Improving environmental interventions by understanding information flows

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Running title: Information flows and behaviour change

Keywords: communication, social networks, complex contagion, social influence

Word count Abstract: 120

25 Word count Text: 3,418

26 References: 85

27 Figures and tables: 4

28 Boxes: 2

29

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Abstract

Conservationists are increasingly interested in changing human behaviour. One understudied aspect of such interventions is information flow. Different patterns of interpersonal communication and social structures within communities influence the adoption of behavioural changes through social influence and social reinforcement. Understanding the structure of information flow in a group, using tools such as social network analysis, can therefore offer important insights for interventions. For example, communications may be targeted to highly connected opinion leaders to leverage their influence, or communication may be facilitated between distinct subgroups to promote peer-learning. Incorporating these approaches into conservation interventions can promote more effective behaviour change. This review introduces conservation researchers and practitioners to key concepts underpinning information flows for interventions targeting networks of individuals.

Behaviour change and communication

Conservation interventions frequently seek to change people's behaviour to stem human-driven loss of biodiversity [1]. As people respond to information received about the world [2], **transfer of information** is a key component of all interventions (table 1). Many types of information can be used to motivate behaviour change, such as information about the risks and benefits of an activity [3]; **social norms** [4]; or evoking emotional responses [5]. Some behavioural changes are simple and adoption is a direct result of receiving information, but for **complex** (see Glossary) behavioural changes, adoption is mediated through **social influences** and **social reinforcement**, which occurs through further interpersonal communication and **information flow** between peers [6, 7].

Much research is devoted to improving the effectiveness of conservation interventions (e.g. [8]), and researchers increasingly look to the behavioural and social sciences for insight [9], such as in the field of conservation marketing [10]. However, the role of information flows in promoting conservation behaviour change is poorly understood (Table 1). This understanding can help to improve the effectiveness of interventions [11], and applications have been developed in other behaviour-change settings, most notably public health and social marketing (e.g. [12]). Nevertheless, conservation problems differ in important ways from those tackled in these fields, with implications for intervention design. Firstly, many conservation problems require collective action and ask individuals to contribute to public goods [13], while health behaviours often focus on individual benefits and behavioural changes [14]. Secondly, much conservation occurs in the biodiversity rich tropics in developing countries, in contexts of weak institutions, where behavioural interventions

form part of broader governance, incentive, or deterrence interventions [15]. Finally, conservation interventions often target low-prevalence, or sensitive behaviours [16].

In this review, we draw on insights from other fields to clarify key concepts in the study of information flows, while paying attention to the particularities of conservation. We examine how messages reach their **targets** and how interpersonal communication and social structures determine patterns of behavioural adoption [17]. We discuss the tools used to study these structures, most notably **social network analysis** (SNA, Box 1), and the insights these methods have generated. Finally, we discuss how strategies from other behaviour-change disciplines could be used to design more effective interventions in conservation.

The Anatomy of Information Flows & Behaviour Change

Information Transfer, Flow, and Communication

The fundamental process of information transfer is that a message is communicated from conservationists to behaviour-change targets. Communicating information is not a magic bullet with predictable effects on the receiver, but a complex social process where messages may reach their intended target by indirect routes and their meanings are produced within the context of social relationships [18]. Understanding these processes is important to enhance the probability of desired targets receiving and acting on a message in the desired way.

Communication occurs through **channels** which differ in what they can convey, who they can reach, and how they are likely to affect behaviour [19]. Mass communications through channels such as TV, radio, and print, can potentially reach large audiences with a uniform message. Such messages can be agenda-setting but are transient [20], though print media such as billboards can remain salient for longer. The internet and social media also enable

large audiences to be reached, but with personalised messages [21]. Where access to technology is low, speaking with people directly may be the only possibility.

Interpersonal communication between peers is likely to comprise a significant volume of information flow in all interventions. Messages disseminated through mass media typically reach much of their audience indirectly through multiple steps, following interpretation and propagation by influential individuals [21]. As a result, messages will usually have reach and influence beyond just those people directly targeted, and these multi-step flows are intentionally embedded into the design of some conservation interventions (Table 2).

When information flows through multiple steps, the identities and relationships of communicators will influence how they understand and respond to a message. This **social influence** is composed of multiple factors, such as the perceived credibility of the information source [22]; the relationship between source and receiver [23]; their positions in larger power structures [24]; and perceptions of relevant social norms [25]. Social influence can make the difference between a message that is rejected and ignored, and a message that changes behaviour [7].

