

Benefits and principles of the Biological Survey of Canada: a model for scientific cooperation

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Abstract—For 40 years, the Biological Survey of Canada (BSC) has encouraged and organised studies of the arthropod fauna of Canada, through the wide involvement of the scientific community and the leadership of an expert steering committee. The benefits of the BSC to science include the completion of major cooperative projects to acquire and synthesise knowledge (documenting faunas in the Yukon, Canadian grasslands, and other significant regions and habitats), the assembly and organisation of information and specimens, and improved communication among entomologists. Its efforts have led to valuable monographs, scientific briefs, newsletters, and other products summarised here, including documents that are also useful to those outside entomology. Key operating principles of the BSC are identified. In particular, decisions come from broadly based scientific considerations, an approach to understanding the fauna that guarantees the scientific relevance of the work and is not offset by political or other influences. Core work is planned over the long term to ensure collaboration, focus, efficiency, integrity, quality, productivity, and delivery. The achievements of the BSC over many years confirm the effectiveness of this model for scientific cooperation.

Introduction

Since 1977, a period of 40 years, the Biological Survey of Canada (BSC) has provided national direction for work on the fauna of insects and their relatives (Biological Survey of Canada 2017). This paper outlines the contributions of the BSC to Canadian entomology and reviews its key principles, confirming the value and importance of genuine cooperative work.

The BSC helps scientists to collaborate effectively to advance taxonomic, zoogeographic, and ecological knowledge of the fauna. Its core is an expert steering group of volunteers, who are in touch with other interested members of the scientific community. This group establishes priorities for action and pursues ways to bring them to fruition. Its deliberations consider scientific ideas, existing information, and available resources, in a broad context, harnessing scientific capabilities across the country for mutual benefit. The work is funded chiefly through the existing resources of cooperators, although the BSC itself provides funds especially for selected publications.

From 1977 until 2009, the BSC was steered by an expert scientific committee of about

15 individual members, and had a small secretariat (an entomologist and a secretary) supported mainly by the National Museum of Natural Sciences, later renamed the Canadian Museum of Nature. Committee members were appointed by the Entomological Society of Canada (ESC), which had started the Biological Survey operation through a series of contracts, the first of which produced an initial baseline of knowledge (Danks 1979). After the first few years, the president of the ESC as well as representatives from the Museum and the Canadian National Collection of Insects, Arachnids, and Nematodes (Department of Agriculture, later renamed Agriculture and Agri-Food Canada) were added to the committee. The Museum withdrew its funding for the BSC secretariat and meetings of the committee from 2009. However, the BSC continued as a non-profit organisation, without the secretariat but with an elected board in the same role as the original scientific committee. Danks (2016) chronicles the development and history of the BSC in detail.

The deliberations of the steering group are followed up in four main ways, briefly summarised

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below and illustrated by the specific examples in later sections:

- Major scientific projects are carefully chosen for their value in characterising the fauna and put into effect through targeted research that includes joint fieldwork, collection-related activities, and publications.
- Scientific information is synthesised to better understand the fauna in taxonomic and other frameworks, to capitalise on the results of the major projects, and to provide a basis for future studies.
- Coordination and communication evaluate available resources, provide information, and encourage participation by the scientific community. In these roles, the BSC publishes relevant briefs and other scientific documents, and promotes awareness through newsletters and other vehicles.
- Letters and briefs are prepared when appropriate and sent to inform and educate non-scientists about issues of concern.

This model provides an efficient and productive way to pool national scientific expertise, even though the central organisation is small.

Benefits of the Biological Survey of Canada

The BSC model for work on the fauna of Canada, based on extensive cooperation among scientists, has contributed to the development and achievements of Canadian entomology in many ways, as summarised in Table 1. In general terms, biological surveys are useful because they allow the fauna to be elucidated for various purposes. Downes (1974) pointed out the benefits of a proper inventory of the species of Canada, such as education and appreciation of nature, inventory of natural resources, applications to human welfare such as agriculture and forestry, and the promotion of knowledge and its long-range applications. The potential benefits to society are in spheres as diverse as agricultural production, animal husbandry, assessment of water quality, interpretation of climate change, environmental monitoring, forest management, habitat conservation, medicine, and protection of species at risk. In other words, information on biodiversity, based

on taxonomic work, underpins knowledge and decision making in many fields of national significance.

