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PERSPECTIVE

AvianBuffer: An interactive tool for characterising and managing wildlife fear responses

Patrick-Jean Guay, Wouter F. D. van Dongen, Randall W. Robinson, Daniel T. Blumstein, Michael A. Weston

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Abstract The characterisation and management of deleterious processes affecting wildlife are ideally based on sound scientific information. However, relevant information is often absent, or difficult to access or contextualise for specific management purposes. We describe 'AvianBuffer', an interactive online tool enabling the estimation of distances at which Australian birds respond fearfully to humans. Users can input species assemblages and determine a 'separation distance' above which the assemblage is predicted to not flee humans. They can also nominate the diversity they wish to minimise disturbance to, or a specific separation distance to obtain an estimate of the diversity that will remain undisturbed. The dataset is based upon flight-initiation distances (FIDs) from 251 Australian bird species ($n = 9190$ FIDs) and a range of human-associated stimuli. The tool will be of interest to a wide audience including conservation managers, pest managers, policy makers, land-use planners, education and public outreach officers, animal welfare proponents and wildlife ecologists. We discuss possible applications of the data, including the construction of buffers, development of codes of conduct, environmental impact assessments and public outreach. This tool will help balance the growing need for biodiversity conservation in areas where humans can experience nature. The online resource will be expanded in future iterations to include an international database of FIDs of both avian and non-avian species.

Keywords Buffers · Co-existence · Flight-initiation distance · Human-wildlife conflict · Wildlife management

INTRODUCTION

The difficulty with which scientific findings are translated into management outcomes has been evident for several decades (Roux et al. 2006), and frustrates diverse stakeholders including ecologists, land managers and policy makers. Part of the difficulty lies in either the lack of generalisability and applicability, and therefore transportability, of scientific results or indeed the complete absence of accessible data (Johannes 1998; Holmes 2006). One solution to this is to provide available data and permit the customisation of scientific data such that stakeholders can apply data themselves in a contextually relevant manner (Roux et al. 2006). This may be a tractable strategy especially where traits are species- rather than area-specific, and where species are widespread, occurring across many areas of publically managed land on which stakeholders wish to implement suitable policy, land-use planning and/or management.

One key issue facing stakeholders is how to balance the increasing demand on public open space for humans (e.g. recreation) with the needs of the animals which inhabit those areas (Madden 2004). For animals, the mere presence of humans can disrupt their normal behaviour, a process called 'disturbance' (Hill et al. 1997; Frid and Dill 2002; Blumstein et al. 2005; Weston et al. 2012). Disturbance has been linked to declines in some species, and is a key threatening process for some threatened species (e.g. Weston et al. 2011). A key to sustainable management of disturbance is spatial separation between the wildlife and

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the entity to which they might respond (i.e. the ‘stimulus’; Weston et al. 2009).

The response of wildlife to external stimuli may be quantified via various behavioural metrics (Cooper and Blumstein 2015). Alert distances (AD) describe the distance between the focal individual and the approaching threat at which the animal does not yet flee, but overtly initiates vigilance (Fernández-Juricic et al. 2001; Cooper and Blumstein 2015). The physiological-initiation distance (PID) is the distance at which a physiological response (e.g. increased heart rate or production of stress hormones) is first initiated (Weston et al. 2012). The distance from a stimulus at which an animal initiates a flight (escape) response is known as the flight-initiation distance (FID). Both AD and FID are useful for the characterisation and management of wildlife disturbance (Fernández-Juricic et al. 2001; Rodgers and Schwikert 2002; Fernández-Juricic et al. 2005; Weston et al. 2012), although AD can be more difficult to accurately quantify (Guay et al. 2013a). In contrast, whilst it could potentially be very useful, PID is not used due to difficulties in collecting measurements. FID represents the minimum distance at which an individual tolerates the presence of a potentially threatening stimulus and is therefore useful for the estimation of buffers around habitat where animals occur or minimum approach distances of humans and human-associated activities (Rodgers and Smith 1995; Rodgers and Schwikert 2002; Fernández-Juricic et al. 2005).

On several continents, longer FIDs are associated with species declines (Møller et al. 2014), and they might have insidious effects such as the creation of ecological traps (Gilroy and Sutherland 2007). Thus, they are of conservation concern. Animal fear responses also have an animal welfare dimension, because at the individual animal level, excessive fear is likely to compromise the wellbeing of affected animals (Weston et al. 2012). Generally, relevant stakeholders have responded to issues such as disturbance by declaring large off-limits areas. While largely but not completely effective, in terms of reducing human presence (Antos et al. 2007), this strategy is achieved at the cost of coexistence, which can engender a lack of awareness of the value of wildlife and habitats (Markovchick-Nicholls et al. 2008).