Social structures

Social influence is important because often only a few low-**threshold** individuals adopt an attitude or behaviour directly after receiving a message, while most targets require social reinforcement and influence from others before they adopt. These **complex contagions** occur for several reasons, depending on the social context and nature of the behavioural change [26]: Firstly, as the outcomes of behavioural change are uncertain, individuals may wait to see how it benefits others (i.e. credibility) before adopting [17]. Secondly, social norms play an important role in human decision-making [25], and people may wait for

114 others to adopt (i.e. legitimacy) before following [27]. Finally, in other cases new behaviours
115 are only beneficial if they are also adopted by others (i.e. complementarity). For example,
116 many conservation issues require collective behavioural changes for the management of
117 common resources [13].

118 For complex behaviours, information about the behaviours and views of social peers are key
119 to driving **diffusion**. Therefore these behaviours diffuse along social **ties** as information
120 about the behaviour flows through repeated interactions [17]. The structure of a social
121 group will therefore influence the rate and patterns of diffusion. For example, strongly
122 connected individuals tend to behave more similarly [28], and shape each other's
123 perceptions of social norms [29]. If a group member receives information about a new
124 behaviour from outside the group, they may not adopt unless other members also adopt
125 [26]. In contexts with poor governance and low trust in institutions, these informal
126 networks are likely to be particularly important. To predict how behavioural changes spread,
127 conservation scientists therefore need to understand these social structures and how
128 information flows through them.

129 Studying Information Flows

130 Understanding how information flows through a group and drives adoption of a behaviour
131 can be a demanding exercise, but there are several key pieces of knowledge that can inform
132 meaningful improvements to intervention design [30]:

133 1) Identifying and defining relevant social interactions
134 2) Measuring or observing these social interactions
135 3) Identifying key structural features and key individuals

1) Identifying relevant interactions

How do targets communicate, seek advice, or learn about the behaviour in question? As a rule of thumb, in traditional societies people tend to communicate with the same people, such as kin, about many different topics and interact with them in many different ways. Conversely, in modern societies individuals seek different types of information from different specialised networks [31]. Even in contexts where information appears to flow through formalised channels (e.g. in organisations), informal ties such as friendships are likely to play a significant role [32, 33]. Researchers can determine the types of ties that are relevant in a given instance by using qualitative methods, such as group discussions, interviews or participant observation. Methods such as **ECCO (Episodic Communications Channels in Organisation)** analysis also allow empirical investigation of the ties through which specific messages flow (Box 1). Understanding the ways in which targets receive information from external sources is also important, particularly if mass-media is used [34].

For coordinating collective action, conservationists should understand which ties are involved in these decision-making processes and are likely to support sustained cooperation. These networks tend to be stronger, multiplex (i.e. encompassing many kinds of interactions) and embedded in everyday routine but may still differ by domain. For example, in rural Cambodia, agricultural practice is strongly influenced through cooperative labour networks, while village 'moral' issues (which may include hunting norms) are often settled by older men who join together at drinking parties, or religious ceremonies [35].

2) Social structure

Once ties have been identified and defined researchers can investigate how they are structured within the group. Social network analysis (SNA) is a powerful tool widely used in

159 the social sciences to study social structures [36] and can provide a global description of the
160 system and identify many important features (Figure 1, Box 1). Qualitative methods can also
161 provide more detailed information about certain features.

162 *Structural features*

163 In **homophilous groups**, where individuals are similar and densely connected, collective
164 action is more likely [37], and new information flows rapidly, but complex behaviours face
165 resistance as individuals resist deviating from existing social norms [29, 30]. Conversely,
166 heterophilous groups with more different individuals and sparser ties tend to be more open
167 to innovations, but less likely to coordinate [17]. Density is rarely uniform across a network,
168 and many groups have a homophilous core or multiple homophilous subgroups (Figure 1),
169 and a periphery of more loosely connected individuals [38]. Information may flow between
170 these subgroups via mutual acquaintances, but the social norms in each may vary [39, 28].
171 For example, subgroups in an information-sharing network of Hawaiian fishers differ in their
172 fishing practices, with significant implications for shark bycatch [11]. Many quantitative
173 methods have been developed to detect such groupings in SNA data [40]. Using qualitative
174 methods to determine groupings requires careful elicitation from respondents with
175 knowledge of the group.

176 *Individual positions – hubs or opinion leaders*

177 The positions that individuals occupy in their networks predicts their role in the flow of
178 information and their social influence [41]. Most importantly, individuals vary in the number
179 of ties they have and their position within the global network. The most connected
180 individuals (i.e. **opinion leaders** or **hubs**) play an important role in successful dissemination
181 of messages and can catalyse widespread adoption of new behaviours due to their social

influence [42, 43]. However, they tend to be less susceptible to influence and are rarely among the first to adopt complex behaviours, while less connected peripheral individuals tend to be less constrained [44].

SNA data can be used to calculate the **centrality** of individuals (Figure 1), as well as indicating different roles [45]. Opinion leaders can also be identified through expert elicitation or peer-nomination surveys [43]. Most commonly, opinion leaders are identified using assumed correspondences with personal characteristics such as wealth, or formal leadership positions. However, comparison with SNA data has shown that these correspondences are context-specific. For example, in a Kenyan fishery formal leaders, but not the wealthy, were among the most connected [45].