The BSC identifies important entomological subjects that are inadequately studied in Canada. The identification of these key priorities enhances the relevance of the projects chosen for development. Studies of the faunas of certain regions, including key taxa there, are especially helpful. For example, the Yukon is a critical area for interpreting the postglacial development of the fauna because part of the region was unglaciated during the Pleistocene. Therefore, the BSC implemented a project that provided many insights into the history and ecology of the fauna (Danks and Downes 1997). The faunas of Newfoundland and Labrador show the influence of cool boreal habitats, postglacial dispersal, and invasions by species introduced from Europe (Larson and Colbo 1983; Biological Survey of Canada 2014). Other lessons derive from attention to key habitats. For example, before the BSC project on grasslands, relatively little was known about biodiversity, ecology, and responses to change in these habitats, despite their importance for understanding the origin and setting of the faunas of present-day range and agricultural lands modified by European settlement (Shorthouse and Wheeler 2002; Floate 2011). Characteristic forests are widespread; they are important in the production of wood and fibre, and there is particular interest in the ability of arthropods to help assess ecosystem impacts and recovery in managed forests (Langor and Spence 2008). The many wetland habitats in Canada help to store, recharge, and purify water supplies; their faunas include marsh insects essential as food for waterfowl (Rosenberg and Danks 1987). Bogs and fens are particularly extensive, but sampling there had been limited. Following an initial review for the aquatic species (Rosenberg and Danks 1987), a BSC project to sample more widely and to complete necessary taxonomic work brought insights into the natural history, distribution, and systematics of peatland arthropods, and confirmed that a significant number of species live only in these habitats (Marshall and Finnamore 1994). Freshwater springs are worthy of study because the faunas of these discrete habitats include unique and potentially endangered species, hold clues about endemism and glaciation, and also

Table 1. Benefits of work carried out by the Biological Survey of Canada (BSC).

Item	Value	Examples (for sample references see text)
General values promoted	Studies of biodiversity characterise the fauna for many purposes	Brief proposing the BSC
Relevance of work enhanced	Pertinent knowledge is obtained by identifying gaps and establishing priorities	Science-based decisions by experts
Major projects initiated	Key scientific projects catalyse work on regions, habitats, taxa, and subjects to best understand the Canadian fauna, serving to unite entomologists and encourage further work	Arthropods of the Yukon, Newfoundland and Labrador, Canadian grasslands, and Canadian forests
Information synthesised	Integrated products are baselines for future effort	Symposia and monographs about key elements and characteristics of the fauna; databases; Canadian Journal of Arthropod Identification
Ancillary projects completed	Key briefs and limited investigations support various efforts	Briefs about collections, biodiversity, and habitats needing study
Group effort promoted: research	Multiple cooperators complete scientific projects	See projects above
Group effort promoted: collecting	Multiple specialists document regional faunas	Joint projects; bioblitzes
Group effort promoted: curation	Multiple experts supplement and improve the usefulness of local collections	Shared trap samples; collection blitzes
Communication enhanced	Nationwide communication favours cooperation	Newsletters; website; symposia
Interest engendered beyond entomology	Letters, resolutions, and other contacts support work on systematics and faunistics	Recommendations to officials and others
Many apposite products produced	Products achieve various aims in characterising the fauna	See Table 2

indicate the quality of their groundwater sources (Williams and Danks 1991; Knysh 2015). A further project of the BSC considered dormancy, cold-hardiness, and other adaptations to seasonal events, which determine the nature of northern faunas (overview by Danks 2007).

A concentration on such topics is a uniting force for Canadian entomology as well as a means to acquire pertinent knowledge, and it stimulates further work. For example, results of the Yukon project led to the recognition that insects from the northern mainland would be especially instructive for analysing postglacial ranges, leading to a series of investigations in that area (*e.g.*, Currie *et al.* 2002). The ways that the BSC inspired further progress in Canada on topics such as the arthropods of Newfoundland and Labrador, the Arctic, grasslands, freshwater springs, peatlands, and forests, are described by Danks (2016).

Moreover, the influence of the BSC on future work also extends beyond completed projects because both established scientists and graduate students who have been involved in BSC activities often maintain these interests later, providing continuity.