This paper describes an online tool designed to assist with achieving coexistence between humans and wildlife. It focuses on Australian birds, but the tool will likely be expanded to include other wildlife. This paper describes the initial version, but user feedback is likely to generate future modifications and improvements.

The tool uses flight-initiation distances to make recommendations on appropriate “separation distances” that will minimise disturbance of wildlife by human-related activities. Three basic approaches may be applied for using flight-initiation distance data when managing disturbance to wildlife. These approaches depend on whether the stimulus, habitat or responder is being buffered (Fig. 1). First, FIDs can be used to describe the zone of disturbance associated with a certain stimulus (e.g. Weston et al. 2009). Zones of disturbance are defined around nodes or corridors of human activity and stimuli that are more threatening to wildlife will be associated with larger disturbance zones. This information is useful for assessing how far the effect of a stimulus carries through a habitat from a node or corridor, and understanding these patterns can inform impact assessments. Second, buffer zones around habitat exclude certain human activities occurring within a set distance from that habitat (e.g. Fernández-Juricic et al. 2005; Glover et al. 2011; Weston et al. 2012). Buffers therefore aim to promote the continuation of normal behaviour and habitat use by wildlife (i.e. that behaviour which would occur in the absence of disturbance by human activities). Last, minimum approach distances are centred around the animal (e.g. Holmes et al. 2005; Schlacher et al. 2013). They are essentially a “mobile buffer” and describe the closest distance at which human activities can occur around an individual or group of individuals without causing disturbance. These conceptually permit wildlife to roam undisturbed by humans. Potential applications of these three basic approaches are described in more detail below.

THE DECISION TOOL

The ‘AvianBuffer’ tool is available at www.avianbuffer.com. The purpose of the decision tool is to enable stakeholders to establish a scientific baseline for characterising and managing disturbance to birds. As such, the tool should be user-friendly (including being time efficient to use), and produce readily interpretable outputs. The tool also should be accessible, free of charge and based on credible data. An additional criterion was that the data had to be contemporary, and reflect the current state of knowledge (i.e. be readily updatable). While data on FIDs have been published (e.g. Blumstein 2006; Weston et al. 2012; Guay et al. 2013b), and occasionally included datasets (as opposed to textual tables) of many taxa (Garnett et al. 2015), none of these current offerings enables easy customisation of results. Customisation is required because, for example, stakeholders typically face the issue of having to manage multiple species at any one site, with assemblages differing between sites, or they have specific species priorities. Furthermore, most of the data available is reported as mean FID which may have limited use in designing buffers (Fernández-Juricic et al. 2005).

