Breaking Fences May Make for Good Neighbours in Collaborative Research

Why the International Foundation for Science will introduce a Collaborative Research Approach

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Abstract

This paper describes the vision behind a new approach to research support for early-career scientists by the International Foundation for Science. The paper discusses why the International Foundation for Science will promote collaborative research through the provision of support for small-scale research collaboration. It articulates the mutual benefits of intellectual and social influence derived from collaboration; the ever widening range of skills required by increasingly complex research demands and the potential benefit to scale, scope and efficacy of research outcomes that interdisciplinary collaboration can bring. The paper explores the phenomenon of research collaboration, highlighting nine evidence-based characteristics: informality, proximity, parity, productivity, acceptability, impact, influence, citation and salary. It identifies four putative differentiating criteria for 'collaborators': proposer(s) and/or fund raiser(s); frequent or substantial contributors; those responsible for the main elements of the research; and those responsible for key steps. The paper outlines seven types of benefit expected from the Collaborative Research Approach: sharing of knowledge, skills and techniques; tacit knowledge transfer; learning social and team management skills; sourcing creativity; intellectual companionship; greater scientific visibility; and pooling equipment. It also identifies five specific costs incurred by this approach: finding collaborative partners; financial costs; time costs; administration and reconciling different financial systems; management cultures and mechanisms. The paper summarises how the IFS Collaborative Research Approach aims to promote research collaboration amongst early-career scientists, through: an on-line collaborative environment for use by all prospective applicants, as well as successful teams of grantees; subject specific and technical mentoring; and, to reduce some of the costs to collaborative researchers, a specific budget for team coordination costs.

Key Words: Research Collaboration, Early-career Scientists, Evidence-based Characteristics, Collaboration Criteria, Costs, Benefits, International Foundation for Science.

Why the International Foundation for Science will introduce a Collaborative Research Approach

1. Background

The International Foundation for Science (IFS) contributes to strengthening the capability of early-career scientists from least-developed countries, who are embarking on a research career in the developing world. Capability is built through the provision of competitive small research grants, skills development, equipment purchasing support, and also mechanisms to facilitate networking.

The 2011-2020 International Foundation for Science (IFS) Strategy, entitled 'Working Together' (IFS, 2011) particularly alludes to the introduction of a new collaborative research approach. This approach complements efforts, also now being introduced, to link young scientists to those who can support their actions to bring about change, through putting their research into use. The overall aim is to build research capability by increasing opportunity and ability to generate valuable research outcomes within the water and biological resources scope of IFS research. The IFS Collaborative Research Approach, will increase opportunity by encouraging research collaboration amongst scientists, and is being piloted with support from the Carnegie Corporation beginning in 2012. The IFS Contributing Innovation Approach will nurture ability by encouraging collaboration between scientific researchers and those who may use their research outcomes, for example, in technological, industry or policy innovations, and will be piloted later in the 10-year strategy.

2. The phenomenon of research collaboration

Throughout history scholarly pursuit has been considered in the context of collaboration, with each advance building on those preceding it. According to the medieval historian Richard Southern (1952), Bernard of Chartres first articulated this in 1159, comparing the then modern scholars (in the 12th century) to the ancient scholars of Greece and Rome. Bernard stated: '*Dicebat Bernardus Carnotensis nos esse quasi nanos, gigantium humeris insidentes, ut possimus plura eis et remotiora videre, non utique proprii visus acumine, aut eminentia corporis, sed quia in altum subvenimur et extollimur magnitudine gigantea'* (We are like dwarfs on the shoulders of giants, so that we can see more than they, and things at a greater distance, not by virtue of any sharpness of sight on our part, or any physical distinction, but because we are carried high and raised up by their giant size.).

In similar fashion, over 500 years later, Isaac Newton remarked in a letter dated February 5, 1676, to his academic rival Robert Hooke '*What Des-Cartes*[1] *did was a good step. You have added much several ways, & especially in taking ye colours of thin plates into philosophical consideration. If I have seen further it is by standing on ye sholders of Giants*' (Turnbull, 1959).