Bridges

Where different subgroups exist, some individuals may be connected to others outside the group, acting as **bridges**. In some cases, groups may be linked by just a single individual, forming a narrow bridge (Figure 1). Such bridging individuals are unique as they have access to information from multiple groups and control the flow of information between them [46]. In homogenous societies this gives them a high level of social capital, but where they bridge conflicting or competing groups they may be mistrusted. For example, in a Hawaiian fishery, individuals who bridged ethnic groupings were denied access to information, resulting in lower individual fishing productivity [47].

Bridges can be identified from SNA data using several metrics [48]. However few other methods of identification have been used. Potential alternatives include eliciting knowledge from local informants, or identifying context-specific individual characteristics (e.g. wealth) that indicate bridging roles [45]. For example, in remote rural areas, individuals with

commercial livelihoods may be more likely to travel, visit markets and interact with outsiders.

SNA or other data on key individuals or structural features are essentially predictions about how information will flow through the group and result in behavioural changes. In some cases, it may be valuable to validate these predictions, such as when piloting an intervention. For example, have the relevant ties been identified correctly? Do identified opinion leaders exert influence on the target behaviours? ECCO analysis, which empirically observes the flow of a message [49], can be used to answer these questions. Weenig [33] used ECCO analysis with SNA to investigate the adoption of a new programme in a large company. Results showed that information about the programme was usually received through formal channels, but that intention to adopt was more strongly influenced by informal ties, such as friendship. **Stochastic Actor-Oriented Models** are statistical models which can investigate change over time in both network structure and actor behaviour, thereby allowing causal inference on their relationships [50].

Network Strategies for Behaviour Change

Disciplines such as public health and marketing have successfully applied interventions which make use of knowledge about social networks (Table 1). Most simply, communications can be targeted more effectively within the existing network, but more complex interventions may attempt to alter group structures. The best strategy will depend on the capacity of the intervener, the type of behaviour change required, as well as current social structures, norms and values (Box 2).

Communication targeting

For widespread dissemination of a message, hubs are essential communication targets [51] (Figure 1). Different SNA metrics can be used to identify individuals for different purposes, such as: closeness for rapid diffusion of information, or eigenvector centrality for widespread diffusion of complex behaviours (see [45]). In certain cases, it may be effective to recruit opinion leaders as change agents, providing training and incentives to help encourage adoption of new behaviours within their network, but this requires buy-in and commitment from these individuals [52]. Where multiple subgroups exist, hubs can be selected and matched to specific target groups [30]. Empirical evidence suggests targeting opinion leaders (e.g. [53]) or recruiting change agents (e.g. [54, 55]) can be more effective than conventional messaging approaches. In conservation, Rare's Pride campaigns target trusted messengers in the community who provide an example for others to follow [56] (Table 2).

For complex behavioural changes, hub individuals may be too constrained by existing group norms to act as initial adopters [43]. In such cases, targeting clusters of connected and similar individuals as **incubator neighbourhoods** can allow a new behaviour to become established within a socially-reinforcing group [57]. These adopters can then influence mutual contacts and collectively promote the behaviour more effectively than an individual could [58] (Figure 1). Complex behaviours are also less likely to spread between sparsely connected subgroups (i.e. via narrow bridges), so clusters within each subgroup could be targeted.

Where equitable development outcomes are required, targeting individuals on the periphery of a community with empowering information may be an end itself, as these are

249 often less likely to have access to social services [30]. Similarly, if the poorest and
250 marginalised are less likely to participate in institutions that are targeted for promoting
251 collective conservation action [59], and therefore do not change their behaviour, it may be
252 important to communicate with them directly. Peripheral individuals may be of particular
253 interest if they are likely to participate in illegal behaviours.

254 Message induction

255 Conservation message design is an area of active research beyond the scope of this review
256 (see [60, 61]), but **induction** approaches to message design are relevant. These approaches
257 attempt to increase information flow by incorporating attractive or encouraging features
258 into the message, such as in viral marketing [51] (Table 2). As evidence suggests widespread
259 behaviour change is more likely when communication between adopters is greater [7],
260 induction can be an important tool. Induction strategies can also encourage adopters to
261 signal their behaviour to others. For example, by incentivising participants in a livelihoods
262 improvement scheme to recruit new members or ensuring that new behaviours are visible
263 to others through public commitment-making or promotional signalling (e.g. free clothing)
264 [62]. Messages can also be designed to reach otherwise hidden or hard-to-reach parts of the
265 population [63]. For example, the relatives of an arrested poacher are likely to know others
266 and could be given communication materials to disseminate.

