience in animal trapping need to be as involved as policy-makers in the drafting of policies. Both researchers and authorities interpreting research on trap selectivity need to be mindful of what they mean by 'selective'; a trap can be relatively more selective than another but may not be of adequate absolute selectivity, threatening endangered carnivores as a consequence. What is happening in Spain could also occur in other countries, this case providing a basis of concern for conservationists. We recommend that further studies are conducted outside Spain and Europe in order to obtain a more global perspective of the scope of the problem.

Where selective devices for trapping or controlling animals are not yet available, selective procedures such as shooting, or habitat management, can be applied where appropriate. New traps can also be developed; these will need to be tested for absolute selectivity using the new ISO standards before approval.

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