Science has more recently been described as a social institution, where each advance depends crucially on interactions with other scientists (e.g., Kuhn, 1970; Subramanyam, 1983). For some fields, this may entail the creation of formal collaborations, of organised and sometimes quite large teams of researchers. A recent salient example would be the research collaboration to test the predictions of different theories of particle physics and high-energy physics[2], which involves a collaboration of over 10,000 scientists and engineers[3]. For others, informal links may be all that are required (Peters and Van Raan, 1989; Stokes and Hartley, 1989). Another high profile example (of a

[1] René Descartes was a French philosopher, mathematician, and writer who spent most of his adult life in the Dutch Republic.
[2] The Large Hadron Collider (LHC) built by the European Organization for Nuclear Research (CERN).
[3] This has contributed to a phenomenon, especially but not exclusively in physics, in recent years of multiple-authorship of scientific papers with in excess of 3,000 authors.

less formal collaboration) would be the regular lunch meetings at the Eagle pub in Cambridge opposite the university's Cavendish Laboratory, where colleagues' discussions contributed to the Nobel Prize winning discovery of the double helical structure of Deoxyribose Nucleic Acid (Watson and Crick, 1953).

Some evidence-based features of the phenomenon of research collaboration in general, drawn mainly from the past 30 years, are ***italicised*** below.

Most collaboration begins informally, often the result of casual conversation (Edge, 1979; Hagstrom, 1965; De Solla Price and deB. Beaver, 1966). Over time, some informal communications may lead to an increasing commitment to co-operate. ***Spatial proximity seems to encourage collaboration***, since it tends to generate more informal communication. If one were to take co-authorship as a loose proxy-indicator of research collaboration, it is known that co-authorship decreases exponentially with the distance separating pairs of institutional partners (Katz, 1993).

However, this does not rule out the possibility that, in cases where the potential collaboration involves a clear division of labour, scientists may be more concerned with seeking the most appropriate expert partners, even if they have to travel some distance to find them (Katz and Martin, 1997). According to Katz and Martin (1997), ***collaboration between peers of similar standing is more likely than collaboration between individuals of unequal rank***, but this is by no means always the case.

Research seems to indicate that ***high productivity (in terms of published output) is correlated with high levels of collaboration*** (Balog, 1979/80; deB. Beaver and Rosen, 1978, 1979a, 1979b; Hodder, 1979/80; Lawani, 1986; Pao, 1980, 1981; de Solla Price, 1963; de Solla Price and deB. Beaver, 1966).

IFS funds studies that are broadly associated with biological and water resources research. However, we can learn much by probing research collaboration experience beyond this remit. Taking an example from astronomy, Gordon (1980) found evidence for ***a significant relationship between levels of multiple authorship for papers submitted to a leading journal, and their frequency of acceptance for publication***. Gordon surmises that the degree of technical competence displayed in the multi-authored paper (regardless of discipline) may be enhanced by overlaps existing in areas of specialized competence, and the opportunity for cross-checking and pre-submission 'internal refereeing' which this provides for.

Taking a further example, from cancer research, Lawani (1986) demonstrates that ***the number of co-authors appears to be strongly correlated with the impact of a paper***. In his study, Lawani found that, as the number of authors per paper increases, the proportion of high-impact papers (i.e., papers earning a high number of citations) also increases.

Goffman and Warren (1980) have also demonstrated that ***research by larger groups tends to be more influential***, while Narin and Whitlow (1990) have found evidence that i***nternationally co-authored papers are cited up to twice as frequently as single-country papers***. Diamond (1985) has even gone so far as to suggest, from his study of Berkeley mathematicians, that ***citations of multiple author papers are worth more to authors in terms of the effect on their earning ability or salary than citations of single-author papers***!