267 Channel choice

268 Communication channels differ in what they can communicate, who they can reach, and
269 how they affect recipients. Complex behavioural changes may require direct experience of
270 the new behaviour and reinforcement through peer learning, while passive use of mass
271 media might be sufficient to prevent future adoption of negative behaviours [20]. For

example, televised health warnings may effectively prevent people from trying new pesticides, whereas in communities where use is already widespread, more work might be needed to encourage alternative practices. Secondly, individuals differ in the types of media they consume, so the appropriate channel will depend on who is targeted. In many cases, mass media can be effective at reaching large audiences, but the media habits of the audience must be understood in detail if this is to occur [34]. Interventions targeting a small select group, such as recruitment of change agents or incubator neighbourhoods, may require more personalised approaches involving direct contact by the intervention team. Ideally, interventions aiming to effect widespread behaviour change will make use of a mix of channels, combining the strategies described. For example, workshops targeted to incubator neighbourhoods could initiate adoption while simultaneously mass media could increase the likelihood of diffusion to the wider population.

Altering Networks

If current network structures are not conducive for widespread behavioural change, interventions can attempt to alter them. New channels of communication can be developed by facilitating meetings or providing communication technology, e.g. to coordinate community-led anti-poaching patrols or facilitate peer-learning. One notable success in agricultural extension has been farmer field schools that enable farmers to collectively learn and adopt more sustainable techniques [64]. Such peer-learning can be more effective than conventional approaches because the group can co-produce the new practice in a socially meaningful way. Connecting adopting individuals alters their normative environment by increasing the proportion of ties engaged in the behaviour and reducing pressure to conform to previous group norms [65]. For example, smokers who have contact with

abstinent ex-smokers are more likely to abstain [66] (Table 2). The existence of disconnected sub-groups could lead to the divergence of norms [67], and so encouraging communication between groups could help maintain desirable norms and improve diffusion. These bridges will need to be wide (i.e. multiple strong connections between members of each group) to enable the spread of complex behaviours and require significant time and investment to form [26, 68].

Where collective action is required, such as for governing common pool resources, it may be necessary to create forums where participants can communicate, develop trust, and ensure compliant behavioral norms are maintained and enforced [13, 69]. Interventions aiming to create such bodies often co-opt existing structures, such as traditional councils, but this risks neglecting peripheral groups or those underrepresented in these structures. For example, in one community-based ecotourism project designed to incentivise protection of wildlife, geographically distant groups had little awareness of the project and may therefore have no incentive to change their behaviour (see http://tinyurl.com/y32jydya). In such cases, identifying disconnected subgroups can enable facilitators to connect them. At the same time, to avoid resentment, exclusion, and conflict, it is important to understand and respect current social structures and norms [70, 71]. For example, existing hierarchies within each subgroup and cultural concepts of legitimacy could be considered in selecting representatives. Finally, providing individuals with access to information can also alter their position in the network with potentially unexpected consequences. Opinion leaders may lose respect if they champion an unpopular cause. Conversely, beneficial information can improve an individual's prestige [72].

Concluding Remarks

Disciplines such as public health have intervention strategies which exploit social networks, such as targeting communications to influential individuals, or facilitating social reinforcement between adopters [30]. Evidence suggests that such network-based interventions can be more effective than conventional approaches (e.g. [43, 54]), and incorporating these practices can make conservation more effective. The optimal strategy will be context-specific, dependent on the behavioural change and the social context. Communication and behaviour-change interventions in conservation will often be embedded within larger governance efforts, and many will require multiple strategies to be implemented at different stages (Box 2). It is therefore essential to gain an in-depth understanding of the context prior to the intervention, including baseline research and active piloting of messages and delivery mechanisms, as well as evaluation of interventions to enable learning [73].

Currently it is unknown what strategies are used to target conservation interventions, and what information about social structures is used when designing interventions. More research is required to understand the types of information flow (or other relevant ties) that are important in conservation contexts [74] and whether generalities exist as rules of thumb to guide intervention planning (see Outstanding Questions). Furthermore, SNA is a costly method, so more feasible accurate methods for identifying important individuals or structural features must be developed if practitioners are to adopt these approaches. As conservation interventions increasingly focus on changing human behaviour, incorporating insights from the social sciences, such as by understanding information flows, will be critical for achieving conservation goals.

Acknowledgments

Emiel de Lange was supported by a studentship from the Natural Environment Research Council E3 Doctoral Training Partnership [grant number NERC NE/L002558/1]. AMK and EJMG acknowledge support from NERC Standard grant [grant NE/N001370/1]. We thank the Wildlife Conservation Society - Cambodia for their collaboration on the intervention described in Box 2.

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600

601

Figure legends

FIGURE 1. The ties between individuals in a group can be visualised as a network, revealing a social structure. Some groups of individuals are more densely connected than others, suggesting the existence of sub-groups (A & B). Each subgroup has a core (green) and a periphery of less connected individuals. The most highly connected individuals (red) tend to be more influential and are also known as Opinion Leaders, while those connecting different sub-groups are known as bridges (blue).