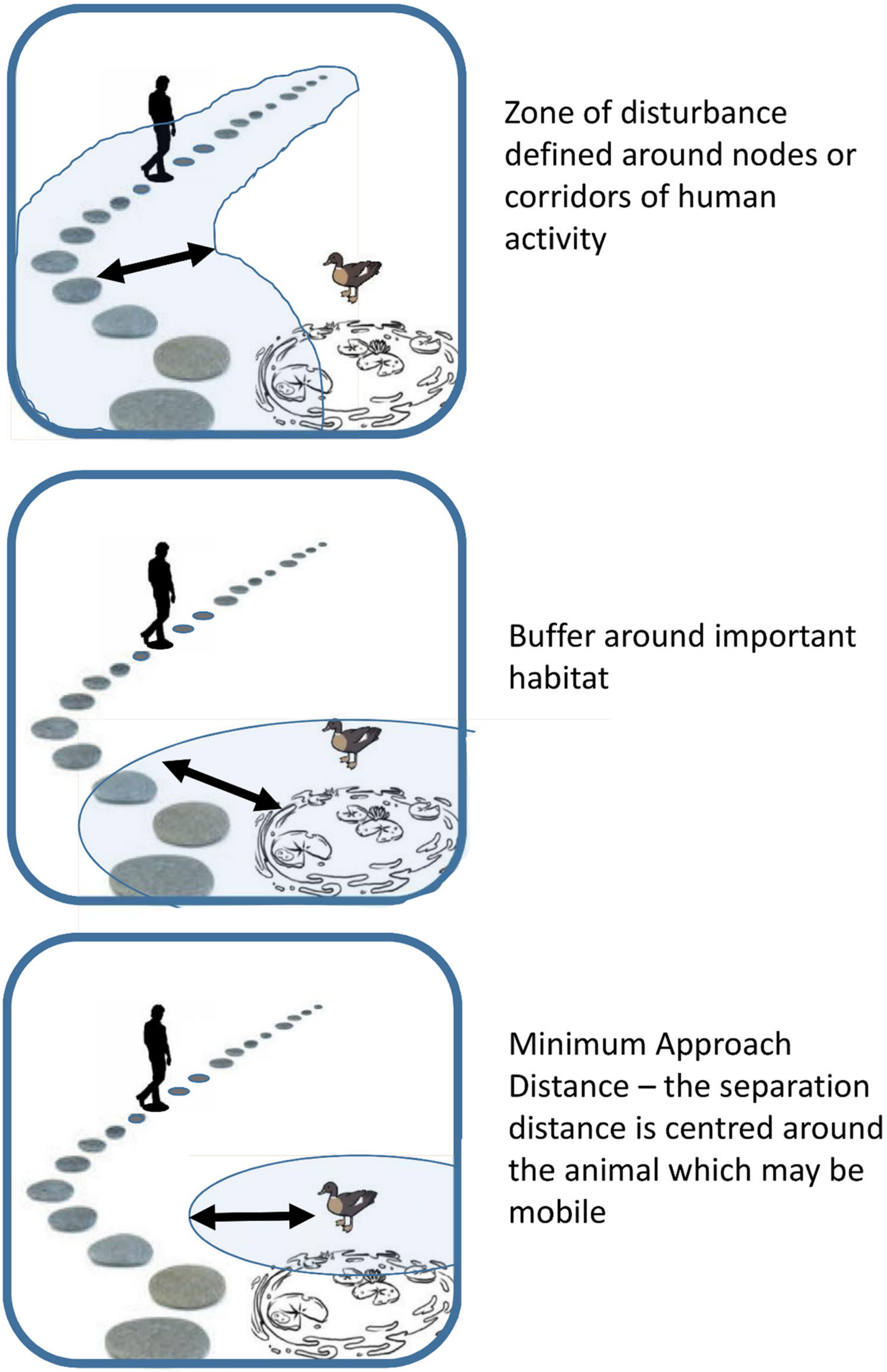

Fig. 1 Schematic of how FID information may be applied to managing disturbance to birds. Three basic approaches are shown. Each *panel* shows a wetland, a pathway, and a wild bird. The zones of interest are indicated for a set distance (*shading* and a *black arrow*)

Data collection

Flight-initiation distance data were collected throughout Australia by our research team. The first data were collected in 1995 and data collection is ongoing as new locations and species are targeted. Approximately 40 researchers have thus far contributed to the database, with consistency in FID estimates tending to be high amongst researchers (e.g. Guay et al. 2013a). All researchers have used consistent methods for data collection (following for example Weston et al. 2012; Guay et al. 2013c; van Dongen et al. 2015a). Essentially, an investigator approaches a bird and measures the distance at which: (1) the approach began (Starting Distance; SD), (2) the bird became vigilant (AD; if possible) and (3) the distance at which it initiates escape (FID). 'Tangential approaches' were conducted when birds could not be approached directly. 'Elevated approaches' involved birds positioned above an investigator. This involved approaching at a tangent from, or from below, the focal individual, but measuring direct distances for SD, AD and FID (Fernández-Juricic et al. 2005).

While the investigator represents a threatening stimulus (which permits study of animal escape ecology and risk aversion) they also mimic the presence of humans in a landscape, for example, as recreationalists (which permits the study of the applied aspects of wildlife responses). FID data in response to a wide variety of human-associated stimuli have already been collected on Australian bird species by our research team, including single pedestrians (e.g. Blumstein 2003; Guay et al. 2013c; Møller et al. 2014), groups of pedestrians (e.g. McLeod et al. 2013), leashed dogs (e.g. Glover et al. 2011), and cars, canoes, buses and bicycles (e.g. McLeod et al. 2013; Guay et al. 2014, Glover et al. 2015). Individual attributes of the stimuli may also influence FIDs, such as pedestrian clothing colour (Gutzwiller and Marcum 1993) or noise levels (Karp and Root 2009), but data are currently lacking for Australian bird species.

The data

A static version of the summarised, and slightly outdated, dataset is available in Weston et al. (2012) and Garnett et al. (2015). These, however, are based on single species reporting and do not readily permit analysis of multi-species sets (species occur in many different assemblages or permutations across sites). The first version of the tool uses 9190 FIDs from 251 Australian bird species (36.6 ± 60.7 Standard Deviation per species; range = 1–377). FIDs are mostly derived from standardised experimental pedestrian approaches to birds (89.4 %), while others are in response to groups of walkers (0.9 %), cars (3.2 %), buses (1.5 %), bicycles (1.0 %), canoes (0.6 %), joggers (1.6 %) and walkers with leashed dogs (1.8 %). The tool is updated manually on an approximately monthly basis as new data become available. Additional data will increase replication for species already represented, add additional species, increase availability of data for the various stimuli and broaden the variety of stimuli for which data are available.