3. Why is IFS supporting research collaboration?

The evidence-based features of the phenomenon of research collaboration that are highlighted above imply a host of benefits from research collaboration. Philosophically, it can certainly be argued that research collaboration can deliver mutual intellectual benefits to the research undertaking and to the prospects for social influence. Katz and Martin (1997) emphasise that modern research is increasingly complex and demands an ever widening range of skills. Research on a particular problem may require a wider range of skills than any single individual, or even a single institution, is likely to possess. There is therefore a clear coherent rationale to bring together scientists, to build capability early in researchers' careers, to understand and manage collaboration. There may be beneficial outcomes to scale, scope and efficacy of research outputs. These are the drivers behind the IFS Collaborative Research Approach.

Associated with this is the growing importance of interdisciplinary fields. It is becoming clear that some of the most significant scientific advances come about as a result of the integration or 'fusion' of previously separate fields (Kodama, 1992). New or emerging fields of collaboration are considered increasingly likely to form the basis of major new technologies (Martin and Irvine, 1989). Linked to this is the recognition that advances in certain areas of biological resources research are crucial for the development of new generic technologies such as biotechnology and new materials. In this context, collaboration not only across scientific disciplinary boundaries, but also between sectors – for example, between universities and industry – becomes increasingly important. This is the driver behind the IFS Contributing Innovation Approach, piloting later in the 10-year strategy.

4. What constitutes research collaboration?

A dictionary definition of *collaboration* suggests the 'working together of individuals to achieve a common goal'. Thus, *research collaboration* could be defined as the 'working together of researchers to achieve the common goal of producing new scientific knowledge'. The scope of collaboration is another issue. At its largest scale, as mentioned, the international research community is sometimes described as *one big collaboration* (Kuhn, 1970; Southern, 1952; Subramanyam, 1983; Turnbull, 1959).

The IFS 10-year strategy (IFS, 2011) describes the investment we hope to make in the capability and agency of early-career scientists in the developing world within the scope described for IFS research. *Capability* in this framework denotes a scientist's opportunity and ability to generate valuable research outcomes. *Agency*[4] in this context is what a scientist is able to do and to achieve with his or her research in application or in pursuit of the goals or values he or she regards as important. Leading on from the previous section, the opportunity to engage in collaborative research is a vital component of capability and agency building. For forty years IFS has provided individual grants to people, not institutions. Fundamentally, it is people who collaborate, not institutions, and it is to people proposing to research in collaboration, that IFS will aim to extend its support. Continuing the

[4] The use of the term *agency* here is best understood via Amartya Sen's description of an agent as someone who acts and brings about change, whose achievement can be evaluated in terms of his or her own values and objectives. This differs from the more common use of the expression "agent" sometimes used in the literature of economics and game theory to signify a person who is acting on someone else's behalf. Furthermore, agency focuses on the ability to personally choose the *functionings* (the beings and doings) that one values (Sen, A. (1999) Development As Freedom. New York: Knopf).

philosophy within IFS of building capability through opportunities at a scale that is suited to early-career scientists, direct co-operation among three to five researchers is to be the core unit of the IFS Collaborative Research Approach. However, this raises the question of exactly how closely researchers have to work together to constitute a 'collaboration'. Some putative criteria for distinguishing 'collaborators' from 'other researchers' could be as follows:

- The original project proposer(s) and/or fund raiser(s), including those whose subsequent principle contribution is to the management of the research (e.g., as Team Coordinator).
- Those who work together on the research project throughout its duration or for a large part of it, or who make frequent or substantial contributions.
- Those responsible for one or more of the main elements of the research (e.g., the experimental design, construction of research equipment, execution of the experiment, analysis and interpretation of the data, or writing up the results in a paper).
- Those responsible for a key step (e.g., the original idea or hypothesis, the theoretical interpretation).

5. Why will IFS promote collaborative research now?

The International Foundation for Science primarily exists to support 'young' scientists to become established in research careers within the developing world. In so doing it helps to counteract the so-called 'brain drain' of talented scientists away from the developing world, by providing opportunities to research challenges within developing countries, and aims to enhance 'the voice' of developing country scientists in global scientific debate.

Our recent analysis (e.g., Zink, 2009) as well as that of others (e.g., Harle, 2011) identifies that many developing world post-graduates may struggle to establish their careers after returning from study abroad. Up to now, IFS has offered support through individual research grants and capability enhancing support to advance intellectual endeavour and support emerging scholarship. Whilst this is demonstrably effective, we believe that through expanding our support to include collaborative research, we can now add a new dimension to this effort, through shared endeavour and communities of research.