Two stylised intervention scenarios showing the flow of a message (red arrows) and the adoption of a new behaviour (red figures) through this social network in time: (left) recruitment of opinion leaders as change agents and (right) targeting an incubator neighbourhood. Recruiting highly-connected individuals to spread a behaviour can be highly effective. Due to the influence these individuals wield, others in their network are likely to follow them in adopting new behaviours. However, they may be resistant to adopting risky or complex behaviours. Using incubator neighbourhoods, the new behaviour is socially reinforced, and adopters can work together to spread the behaviour. In this example, two adopters are needed to recruit another. In the subgroup on the left (right panel), the central hub has catalysed a widespread shift in behaviour, but the behaviour is not able to spread to the other group via a single bridging individual.

FIGURE I (Box 2). Two scenes from our social marketing campaign aiming to reduce wildlife poisoning through pesticide misuse. Above: a villager receives a certificate at a public ceremony for pledging to use pesticides responsibly and report misuse. Below: A mother and child look at some of the materials used to transfer information about responsible

pesticide use, including the poster given to pledgees. Photo credit: Hom Sakuna, WCS Cambodia.

Box 1: Methods for studying information flows

ECCO Analysis

Episodic Communication Channels in Organisations analysis is used to understand how messages flow through informal channels. Conservation researchers could use this method to test assumptions about information flow when piloting interventions; to investigate the types of ties through which a message flows, to map a social network, or validate whether a mapped network predicts the route taken by a message. Firstly, a relevant message is identified and disseminated in a controlled manner. A series of follow-up questionnaire surveys is then administered, assessing which individuals have received the message and asking them from whom they received the message [49].

Social Network Analysis

Social Network Analysis (SNA) is a powerful tool that is widely used in the social sciences to study the structures of social groups. A vast multi-disciplinary literature has contributed to the development, application and interpretation of SNA data [75]. Here, we give an overview of the basic principles of SNA.

SNA generates a sociogram (Figure 1), depicting individuals as nodes and their interactions as ties. The interactions represented are usually of a single type, can be directional or non-directional (i.e. going both ways), and usually have some measurement of tie-strength associated. For example, an intervention aiming to promote new agricultural techniques

may ask farmers to nominate individuals they go to for advice [76]. Advice-seeking is a directional interaction, and tie-strength could be measured in the frequency of interaction, or perceived value of the advice received.

SNA data can be collected using several methods. Most common is the name-generator questionnaire, which is suitable when the relationships can be reported on by the actors involved in them; such as most communicative interactions. Respondents list the names of people with whom they interact, and provide other information such as interaction frequency. This method is simple and reliable, but effort-intensive as a large proportion of the community must be questioned to obtain an accurate representation of the network. Furthermore, responses may be subject to recall or social desirability bias [75].

Box 2: Integrating information flows into behaviour-change interventions

How can conservation practitioners integrate information flow strategies into their interventions? To illustrate some of the possibilities, we draw on the authors' experience in the Northern Plains of Cambodia where multiple conservation interventions are run by the Wildlife Conservation Society [69].

Firstly, a social marketing campaign is being developed to reduce wildlife poisoning through pesticide misuse. One component of this campaign is a good citizenship pledge which villagers can take at a public ceremony. Public commitments are more likely to be followed, but also send strong normative signals to others [77]. Print materials such as posters and certificates were provided so the behaviour of pledgees is visible to others, and stickers and leaflets were distributed so that they remain salient (Figure I). Qualitative methods were used to understand the types of interactions in which villagers were communicating and

learning about pesticide practices, and a SNA was produced using a name-generator survey. Using this information, we will match opinion leaders to village subgroups, and work with them as change agents to recruit villagers into the good citizenship programme.

[Figure I]

A second conservation programme recruits farmers into a Village Market Network. If members follow a participatory land-use plan, apply organic farming methods, and refrain from illegal logging and hunting, they can sell their rice at a price premium to the Ibis Rice company [69] (see https://ibisrice.com). To date, recruitment, outreach, and compliance have been the responsibility of an elected committee in each village, supported by a local NGO (Sansom Mlup Prey). However, research into household decision-making and social networks showed that these centralised committees were mismatched with the highly modular and decentralised household social networks. This modularity is driven largely by kinship patterns and co-location [78]. Although the committees were able to reach all households with information, they lacked the strong ties needed to recruit many socially distant households. Furthermore, complex changes in agricultural practice are difficult to adopt unless the relations who exchange cooperative labour also adopt [35]. A more successful recruitment strategy might be to have NGO staff meet with these smaller groups and provide a bonus incentive if the whole group is recruited [79]. Furthermore, farmers could be incentivised to recruit members of their close network. Although these methods have not been formally evaluated, in one pilot village a 50% increase in recruitment was recorded by Sansom Mlup Prey (K Socheat, 2019, personal communication 19th March).