Reporting flight-initiation distances

The tool reports FID rather than AD because the former is reliably collected when there are multiple investigators (Guay et al. 2013a). Importantly, there are more FID available than there are AD data which maximise the taxonomic scope of the tool. However, AD may also be incorporated into future versions of this tool because it may provide a more robust estimate of desirable separation distances (i.e. vigilance reflects presumably low-intensity disturbance; Fernández-Juricic et al. 2001, 2005).

One complication of FID data is the influence of SD, which is usually positively related to FID (Blumstein 2003). SD is a decision made on the part of the investigator and has no biological or applied value (though 'screening', for example through the use of walls or trees, could conceptually alter SD at a site). The current version of the tool presents all FIDs, unstandardized for SD. This may represent a more natural situation whereby effective start distances by pedestrians in natural areas vary greatly. Future iterations of the tool may include the capability of users to adjust SD to reflect the visibility of humans to birds at different sites varying in habitat density (i.e. the distances at which humans are detected).

A number of methods have been used by researchers to estimate appropriate separation distances based on both FID and AD (reviewed in Fernández-Juricic et al. 2005). Separation estimates may vary markedly based on the mathematical calculation used. Based on their study system, Fernández-Juricic et al. (2005) concluded that a robust method to calculate separation distances incorporated 95th percentiles of FIDs (see also Rodgers and Smith 1995; Rodgers and Schwikert 2002). We therefore also based our estimates of separation distances on 95th percentiles. This follows a precautionary approach and provides an appropriately conservative estimate of the distances at which disturbance commences, while reducing the sensitivity of our estimates to large outliers in the FID dataset.

As with any data, FID summary statistics can be reported in a variety of ways (Glover et al. 2011; Glover et al. 2015). We considered two candidate statistics: (1) the 95th percentile of raw FID data (95^{th}_raw) and (2) the 95th percentile calculated using the formula $95^{th}\_StDev = \text{mean} + 1.645*$(standard deviation). The two measures were highly correlated (spearman $r = 0.982, n = 251, P < 0.001$; Fig. 2). Overall, the 95^{th}_StDev resulted in higher estimates than 95^{th}_raw for 60.6% of all species included in the database. A key criterion for metric selection was how each performed at low sample sizes (Fig. 3). We therefore subtracted 95^{th}_StDev from 95^{th}_raw and correlated this difference with the number of FIDs collected for each species. The association was logarithmic, with 95^{th}_StDev resulting in much higher estimates than 95^{th}_raw at low sample sizes, while 95^{th}_raw

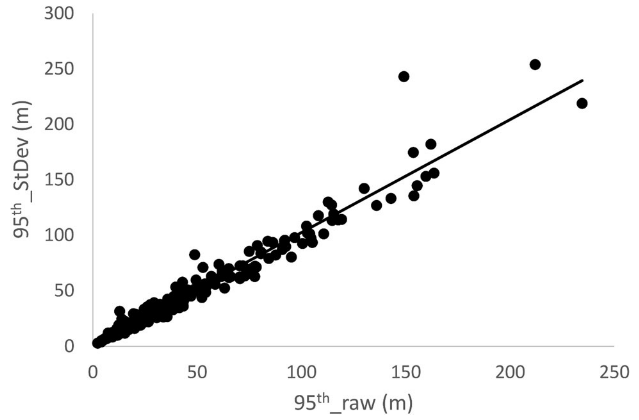

Fig. 2 A comparison of two measures of Flight-initiation Distance (FID): 95th percentile of raw data and that derived from the 95th percentile calculated using the formula (mean + 1.645[standard deviation]). Each *dot* represents a species

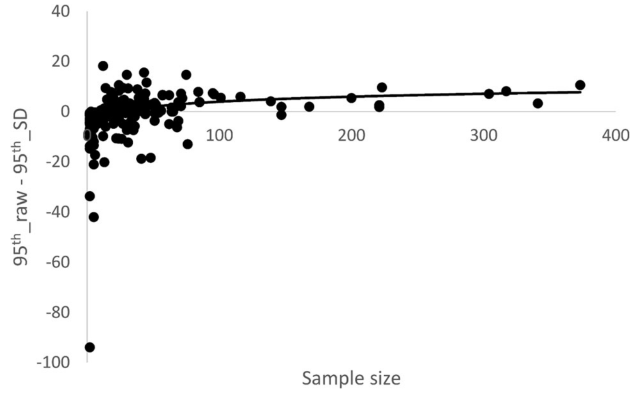

Fig. 3 The influence of sample size on the relative value of two metrics of Flight-initiation Distance (FID): (1) 95th percentile of raw data and (2) the 95th percentile calculated using the formula (mean + 1.645[standard deviation]). The *x*-axis shows the difference (in m) between metric 1 and 2. Each *dot* represents a species

resulted in slightly higher estimates than 95^{th}_ *StDev* at high sample sizes (logarithmic curve: $r^2 = 0.175$, $F_{1,249} = 52.829$, $P < 0.001$; Fig. 3). Overall, 95^{th}_ *StDev* was more often higher than 95^{th}_*raw* and we therefore conservatively use this measure for outputs as a modest and acceptable overestimation of appropriate separation distances in preference to the risk of underestimation.