The BSC increases the impact of its projects by synthesising their results. Typically, each monograph or symposium proceedings contains a chapter that integrates the results of the other chapters (*e.g.*, Danks *et al.* 1997). These publications underpin future work. The Canadian Journal of Arthropod Identification, a BSC product, publishes significant taxonomic work on arthropods to assist in their recognition and documentation (Canadian Journal of Arthropod Identification 2017), and is available without cost to users. Its treatments of horse flies (Thomas and Marshall 2009; Thomas 2011), blow flies (Marshall *et al.* 2011),

and many other groups allow Canadian species to be identified correctly, document their ranges, and make relevant information much more accessible.

Beyond the major projects of the BSC, entomology is supported especially through the production of briefs to draw attention to key subjects, and to ensure that faunal studies are done in a valid way. These briefs are widely used and assist in research efforts. They cover such topics as the value of research collections (Wiggins *et al.* 1991), standards for such collections (Wheeler *et al.* 2001), and recommended procedures to assess the biodiversity of arthropods (Marshall *et al.* 1994; Danks 1996) or to use them for evaluating environmental disturbance (Lehmkuhl *et al.* 1984).

The group efforts carried out through the BSC bring more substantial results than without such cooperation. For example, major projects can be pursued across many typical funding cycles. Multiple specialists combine expertise to document and analyse regional faunas (*e.g.*, Danks and Downes 1997; Shorthouse and Floate 2010; Floate 2011; Cárcamo and Giberson 2014; Giberson and Cárcamo 2014), assemble and curate reference material (especially linked with the major projects), and add to the organisation and identification of specimens in museums. Collections are enhanced through the exchange of material, and the BSC has also convened groups of experts to curate specific collections, in association with annual meetings of the ESC (*e.g.*, McCorquodale 2008).

Communication with entomologists across the country fosters this cooperation. Newsletters, including the flagship Newsletter of the Biological Survey of Canada, give facts about the current projects of the BSC, the Canadian fauna, and other topics, and a website provides access to a great deal of information. Frequent individual contacts take place among project participants. Communication is favoured by BSC sponsorship of symposia and workshops, chiefly at ESC meetings. When the secretariat was in place, the secretariat entomologist made annual national tours of entomological centres to keep in touch with entomologists (including graduate students), acquire information, publicise the BSC, and coordinate activities.

Finally, the BSC has worked to engender support for systematic and faunistic entomology through communications outside entomology.

The scientific briefs of the BSC are made available to audiences such as managers and biologists charged with local biodiversity assessments. The reach of the website extends well beyond entomologists. Individual letters and briefs seek to educate federal and provincial commissions, boards, and officials about neglected avenues of enquiry, as well as needs and procedures for work. For example, a brief about the need for an inventory of springs was submitted to the Commission of Inquiry on Federal Water Policy, and recommendations for support of biological collections infrastructure were addressed to the Natural Sciences and Engineering Research Council of Canada. The BSC also supports certain major grant applications related to its projects.

The benefits just summarised are reflected in the products of the BSC, which are enumerated in Table 2. These outputs are many and varied, with specific aims in advancing knowledge of the Canadian fauna. Moreover, this tabulation does not include the very large number of separate papers published by individual participants in BSC projects.

Since its establishment, the BSC has produced more than 6500 pages of major integrated scientific publications, taxonomic treatments of arthropod groups in the Canadian Journal of Arthropod Identification equivalent to about 4000 pages, many formal briefs on issues of concern, and nearly 100 substantial newsletters. The BSC also organised 25 scientific symposia and workshops, and enhanced many museum collections. Other products include the extensive website and other communications, as well as various databases, regular reports in the Bulletin of the Entomological Society of Canada (until 2009), and commentaries and official letters.

Operating principles of the Biological Survey of Canada

The BSC has been able to combine the interests of cooperators to produce valuable outputs by adhering to a significant number of basic operating principles, which are listed in Table 3. First, key decisions are based on scientific evaluations in a national framework, as explained above. Indeed, given the patterns of species distributions, the nature of ecosystems at different latitudes,

Table 2. Products from the Biological Survey of Canada (BSC) 1977–2016, excluding other papers by individual cooperators.