Young people today constitute the largest youth cohort in human history, with the vast majority in developing countries (Lin and Cunningham, 2010). They, more than ever before, need science in developing countries to expand; and for peers to join forces with them in research collaborations. Working together, developing world scientists are well placed to identify the challenges they face, and to propose transformational research, to build resilience to global volatility; to engage in global negotiations; and to innovate for sustainable futures.

Whilst it was identified from earlier research (Katz, 1993) that spatial proximity encourages research collaboration, there are two more contemporary factors that encourage greater collaboration than has ever been possible in the past. One is the digital revolution; the other is the substantial fall in real terms in the cost of travel and of communication, accompanied by growing availability and easy access to both. Air travel is many times cheaper in relative terms than in the 1950s (when a journey by sea and/or rail was also often the only option) or even in the succeeding decades, and flights are now readily available between most major cities. Likewise, the falling cost and growing ease of communication, especially Internet and other digital communication options, as well as the phenomenal rise in social networking has made collaboration between scientists, even when separated by great distances, far easier. Furthermore, these developments now greatly reduce the time needed to travel, or to communicate via audio or video connections, in order to share ideas, documents, and to work together to develop proposals, experiments, reports or presentations.

Along with these contemporary enabling factors, practical manifestations of the political will to support researchers working together are also emerging. Open Science in the 21st century, and the evolution of some of the largest instruments in support of collaborative research, development and innovations in science, engineering and technology ever conceived are two contemporary examples described below:

- The first concerns policy. In April 2012 all European Science Academies declared their commitment *towards open science in the 21st century* (ALLEA, 2012). They publicly and collectively expressed the view that 21st century grand challenges transcend borders, and that science will reinforce its global nature. They expressed a strong commitment from the scientific community to adopt Open Science and an emerging Global Knowledge Partnership that promises more efficient data-sharing, replication of experiments, better testing of theories and accelerated innovation. This they expect will enhance transparency and integrity of the scientific enterprise.
- The second concerns funding instruments. The Seventh European Union (Research) Framework Programme, known as FP7, had a budget of €50 billion over its 7-year timeframe which ends in 2013. Its successor Horizon 2020 (previously named FP8) will shape the future of European research starting in 2014 and running to 2020 with an €80 billion budget. A central tenet of both of these flagship programmes is research collaboration, incorporating provision for the participation of non-EU countries.

The International Foundation for Science will promote collaborative research, because building capability in research collaboration amongst developing country scientists now can empower colleagues to shape, play meaningful roles in, and benefit from Open Science. It can better equip early-career developing country scientists to demand and fulfil meaningful roles within collaborative research, development and innovations in science, engineering and technology. *Now* is the time to increase support for developing country scientists to realize the right “to share in scientific advancement and its benefits” (Article 27 of the Universal Declaration of Human Rights).

6. How does IFS plan to promote the benefits and reduce the costs of research collaboration?

When considering collaboration, researchers, funding agencies and policy-makers have often tended to see only the benefits, and consequently to view collaboration as 'a good thing' that should be universally encouraged. In recent years however, policy shapers (e.g., Katz and Martin, 1997; Loan-Clarke and Preston, 2002; Meehan, 2006) have begun to argue that a more balanced approach should be adopted when assessing the potential costs and benefits. Building on this call for more balance, this section highlights not only the benefits of collaborative research, but also the likely costs, and identifies how the IFS Collaborative Research Approach aims to promote the benefits of collaboration to early-career scientists and diminish some of the costs to potential collaborators.

Promoting the benefits

The first approach to try to maximise the benefit from collaborative research, is one which addresses the level at which collaboration is encouraged. Conceptually, there are several levels at which collaboration can take place. According to Brousseau's (1993) contact theory, collaboration amongst different partners may be motivated by three main considerations: strategic, organisational and operational. As Traore and Landryn (1997) describe it, in strategic partnerships, partners determining the goals and directions of collaborative activities. In an organisational collaboration, collaborative activities are outlined, the budget requirements are determined, and the prospectus and the methodology of the research are defined. Operational collaboration concerns making decisions about the use of joint resources and the publication and diffusion of the results from collaborative research.