We acknowledge that both our measures of the 95th percentile are problematic in certain ways (e.g. both are based on non-normal distributions). For multiple-species analyses (i.e. those which involve FID data from > 1 species), the 95th percentile of the most sensitive species (i.e. the species with the longest FID) is reported. When only one FID is available for a specific species and stimulus, then the raw value of that FID is given.

Users of the tool will likely be interested in the confidence in our estimates of the 95th percentile. For example, the estimates are derived from between 1 and 373 FIDs per species. To test how estimates of the 95th percentile vary with sample size, we conducted a bootstrapping analysis for species for which more than 150 FIDs were available for the single pedestrian stimulus ($n = 9$ species). For each species, we estimated the 95th percentile for a range of sample sizes between $n = 2$ and $n = 150$, using 1000 bootstrap randomisations per sample size. The 95th percentile tends to be underestimated at low sample sizes, but plateaus at sample sizes of approximately 20 FIDs (Electronic Supplementary Material, Fig. S1). We therefore defined three categories of confidence comprising "lower" when $n < 5$, "medium" when $5 \leq n \leq 19$ and "higher" when $n \geq 20$. The tool allows the user to select a confidence level for the subsequent analyses. If a "higher" confidence level is selected, then all subsequent proposed separation distances will be based on the 95th percentiles of the selected species for which at least 20 FIDs are available for the nominated stimulus. We suggest that care is taken to select an appropriate confidence level for analyses. Using a low level of confidence may result in misleading separation distances that are calculated from a very low number of FIDs. We base our estimates of confidence on sample size rather than other measures of data variability (e.g. coefficients of variation) because it is a more direct measure of the robustness of the percentile estimate. For example, coefficients of variation reflect variation around the mean instead of around the 95th percentile.

Following Lessells and Boag (1987), we calculated repeatability of FIDs within species, not corrected for SD. Repeatability was calculated twice, including once for two randomly selected individuals of each species that occurred at the same site and again for two randomly selected individuals that occurred at sites separated by at least 100 km (mean distance = 855 ± 441 Standard Deviation km; range = 223–2282 km). For this analysis, we only used those species that had at least two FIDs from one site and at least one FID from a second site that was located at least 100 km away. Repeatability of FIDs was very high both within sites (repeatability = 0.990, $F_{1,176} = 192.990$, $P < 0.001$) and across sites (repeatability = 0.948, $F_{1,176} = 37.291$, $P < 0.001$). These results are in accordance with previous studies (e.g. Garamszegi et al. 2014; Møller 2014; van Dongen et al. 2015b) and suggest that variability in FID is much greater between species than it is within species. This justifies the use of a small number of FIDs per individual and multiple FIDs from contrasting sites or habitats (see below).

User inputs and outputs

The tool allows a substantial degree of flexibility, permitting the user to define multiple parameters in the analyses.

The current version of the tool enables three basic functions, which were considered to be of particular interest to those managing human disturbance to birds.

1. The derivation of appropriate separation distances between humans and wildlife, for user-specified multispecies sets and a range of human-related stimuli.
2. The ability to nominate a separation distance and examine which species are 'retained'. In this context, 'retained' refers to the maintenance of undisturbed behaviour and habitat use to the original extent by the focal species'.
3. The ability to nominate the percentage of species that are desirable to retain (i.e. the diversity of species which will remained undisturbed), and obtain the separation distance above which this would be predicted.

Once the analysis has been conducted, an option exists to generate an electronic record of the output. The user-specifications are reiterated in the output.