Glossary

Bridge; an individual or individuals that connect two subgroups in a community, or connect neighbourhoods in a network

Centrality; various measures indicating an individual's importance in a network (e.g. degree centrality is the number of connections an individual has to others in the network).

Channels; the technology or media used for communication, such as television, radio, social media or interpersonal communication

Complex contagion; contagions, such as behaviours, that require social reinforcement before they can be adopted by individuals

Contagion; the cultural items, such as behaviours or information, that spread within a group

Diffusion; the spread of cultural items such as behaviours, ideas, or knowledge.

ECCO analysis; stands for Episodic Communication Channels in Organisations. A method developed by organisational scientists for studying information flows using repeated surveys

Homophilous groups; are groups that consist of similar individuals that are highly connected. The same community may be characterised as homophilous or heterophilous depending on the behaviours and interactions in question. For example, a small, rural community of rice farmers is homophilous in the context of agricultural activity, but may be heterophilous in terms of the forest products they gather.

Incubator neighbourhoods; a small group of individuals that are socially connected and that are collectively targeted for adoption of a new behaviour

Induction; attempts to stimulate information flows and encourage further communication of a message, by incentives or incorporating encouraging features into the message. Inductive messaging strategies are designed to encourage further dissemination or spread of the message, such as by incentivising communication, facilitating signalling, or incorporating encouraging features into the message.

Information flow; the overall pattern of communication within a group or the route taken by a specific message within the group

Information transfer; the directed communication of a message by the conservation to its intended recipient, whether directly or indirectly

Opinion leaders or hubs; highly connected individuals who can exert influence on their groups, often key to disseminating new information or behaviours

Social influence; the complex mix of factors, such as trust and persuasiveness, through which individuals affect the behaviours of other individuals

Social Network Analysis (SNA); an approach to analysing social structures by conceptualising individuals as nodes connected via links representing their relationships or interactions

Social norms; expectations or rules around appropriate behaviour within a social context.

Social reinforcement; positive signals or information received from others about a behaviour.

Stochastic Actor-Oriented Models; a set of modelling techniques used to analyse longitudinal network data. Can be used to understand the processes driving changes in behaviour through a network, or changes in the network itself over time.

734 **Target;** the individuals who are intended to receive a communication, or the individuals who
735 are intended to change their behaviour

736 **Threshold;** the number of an individual's social relations, or the proportion of their ties, that
737 must adopt a behaviour before an individual also adopts

738 **Ties;** are the links between individuals. In the context of information flows these will usually
739 be the interactions through which individuals communicate, but many other types exist.

740

Table 1. Selected information flow concepts and examples of interventions using these concepts from various disciplines

Concept	**Public health or development example**	**Marketing or Management example**	**Conservation example**
Targeting communications at opinion leaders	In a randomised trial across 32 villages, a sample of villagers were educated and given multivitamins, as well as vouchers to pass on to others. In villages where targets were identified using peer-nomination surveys a 12.2% increase in adoption was seen compared with villages where targets were randomly selected [53]	Microsoft identified opinion leaders and distributed pre-release copies of *Windows 95* to 450,000 of them. The commercial product was quickly adopted and within four days of release a million copies were sold [80]	Rare, a US-based NGO, uses Pride campaigns to promote conservation in communities. Among other things, these campaigns seek to identify 'trusted messengers': influential community members that can drive widespread behavioural change, once a number of peers have already adopted the new behaviour and some momentum has been generated [56]
Targeting an incubator neighbourhood	In a randomised controlled trial, agricultural extension workers in Malawi trained individuals in 200 villages on pit-planting (an agricultural technique), and trained them to disseminate this in their village. In some villages, these individuals were chosen to span the entire network, but in other villages they were chosen as 'clusters' of connected individuals. In clustered villages, there was a 56% greater likelihood that diffusion would occur, and after three years a 3% greater adoption [57]	None found	None found
Recruiting opinion leaders as change agents	An anti-conflict intervention was experimentally introduced to 54 schools with 24,191 students, after measuring their social networks. Selected students were	Marketers working for Hokey Pokey, a premium ice-cream store in India, researched the local social media market. They identified influential social media users that were	Ewaso Lions' 'Warrior Watch' programme recruits Samburu Warriors to act as ambassadors for wildlife in their community, raising awareness and mitigating conflicts