Type of product	Description	Number of items (number of pages for publications)	Sample items
Scientific books and proceedings	Major fully reviewed volumes that assemble and synthesise results	19 (6569)*	Insects of the Yukon; Arthropods of Canadian grasslands
Electronic journal	The Canadian Journal of Arthropod Identification, publishing definitive guides to the fauna	29 (3827 as pdf, plus matrix key)	Bee flies of Ontario; Siricidae of the western hemisphere
Scientific briefs and reports	Formal publications about issues of concern, procedures for research, and other subjects relevant to faunistic work	20 (792)	Freshwater springs: a national heritage; The role of voucher specimens in validating faunistic and ecological research
Newsletters	Newsletters with information and results about current activities	96 (2729)	Newsletter of the Biological Survey of Canada; Arctic insect news
Symposia and workshops	Scientific conferences promoting and consolidating key topics	25	Terrestrial arthropods of peatlands; Maintaining arthropods in northern forest ecosystems
Enhanced collections	Assembly and organisation of specimens to facilitate study	Many	Bioblitzes; collection blitzes; joint projects
Website	Information, publications, and databases available online	Many (about 1.5 million words)	biologicalsurvey.ca
Other communications	Connections through meetings and internet communication	Many	Entomological Society of Canada meetings; modern media including Facebook and blog
Databases	Data summaries and analyses with electronic access	3	List of families of insects of Newfoundland and Labrador; Canadian locality database
Reports in the Bulletin of the Entomological Society of Canada	Updates about BSC activities, for members of the Entomological Society of Canada	76 (235)	Included in March and September issues of the Bulletin for many years until 2009
Official letters and briefs	Communications with officials in governments, universities, and elsewhere, addressing issues of concern	Many	Letters and other documents to Parks Canada; briefs to the Natural Sciences and Engineering Research Council

Summarised mainly from Danks (2016), which lists all BSC products in detail.

* Excluding the Canadian Journal of Arthropod Identification, which is listed separately.

Table 3. Key operating principles of the Biological Survey of Canada.

Principle	Elements	Outcome
Agenda primarily scientific	Scientific context; “bottom-up” approach	Science optimised
Wide scope	Taxonomy, ecology, zoogeography, adaptation, and other themes considered; scientific and practical relevance	Proper characterisation of the fauna for understanding; wider utility of the results
Core work	Detailed studies of species and analyses of the fauna	New data discovered and assimilated
Long-term perspective	Key elements targeted over prolonged periods	Extensive in-depth findings
Synthesis	Work integrated	Results fully exploited and can be built on
National involvement	Wide membership and representation	Input from different interests, regions, and jurisdictions
Collaboration	Cooperation, discussion	Expertise and ideas combined for faster progress
Administrative focus	Simple operation with advisory group	Scientists work together; no extensive bureaucracy
Scientific focus	Concentration on key themes	Projects done without dilution of effort
Logistic focus	Combination and coordination of individual interests	Increased effectiveness
Efficiency	Combined efforts lead to synergies	More achieved together
Integrity	Overall scientific goals, not just individual advantages	Ongoing trust, supporting wide involvement
Quality	High and consistent scientific standards	Long-term development of knowledge
Productivity	End products as well as initial activities targeted	Enhanced scientific value of the work
Delivery	Projects followed up and completed; products freely available	Cooperation and use encouraged

temporal variations in habitat quality, and other characteristics of Canada, the most useful way to understand the arthropod fauna is to consider it in the broadest possible scientific context (Danks 2003). This “bottom-up” or “grass-roots” approach, based on expert scientific analysis, contrasts markedly with decisions based on political and economic considerations, the maintenance of local control, concerns about public profile, or other factors. As a result, the projects undertaken by the BSC are credible and readily accepted by entomologists.

Second, the scientific approach addresses many disciplines in addition to taxonomy in order to fully characterise the fauna. Such an approach prompts wide-ranging interest and engagement, connecting the projects with major themes such as agriculture (as in the project on grasslands), sustainability (forests), water quality (springs), dispersal, colonisation, invasion, and adaptation to northern climates (Arctic, Yukon, Newfoundland and Labrador, invasive species, and seasonal

adaptations). Nevertheless, the approach has necessarily been somewhat narrower since the assistance provided by the secretariat was withdrawn.

The BSC promotes the fundamental work of discovering and identifying species and their distributions. Many other current endeavours under the rubric of biodiversity seek only to make existing data available through web portals. Once the original data have been exploited, often on multiple platforms, there is no means to gather new data. Some other government activities in the context of the Convention on Biological Diversity aim to produce highly visible protocols or other documents, but without carrying out or funding the necessary basic work. The BSC emphasises primary scientific research, generating and integrating data on the fauna to sustain all other analyses.