Detailed analysis by Traore and Landryn (1997) of collaboration by scientists reveals a complex set of intertwined factors that determine scientists' collaboration. Their conclusions from a research funding policy perspective suggests that 'mechanisms should be put in place to encourage scientists to take an organizational and strategic approach concerning their relations with partners, as this approach will be beneficial to partners because strategic and organizational collaboration lead to increased joint outputs'. Therefore, as IFS extends its support to research collaboration, we are encouraging partners in the Collaborative Research Approach to determine the goals and directions of their collaborative activities, and to define together their budget requirements and the methodology of the research from the outset, that is at the application stage. This is an especially critical strategy for IFS targeted recipients. They are scientists, early in their careers within the developing world, and as Traore and Landryn (1997) identify, scientists who start collaborating early in their careers are more likely to be operationally orientated in their collaborative decision making. Therefore, developing an application process which deliberately aims to shift an early-career scientist's orientation from the operational to the organizational and strategic should enhance the benefits and productivity of collaboration.

At the implementation stage, some of the potential benefits from research collaboration amongst early-career scientists are listed and characterized in Table 1 below. In order to shape and improve our approach to collaborative research support, these seven specific benefits will be monitored and evaluated from the collaborative research pilot.

Table 1: A typology of benefits from Research Collaboration (after Katz and Martin, 1997)

Benefit	**Explanation**
1. The sharing of knowledge, skills and techniques	Often, no single individual will possess all the knowledge, skills and techniques required in a research undertaking. In principle, he or she might be able to learn or acquire, say, all the techniques needed to solve a particular problem, but this can be time-consuming. If two or more researchers collaborate, there is a greater probability that between them they will possess the necessary range of techniques. In collaborations, there may be a fairly formal division of labour. For example, one person may be good at constructing, operating and maintaining scientific instrumentation and another at analysing the data produced. Collaboration may therefore provide a more effective and cost-efficient use of the combined talents.
2. Tacit knowledge transfer	Not all the details concerning new advances are necessarily documented. Much of the knowledge may be tacit (Collins, 1974; Senker, 1993) and remains so until researchers have had the time to deliberate and set out their findings in a publication. Frequently, considerable time elapses before the knowledge appears in written form. Collaboration may be one way of transferring new knowledge, especially tacit knowledge.
3. Learning the social and management skills needed to work as part of a team	Collaborative research requires not only scientific and technical expertise, but also the social and management skills needed to work as part of a team. These cannot be readily taught in the classroom; they are best learned 'on the job' by engaging graduate students or young postdoctoral researchers in collaborative activities. IFS team application procedures emphasize the capability building element of such 'on the job' learning by specifically giving preference to teams where the Team Coordinator is an early-career scientist. The IFS on-line and written support for team applications encourages consideration of different organisational models suited to small teams, team roles (IFS, 2012a), intellectual property, publication and authorship, credit and data availability issues (IFS, 2012b).
4. Source of creativity	Collaboration may bring about a clash of views, a cross-fertilisation of ideas which may in turn generate new insights or perspectives that individuals, working on their own, would not have grasped (or grasped as quickly) (Hoch 1987; Hodder, 1979/80; Mulkay, 1972). The act of collaborating may thus be a source of stimulation and creativity. Hence, collaboration is greater than the sum of its parts. Such benefits are likely to be largest when the collaboration involves partners from more divergent scientific backgrounds. However, the difficulties in working productively together may then be greater.
5. Intellectual companionship / Expanded networking	Research can be a lonely occupation, probing the frontiers of knowledge where few, if any, investigators have been before. An individual can partly overcome that intellectual isolation through collaborating with others, forming working and perhaps also personal relationships with them. Moreover, the benefits of working with others are not confined to the links with one's immediate collaborators. Collaboration also has the effect of 'plugging' the researcher into a wider network of contacts in the scientific community. An individual researcher may have good contacts with 10 or 20 other researchers in his or her field around the world whom he or she can contact for information or advice. By collaborating with others in another institution or country, the individual may greatly extend that network.
6. Greater scientific visibility	Collaboration can enhance the potential visibility of the work. Using their network of contacts, one's collaborators can diffuse the findings, either formally (e.g., through pre-prints, seminars or conference presentations) or through informal discussions. Together, collaborators are likely to arrive at a more informed decision as to the best journal in which to publish the results (or the one most likely to accept the paper). Once published, the paper may be picked up in library searches by scanning for work produced by any of the collaborating authors, multiplying the chance that it will be located and used by others. On average, it may therefore be likely to be cited more frequently and to have greater impact.
7. Pooling equipment	In many fields, scientific instrumentation costs have jumped appreciably with the introduction of successive generations of technology. As a consequence, it has often become impossible for funding agencies to provide the necessary research facilities to all the research groups working in the area. Resources have had to be pooled, either at a local, regional, national or (in the most expensive cases) at an international level. Consequently, the researchers involved have been able share equipment and maybe to collaborate more closely (see IFS, 2012c).