	trained and then took the lead in designing anti-conflict strategies for their school. Schools where highly connected students were recruited had a 30% greater reduction in conflict than where students were randomly selected [54].	observed to have many connections and gained many responses to their activity, in addition to other characteristics. Influencers with relevant interests were invited to create a personal ice-cream creation and incentivised to tweet and post on Facebook about their creation. Customers could also see these creations on a wall at the store and purchase them. Flavours used in these creations increased in popularity, and brand awareness and sales revenue increased dramatically [81].	with predators. These warrior ambassadors are selected in cooperation with community leaders, and are provided a small stipend and education in return. Attitudes toward wildlife were found to have improved for 90% of community members, with most attributing this to information received from the warriors (H. Gurd, MSc thesis, Imperial College London, 2012).
Connecting subgroups	In 1995 the US Public Health Service launched the National Information Infrastructure. One of the key objectives was to improve communication between healthcare providers across the US, as well as other actors essential to delivering public health such as the media, government and citizens. For example, medical practices across a city now began to share information with a central database, which enabled monitoring of wider trends and early warnings for epidemics [82].	A global consultancy firm believed one of their highly-skilled strategic teams was underperforming. An SNA was performed to understand the information flows, revealing two disconnected sub-groups within the team. Each group had a different expertise and skillset, with little knowledge of the other. A facilitated discussion was held with the entire team, resulting in practice changes designed to encourage closer connection: projects were jointly led by one member of each group, and new communication channels were opened. This led to improvement in outcomes, and a follow-up SNA revealed a much more connected group [83].	Three settlements in Nepal made use of the same forest, but had organised themselves into two separate forest associations, as two of the settlements were more closely connected. This led to conflicts over boundaries and memberships. Meetings were organised between the leaders of the three settlements where residents agreed to merge the two forest associations. The new, single, forest association functions well and has overseen improvements in the condition of the forest [84].
Connecting peers for learning and reinforcement	Alcoholics Anonymous is one of the few models to show positive abstinence outcomes. Participants join support groups	As part of a strategy to increase the effectiveness of institutions in developing countries, the OECD organises peer-learning	Following requests from local women, Ewaso Lions' 'Mama Simba' project provides general and environmental education to

	where they are connected with peers undergoing the same behavioural change, and discuss their experiences. Support-group peers often replace non-supportive friends in participants social-networks; this method is most effective for individuals with harmful social networks [85].	sessions. For example, individuals working at anti-corruption organisations in Eastern Europe and Central Asia were invited to a workshop to meet with experts and discuss their experiences and knowledge. Though little evaluation has been done, it is thought that this enables greater learning and that the connections generated between peers will sustain long-term knowledge sharing [86].	women in Samburu communities. Participants learn and share their knowledge together, including of environmentally sustainable practices, and disseminate this knowledge to their peers (see http://ewasolions.org/conservation/mamasimba/).
Inducing multi-step communication flows to indirectly reach the target audience	Injecting drug users (seeds) were given coupons to distribute to their peers, which contained information about a safety education class. When a peer redeemed a coupon at the education centre, they were given additional coupons to distribute, and the seed was awarded $10, incentivising distribution. An additional $10 was awarded if the peer had been given some education by the seed before arriving. Compared to worker-based outreach, this method recruited 36% more participants over a 2-year period, and a much wider range of individuals. Peer-outreach was also found to be more effective at reducing risk-related behaviours, and many times more cost-effective [87].	In 2008, Burger King began their 'Whopper Sacrifice' campaign. Using a specially designed application on Facebook, individuals would receive a coupon for a free whopper in return for removing 10 connections from their Facebook account. These connections would receive a message explaining why they had been removed and encouraging them to download the app themselves. The campaign only ran for 10 days but over 20,000 coupons were generated and 233,096 people were reached [51].	Environmental education is often targeted to children. One reason for this is the assumption that children will pass information to their adult relatives and influence them. Lessons are often designed to induce such further communication, for example by asking students to complete worksheets together with their parents [88, 89]

Table 2: Examples of information transfer and targeting strategies in common conservation behaviour change interventions

Behaviour-change Strategy	**Information Transferred**	**Example Targeting strategy**	**Reference**
Rule enforcement	Risks & costs of punishment	Offenders learn this information when caught and pass it on to their network	90
Environmental education	The importance and cultural value of nature	Education sessions are held at local schools and children pass information to their parents	91
Payments for ecosystem services	Payment structure & conditions	Communities are invited to a meeting where this is explained directly	69
Alternative Livelihoods	New livelihood options	Training workshops are held to teach local farmers alternative livelihoods	92

HIGHLIGHTS & OUTSTANDING QUESTIONS INSERTED FOR ED COMMENT PURPOSES

Highlights

- Social scientists have advanced understanding of 'complex contagions' – how behaviours spread through social networks - rapidly in recent years, suggesting new approaches to promote widespread behaviour change
- Social network analysis is a powerful tool for understanding the social structures that influence the spread of behavioural changes, and can be used to inform these interventions. For example, measures of centrality can be calculated to identify key individuals, or community detection algorithms used to delineate socially important subgroups.
- Some intervention approaches are already being adopted in conservation, such as targeting influential opinion leaders, but further integrating understanding of information flows and social structures will make conservation behaviour-change interventions more effective, such as by targeting incubator neighbourhoods to initiate behavioural diffusion, or connecting subgroups for collective action.