Assumptions and caveats

A series of assumptions are made by the analyses that underlie the tool, which are often difficult to meet (Fernández-Juricic et al. 2005). Important caveats should also be noted in the application of the tool. Many assumptions and caveats are discussed in detail in Fernández-Juricic et al. (2005). Assumptions include:

1. Multispecies interactions do not influence FID. Currently, multispecies FID data are unavailable, and are not anticipated to be available in the near future given the high number of possible species permutations.
2. Variation between areas in FID is reasonably minor. This is supported by the above finding that repeatability is high within species and across sites. However, some species have lower FIDs in areas where humans are frequent (Møller 2008; Kitchen et al. 2010; van Dongen et al. 2015b). Importantly, the existence of lower FIDs (which is often attributed to habituation) is not necessarily benign to the species which exhibit them, and could indicate selection for the boldest individuals rather than within-animal learning (Weston et al. 2012; Sol et al. 2013; van Dongen et al. 2015b). This would be an insidious process which alters species dynamics and habitat use, and is of conservation concern. Our measures of FID (currently pooled across urban and rural areas) generally include both habitats for most species, so our metrics would seem reasonable in terms of avoiding selection towards bold animals. Future iterations of the tool will also feature a coarse habitat selection tool.
3. SD is random across FIDs and does not unduly influence the results. In an applied sense, we contend that SD is dictated by site characteristics which influence the distance at which birds detect approaching humans. Such characteristics could also vary within a site. Future iterations of the tool may incorporate an SD adjustment tool for species in which enough data are available.
4. The type of approach (e.g. direct or tangential) does not influence the FID. This may not always be the case (e.g. Burger and Gochfeld 1981; Fernández-Juricic et al. 2005). The majority of our data (94 %) were generated from direct approaches. The direction and difference between FIDs from direct and tangential approaches varies greatly between species (Fernández-Juricic et al. 2005), and general conclusions on their effects on recommended separation distances are therefore difficult to make. However, the variation in FID between approach types is typically much smaller than variation between species (Fernández-Juricic et al. 2005) and within our dataset, FID did not differ between direct and tangential approaches (McLeod et al. 2013).

Caveats associated with the tool include

1. The recommended separation distances calculated by the tool do not include AD. Therefore, target species may show some response (i.e. increased vigilance) to approaching humans outside the separation distance recommended by the tool. Given our conservative approach to estimating appropriate separation distances and the relatively small differences between AD and FID typical in many species (e.g. Fernández-Juricic et al. 2001, 2005), the recommended separation distances may often include the distance at which birds become alert to the approaching stimulus.
2. The probability of detecting an approaching human is constant in space and time. This may not always be true. For example, habitat variation within a buffer zone may influence the detectability of approaching threats, as detectability is lower in denser habitats (Fernández-Juricic et al. 2001; Stankowich and Blumstein 2005). Similarly, FIDs may vary throughout the year or between breeding and non-breeding individuals (Stankowich and Blumstein 2005).
3. Individuals may eventually habituate to the stimulus. Habituation is an often rapid process, but it may not occur in all species or may be more pronounced in some species over others. For example, larger bird species tend to habituate more rapidly to human disturbance than smaller species, while resident species may tolerate humans more than migratory species (Burger and Gochfeld 1991; Samia et al.

2015). In the context of wildlife management, habituation will decrease the disturbance to birds caused by humans and may therefore be favourable (although decreased responsiveness can be maladaptive; e.g. Baudains and Lloyd 2007). However, in the context of pest management, habituation will decrease animal responsiveness to deterring stimuli and multi-faceted approaches must therefore be adopted (see below).

Although many of these above assumptions are difficult to meet, the tool's output is superior to *ad hoc* non-scientifically based separation distances which currently prevail (Weston et al. 2009). In addition, future versions of the tool may allow the user to control some of these assumptions (e.g. reporting FIDs based on direct or tangential approaches, or during the breeding or non-breeding season).

Desirable enhancements

We envisage several enhancements to the existing version (apart from updated data uploads). These fall into two broad categories:

- Scope:
    - An increase of the taxonomic breadth of the tool, to include more bird species but also mammal, reptile and amphibian species.
    - An increase in the geographical scope of the tool to include species from other continents.
    - An enhanced array of stimuli, especially those relevant to major management issues (e.g. dogs, horses, watercraft etc.).
    - A possible predictive component, to estimate FID based on, for example, species mass (Weston et al. 2012) or ancestral phenotypes (Revell 2014). This would enable extrapolation to species for which no data are available, and will require validation.
- Incorporating greater customisation (dealing with covariates) including:
    - Provision to alter the reporting, for example by being able to select a percentile (FIDs are currently calculated using a default 95th percentile).
    - Provision to identify the prevailing regime of human occurrence in a site, which may influence FIDs (see above).
    - Potentially greater reporting or filtering functionality in regard to tangential approaches, or approaches to birds on water as opposed to those on land (see Weston et al. 2012).
    - Provision to examine data over time to establish any trends associated with, for example, population adaptation or management intervention.