Reducing the costs

As discussed, it is important to identify and where possible diminish some of the costs to potential collaborators. These are listed and characterized in Table 2 below.

Table 2: A typology of costs from Research Collaboration (after Katz and Martin, 1997)

Cost	**Explanation**
1. Finding collaborative partners	Finding collaborative partners and identifying those with whom one might work is an *a priori* cost of research collaboration. Historically, close proximity has been known to promote collaboration, and physical distance separating partners to reduce its incidence. In section 5, above, it was highlighted that contemporary enabling factors include the Internet, digital communication and the phenomenal rise in social networking. Today social networking and other digital tools may be effective distance spanning tools. IFS is piloting an on-line collaborative environment for use by prospective applicants for IFS Collaborative Research Grants (IFS, 2012d).
2. Financial	For inter-institutional, inter-sectoral and international collaborations, travel and subsistence costs are incurred as researchers move from one location to another. Equipment and material may also have to be transported. Once moved, the instrumentation may need to be carefully set up again, perhaps requiring the assistance of technicians from the original institution, incurring further costs. Digital communications options can be valuable to disparate researchers but also incur costs. IFS is piloting the provision of a specific budget for team coordination costs to be proposed within specified financial limits by the applicants (IFS, 2012e).
3. Time	Time may have to be spent in preparing a joint proposal or securing joint funds from two or more sponsors, and in jointly defining the research problems and planning the approach. Different parts of the research may be carried out at different locations, again introducing time costs. Time must be spent keeping all the collaborators fully informed of progress as well as deciding who is to do what next. Differences of opinion are almost inevitable and time will be needed to resolve these amicably. Writing up results jointly may also take more time where there are disagreements over the findings and their significance, or over who should be included among the co-authors and in what order they should be listed. Moreover, besides these direct time costs, there are also such indirect time costs as recovering from the effects of travel (e.g., 'jet lag'), working in an unfamiliar environment, and developing new working and personal relationships with one's collaborators. These may be real costs which collaborators must weigh against their perceived benefits from collaboration.
4. Increased administration	Collaboration brings certain costs in terms of increased administration. With more people and perhaps several institutions involved, greater effort is required to manage the research. If the collaboration is extensive or spans a considerable distance, it might need more formal management procedures which may create bureaucratic burdens. Even when the burdens are not bureaucratic, when difficulties arise, they may nevertheless be blamed upon 'bureaucracy', and foster a sense of grievance against other collaborators, which must be resolved by the project management. A more formal management structure may also stifle the creativity of the researchers, offsetting the benefits of cross-fertilisation outlined above. These may be real costs which collaborators must weigh against their perceived benefits from collaboration.
5. Reconciling different financial systems, management cultures and mechanisms	Where two or more institutions are collaborating, there is often the problem of reconciling different management cultures, financial systems, and rules on intellectual property rights. There may also be differences over reward systems, promotion criteria and time-scales, and even a more general clash of values over what is the most important research to pursue, how to carry it out, or over commercial or ethical implications. All these potential differences need to be reconciled if serious problems are not to disrupt the collaboration. IFS aims to reduce part of this cost to collaborators by continuing individual financial arrangements with each collaborator within the collaborative research approach (IFS, 2012e).