Outstanding Questions

- How do conservationists currently target their communications in behaviour change interventions?
- What sort of information about group structures is currently used when designing interventions?
- How well do qualitative methods for identifying key positions or structural features correspond to SNA results? What low-cost methods are most reliable?

- How do conservation interventions alter the structure of local social networks, and how does this influence conservation and wellbeing outcomes?
- What sorts of social ties are most important for influencing conservation behaviours, and how are these networks structured in conservation areas?
- What are the costs and benefits of adopting network-informed intervention strategies? Do the increases in effectiveness justify the costs of conducting formative research?

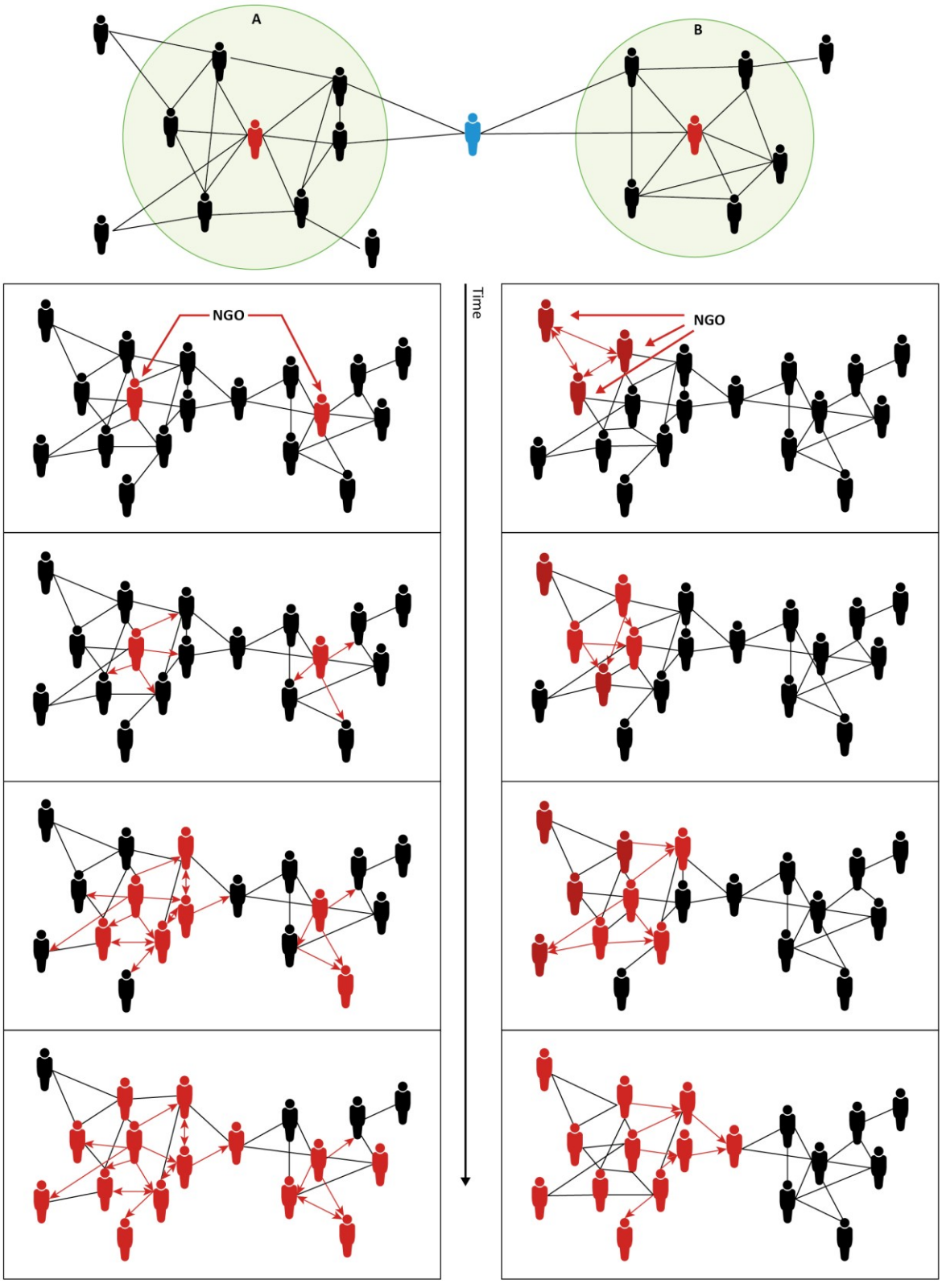

Figure 1

Figure I