APPLICATIONS

A large number of applications of the tool are possible which we anticipate will be of use for a broad audience, although none have been independently validated. In addition, the profile of those who will use the tool, and uptake rates of its applications, are not yet available. The application of publically available large-scale avian datasets is generally poorly known and often unreported (see Dunn and Weston 2008), but this website will have tools which enable the generation of usage statistics. We envisage a wide variety of applications of the tool including within or across sites, and in proactive (i.e. planning for human presence in natural areas) or reactive ways (i.e. assessing possible impacts of human activity). Table 1 outlines a number of target audiences and potential uses of the tool, although this list is by no means exhaustive.

The first target group for the tool is conservation managers, including species, area and threat managers. The tool could recommend buffer zones or 'set-backs' around sensitive habitat, based on a sound scientific basis, at least for buffers which aim to reduce disturbance to wildlife (Weston et al. 2009). As an extension to the setting of buffers, suggested buffers could be used in public consultation processes to act as a basis for socio-politically, as well as ecologically, sustainable outcomes. Glover et al. (2011) reported local public support for buffers of different widths and the proportion of shorebird flight responses associated with different buffer options. Managers can then balance public support (and perhaps compliance) with effectiveness at reducing shorebird disturbance for a range of buffer widths.

Quantifying zones of disturbance may be useful for prescribing certain activities in a given habitat. Human activities could be channelled to establish or maintain buffers, by using infrastructure such as paths or barriers, or humans could be hidden using vegetation or hides (Weston et al. 2012). Alternatively, disturbance could be mediated by prescribing which stimuli occur in particular areas, for example, cars are associated with lower FIDs than for walkers, so may effectively reduce disturbance at some sites (McLeod et al. 2013; Guay et al. 2014).

The tool also has application across sites by altering human behaviours. Buffers could be effectively implemented through codes-of-conduct which specify minimum approach distances, conceptually a mobile buffer around an animal which moves with the animal (e.g. Holmes et al. 2005; Schlacher et al. 2013). This will have important implications for those interested in approaching wildlife such as wildlife photographers and ecotourism operators.

Secondly, the tool will also be of interest to policy makers and land-use planners. For example, the tool could be used to consider the potential impact of the introduction

Table 1 Potential audiences and uses of AvianBuffer. Refer to the text for more detail

Potential audience	Example uses
Conservation managers (including species, threat and area managers)	1. Retention of sensitive species in reserve networks by: (a) creating buffer zones around sensitive habitat (b) prescribing codes of conduct (e.g. which stimuli may occur within reserves) 2. Reduce disturbance as a threat by prescribing minimum approach distances (around mobile animals) for recreationists and eco-tourism operators
Land-use planners and policy makers	1. Incorporation of buffer zones into land-use planning 2. Improved evaluation of impacts of certain activities during Environmental Impact Assessments 3. Better-defined legislative triggers for "significant impacts" which permit efficient government assessment or intervention in proposed developments or changes in prevailing human regimes
Pest/risk managers	Assist in the establishment of effective hazing regimes to discourage habitat use by pests in undesirable locations (e.g., tailings dams)
Animal welfare proponents	Determination of appropriate separation distances between wildlife and humans to minimise stress to wild (or wild captive) animals
Education and public outreach	1. Increase capacity of local communities to collect scientific relevant data for wildlife conservation 2. Educate the public on how to balance human and wildlife considerations so as to achieve coexistence, and in doing so improve awareness of disturbance as threat, and effectively engage the human community 3. Enable groups or individuals to develop their own codes of conduct, which could potentially be customised depending on the species they are likely to encounter
Behavioural and general ecologists	Investigation of species escape behaviour in response to, for example, ecological factors such as internal states, ecosystem change and novel predator regimes

of stimuli into an environment (i.e. how humans will be present within a landscape). In a proactive sense, the data could be combined with spatially explicit species habitat maps to determine optimal areas or "corridors" where stimuli could occur, thus assisting in planning which minimised wildlife disturbance. In a reactive way, it is possible that the impacts (or "footprints") of proposed developments could also conceivably be assessed or minimised, or that such information could feed into debate regarding controversial developments. While many impact assessments focus on the "direct footprint" of developments (i.e. that which is permanently modified) they often neglect the halo-like effect caused by disturbance from increased human presence. For example, a tourist development impacts the area over which the relevant infrastructure will be constructed, and this is usually assessed in terms of its environmental impact. However, the impact of the tourists which will use the facility, and often move into nearby or adjoining areas (e.g. a nearby beach), are often omitted from impact assessments. The impact of the latter process could be assessed partly through the application of the online FID tool. Such information will be of use for policy makers and regulators as they plan land-use and fine-tune processes such as Environmental Impact Assessments. Overall, these applications could optimise the coexistence between people and wildlife.