There appears to be little documentation describing the relative importance to research collaborators of different costs of collaboration. Réjean and Nabil (1998) demonstrated that the administrative burdens and the time required to coordinate collaborative research were unimportant factors in explaining the choices of institutional structures made by university researchers when they become involved in collaborative research projects. Choices were much more influenced by perceptions of publication assets, coordination costs, and additional funding opportunities. In order to shape and improve our approach to collaborative research support, the five costs identified in Table 2 and efforts to reduce these will be monitored and evaluated from the collaborative research pilot.

7. Why breaking fences may make for 'good neighbours' in science

In an essay by the Oxford and Stanford University economist Paul A. David (David, 2001) one is reminded of the American poet Robert Frost's '*Ode to Individualism'*, which celebrates the stone fences that distinguish the rural landscape of upland New England. Frost extols the virtue of good fences and their role in ensuring good neighbourliness. However, the advice that David offers related to research collaboration is the opposite. In his own words David writes:

'Information is not like forage, depleted by use for consumption; data-sets are not subject to being "over-grazed" but, instead, are likely to be enriched and rendered more accurate, and more fully documented the more that researchers are allowed to comb through them. It is by means of wide and complete disclosure and the sceptical efforts to replicate novel research findings that scientific communities collectively build bodies of "reliable knowledge."'

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A number of interdisciplinary research collaborations were of particular significance. These include:

Beginning in 1996 two DFID Natural Resources Systems Programme / Land Water Interface Programme funded projects involving the Department of Anthropology, Durham University, Newcastle University's Centre for Land Use and Water Resources Research (CLUWRR), and Stirling University's Institute of Aquaculture entitled: 'A preliminary investigation of agricultural diversification and farmers' practices in Bangladesh floodplain production systems - a whole farm system approach' and 'Investigation of whole farm strategies and resource use patterns in floodplain production systems based on rice and fish in Bangladesh'.

These initiatives confronted myriad interdisciplinary and institutional constraints that hinder effective research collaboration including the incorporation of natural science research into production constraints, biodiversity and sustainability with anthropological and local perspectives in development work. As anthropologist Paul Sillitoe described it 'Our work sought to advance appropriate methods, acceptable to development agencies that were sensitive to the socio-cultural and epistemological gulf that separates local and scientific perspectives, without unduly compromising anthropological expectations'.

A substantial intellectual debt, owed to Paul Sillitoe, Julian Barr, Peter Dixon and the rest of the team is gratefully acknowledged. A range of suitable methods to facilitate the integration of local knowledge of natural resources and their management and the collaborative research process itself are captured in several of the resulting publications (Sillitoe, 2004; Sillitoe, Dixon and Barr, 2005).

Beginning in 2002, two DFID Natural Resources Systems Programme / High-Potential Systems Programme funded projects undertaken by the STREAM Initiative entitled: 'Investigating Improved Policy on Aquaculture Service Provision to Poor People, DFID NRSP Project R8100' and 'Promoting Pro-Poor Policy Lessons, DFID NRSP Project R8334'.

These initiatives also confronted myriad interdisciplinary and institutional constraints that hinder effective research collaboration including in this case the incorporation of natural science research into policy influence and development work, and sought to advance appropriate methods, acceptable to policy makers and shapers, development agencies, sensitive to the socio-cultural and conceptual and operational gulf that separates local, policy and scientific perspectives, without compromising unduly the expectations of all.

A substantial intellectual debt owed to William Savage, Dr S D Tripathi, and the rest of the team is also gratefully acknowledged. A range of suitable methods to facilitate the integration of local knowledge of natural resources and their management, policy influence and the collaborative research process itself are captured in several of the resulting publications (Haylor and Savage, 2003; Haylor and Tripathi, 2008).

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