By the same token, the BSC cultivates a long-term perspective. Major projects are promoted for many years if necessary until substantial scientific

findings, not just individual elements, can be brought out. As the work of exploration, identification, and analysis proceeds, the interest of participants is maintained by such means as joint field trips (including “bioblitzes”), workshops or symposia, and specific newsletters. For example, a grasslands newsletter was published at intervals over a period of 23 years to support the project on arthropods of Canadian grasslands, and eventually four major books were published.

A long-term view allows the synthesis of results, as noted above. Synthetic publications provide recognisable staging points in the acquisition of data, and serve as foundations for future endeavours. Consequently, they are frequently cited.

Enlisting partners from the whole of the Canadian entomological community ensures input by people from different places and organisations, and with a range of interests. Many different regions are represented on the steering group, and the interests of the BSC are harmonised nationally with those of the ESC. Such wide representation favours both scientific validity and extensive collaboration. In turn, cooperative ideas and expertise accelerate work on the fauna.

Although the BSC has diverse interests, its administrative, scientific, and logistic elements are focussed. Administration is done simply through an advisory group, rather than by any extensive directorate; the addition of a small secretariat, as originally supported, makes feasible a larger number and range of projects. A focus on key topics prevents undue dilution of effort. Feasibility is considered, too, in the light of available resources. Therefore, although the scientific orientation is broad, there is a focus on finite, achievable projects, directing the interests of individuals efficiently towards a common goal. More can be achieved together than separately.

Another essential principle of the BSC is integrity. Individuals combine their efforts to achieve major scientific goals, not to further their own exclusive interests. Such a mindset leads to mutual trust in the scientific community, a setting that encourages further cooperation.

The BSC insists on quality: its monographs are subjected to rigorous review and consistent editing, and are renowned for their high scientific standard (*e.g.*, Zack 1998). This principle adds to the long-term use of the documents as building blocks for future research.

Finally, the BSC emphasises productivity and delivery. Projects are planned to ensure that there will be useful products and not just ongoing activities, and that work proceeds to completion so that initial efforts will not be wasted. In addition, whenever possible, key tools and syntheses are made available without cost to users in order to share knowledge widely and advance science, rather than to exploit potential purchasers. Useful, coherent, and accessible delivery is widely appreciated. It encourages participation and enhances the value of the projects.

Conclusions

The BSC model demonstrates how powerful and constructive true cooperation can be. Scientists bring their interests into broad projects and assist each other to advance knowledge.

A crucial feature of this model is the “bottom up” selection of projects on scientific grounds, in contrast to schemes where “top down” priorities are enforced by the authority of senior decision makers, many of them non-scientists. This BSC is feasible and has continued to be effective because it is supported by individuals who are studying the fauna, and does not attempt to change or fund complex administrative structures or staffing, nor respond to short-term political whims. Other more ambitious biological survey initiatives have proved to be unfeasible in North America in the face of economic pressures, and in particular because of disagreements over jurisdiction and other political considerations. For example, during the establishment of the BSC there were difficulties with the Department of Agriculture, which had responsibility for systematic entomology (Danks 2016: 30–35). Krahe (2012) outlines how political developments derailed one attempt to consolidate a National Biological Survey in the United States of America. Indeed, in Canada a group of expert volunteers organised through a professional society – rather than a government agency – established the current approach that provides national leadership and support to discover and characterise the whole arthropod fauna. Most other potential approaches lack a way to incorporate the breadth of knowledge and experience of the BSC.

In summary, scientific work on the Canadian arthropod fauna over the past 40 years would not

have been of such wide scope, large scale, and key relevance without the catalysis, planning, organisation, and coordination available through the Biological Survey of Canada. In the BSC, co-operative projects to acquire core faunal information of broad interest are chosen on scientific grounds, organised and led over the long term, and culminate in useful products of high quality. Therefore, the BSC, working with the ESC, has had a positive influence on the direction and quality of Canadian entomology, enhancing knowledge of the fauna and generating widely used synthetic publications. Some of its results are included in subsequent papers in this special issue of the *Canadian Entomologist*.

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