A third target audience is pest and risk managers, in contexts such as controlling species causing damage to agriculture, buildings or aircraft (Bomford and Sinclair 2002). In essence, the most disturbing stimuli could be used to deter pests from sensitive areas. In these applications, the tool could inform and permit optimisation of management strategies based on frightening ('hazing') and active deterrents. However, a caveat of this application is that pests may habituate to the stimulus (Magle et al. 2005; McCleery 2009) and effective pest control is likely to remain multi-faceted (e.g. alternating between a high number of threatening stimuli or reinforcing the presence of stimuli with actual danger).

The tool could be used by proponents of animal welfare to set guidelines of minimum approach distances to minimise stress to wild animals (e.g. Dwyer 2004). Monitoring of FIDs over time may help inform on the efficacy of efforts to reduce disturbance (e.g. screening and the installation of bird hides), and may even indicate the occurrence or development of extreme habituation, such as that associated with wildlife feeding, a practice considered problematic by many wildlife management agencies (Jones 2011). Incorporating a temporal aspect to the tool is a worthy likely future enhancement.

The tool also offers educational and engagement opportunities for the general public. Education and public outreach officers may use the tool to mobilise local communities and interested parties (e.g., schools) to collect FID data from local wildlife thus employing a "citizen science" model. These data could then be incorporated into the tool which may then be used by land managers for planning and management of local green spaces which includes local community input. Thus, the tool could increase the sense of local communities that they are making genuine contributions to local wildlife conservation and engage them meaningfully in land-use planning. This application will be particularly effective when geographic location is added as a selectable feature in future versions of this tool.

Finally, the tool will be of use to ecologists interested in the causes and consequences of escape strategies in wildlife (e.g. Stankowich and Blumstein 2005). For example, the data available from the tool could be coupled with ecological data to allow ecologists to explore the impacts of changes in ecosystems or predator regimes on escape strategies (Samia et al. 2015). Using phylogenetic approaches, ancestral FIDs and phylogenetic signals could be characterised to estimate FIDs of species for which data are lacking (Revell 2014).

Acknowledgments FIDs need to be collected under animal ethics and other permissions in Australia, and all our FID data were collected with appropriate permissions. Disclaimers on the use of the tool are provided therein. While the tool is provided free to any practitioner managing wildlife, commercial users are requested to contact the authors. We thank the many field volunteers who have collected data that have contributed to this online tool. The tool was funded by the Helen Macpherson Smith Trust and Victoria University.

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AUTHOR BIOGRAPHIES

Patrick-Jean Guay is a Research Facilitation and Development Manager at Victoria University. His past research interests have included the behavioural ecology of musk ducks, hybridisation in native Australian ducks with introduced mallards, correlates of bird brain size with life-history traits and quantifying and managing human disturbance to birds.

Address: Applied Ecology Research Group and Institute for Sustainability and Innovation, College of Engineering and Science, Victoria University, Footscray Park Campus, PO Box 14428, Melbourne, VIC MC 8001, Australia.
e-mail: patrick.guay@vu.edu.au

Wouter F. D. van Dongen is a research fellow at Victoria University. His research interests include understanding genetic and environmental factors which influence the fear of birds towards humans, interactions between bacteria and their animal hosts, animal population genetics and the behavioural ecology of birds.

Address: Applied Ecology Research Group and Institute for Sustainability and Innovation, College of Engineering and Science, Victoria University, Footscray Park Campus, PO Box 14428, Melbourne, VIC MC 8001, Australia.
e-mail: wouter.v.dongen@gmail.com

Randall W. Robinson is the Discipline Group Leader for Science at Victoria University. His research interests include understanding human disturbances to birds, recruitment in *Zostera* seagrass, genetics of *Cymbidium* orchids and chemically mediated growth suppression of native plants by invasive plants.

Address: Applied Ecology Research Group and Institute for Sustainability and Innovation, College of Engineering and Science, Victoria University, Footscray Park Campus, PO Box 14428, Melbourne, VIC MC 8001, Australia.
e-mail: randall.robinson@vu.edu.au

Daniel T. Blumstein is a Professor of Ecology and Evolutionary Biology and a Professor in the Institute of the Environment and Sustainability at the University of California Los Angeles. His research interests include developing predictive models of human disturbance on wildlife so as to better facilitate coexistence in an increasingly urban world.

Address: Department of Ecology and Evolutionary Biology, University of California, Los Angeles, CA, USA.
e-mail: marmots@ucla.edu

Michael A. Weston (✉) is a senior lecturer at Deakin University. His research interests include finding effective solutions that permit the co-existence between people and wildlife.
Address: Centre for Integrative Ecology, School of Life and Environmental Sciences, Faculty of Science, Engineering and the Built Environment, Deakin University, 221 Burwood Highway, Burwood, VIC 3125, Australia.
e-mail: mike.weston@deakin.edu.au