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CASE STUDIES AND REVIEWS

Historic marine invertebrate species inventory: case study of a science baseline towards establishing a marine conservation area

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ABSTRACT

(1) Assessing species diversity is a basic requirement for conservation, and protecting biodiversity is a major goal of marine area conservation.
(2) A case study is presented on the development of a literature-based (1870s to 2000), museum collection-based, georeferenced inventory of marine invertebrate species of the Haida Gwaii (Queen Charlotte Islands) region, Canada.
(3) Database structure and quality assurance are described, along with including indigenous people's words for species towards using traditional knowledge within cooperative marine conservation area management.
(4) The utility of this type of inventory is proposed as a starting point for gathering regional biodiversity knowledge, and facilitating addition of other knowledge types, towards marine area conservation.

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KEY WORDS: species inventory; marine invertebrate; marine protected area; Queen Charlotte Islands; Haida Gwaii

INTRODUCTION

> 'We need to launch a major effort to measure biodiversity, to create a complete inventory of all the species of organisms on Earth, and to assess their importance for the environment and humanity.' E.O. Wilson (1987)

Natural history, taxonomy and species occurrence data, including those from professionally curated collections, link biological disciplines and are foundational to monitoring and conservation (May, 1990; Wheeler, 1995; Noss, 1996; Balmford and Gaston, 1999; Snow and Keating, 1999; Dayton, 2003; Brooks *et al*., 2004; Goldstein, 2004; Pressey, 2004; Yahner, 2004; White and Langdon, 2006; Teder *et al*., 2007). Assembling geo-referenced occurrences of species into a geographic information system (GIS), that is, mapping species in space (and time) is an important aspect of conservation planning (Stork and Samways, 1995; Bowker, 2000; Brooks *et al*., 2004; Guralnick and Neufeld, 2005; Schmidt-Kloiber *et al*., 2006). Indeed, Wilson (2002) refers to biodiversity mapping as 'the instrument that unites biology'.

Biodiversity occurs on different scales (genetic through to landscape). However, the scale at which species occur — and therefore species diversity — is the most widely understood by the general public. Species are the most commonly used unit of biodiversity for conservation planning (Costello, 2000; Brooks *et al*., 2004). Biodiversity frames the main attributes of ecosystems — composition, structure and function — the science of which remains dominated by research into composition at the species/community level (Angermeier and Schlosser, 1995). As part of composition, species data are central, and, for benthic marine systems, biological characteristics expressed by the taxa present are beginning to be used as indicators of key ecosystem functions (Frid *et al*., 2008).

The Internet, along with computer database and GIS developments, have aided collection of enormous amounts of taxonomic and biodiversity information (Wheeler, 1995; Knapp *et al*., 2002; Graham *et al*., 2004; Soberón and Peterson, 2004). Indeed, Raven *et al*. (1991) suggested that the application of computer technology has been more important to taxonomic information management than the mid-15th century development of movable type. The United Nations Convention on Biological Diversity (CBD) has increased the demand for biodiversity information (Tickell, 1997; Samper, 2004) and set a target among the 190 signatory nations for a significant reduction of the current rate of biodiversity loss by 2010 (Balmford *et al*., 2005). This has motivated collaborative digital cataloguing projects that,

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collectively, are revolutionizing biodiversity information. The foundation of these efforts is a global pool of taxonomists and systematists. Their collective expertise is used by the Biodiversity Information Standards organization [http://www.tdwg.org] to develop and promote standards for recording and sharing biological information. The collective knowledge of these specialists is also harnessed by Integrated Taxonomic Information System (ITIS) [http://www.itis.gov] and Species 2000 [http://www.sp2000.org] that together run the web-accessible Catalogue of Life [http://www.catalogueoflife.org]. The Catalogue of Life listed 220 000 species in 2000, >1 million species by the end of 2007 and has a goal to list all known species (approximately 1.75 million) by 2011. The Catalogue's checklist is used as the taxonomic standard with which the Global Biodiversity Information Facility [http://www.gbif.org] has aggregated >7500 biodiversity datasets containing >151 million records and is growing rapidly. These records can be searched as a single aggregated database by location, taxonomy or occurrence.

Concerning marine species, the Census of Marine Life [http://www.coml.org] is a global initiative to assess diversity, distribution and abundance of all marine species using its Ocean Biogeographic Information System (OBIS) [http://www.iobis.org] that was launched in 2000 (Yarincik and O'Dor, 2005). The OBIS is an integral part of the new field of ocean biodiversity informatics, about which Costello and Vander Berghe (2006) stated that '.... marine biology has entered the information age'. Electronic data organization helps address the need to make marine data more accessible and applicable to protecting the marine environment (Hiscock *et al*., 2003) and facilitates GIS applications in the marine realm (Wright and Scholz, 2005).

Inventory of biodiversity is a basic, often overlooked, requirement for marine conservation (Grassle *et al*., 1991; Snelgrove, 1999; Hixon *et al*., 2001; NRC, 2001; Edgar *et al*., 2005; Hendriks *et al*., 2006). Protecting biodiversity is a major goal of marine area conservation (Jones, 1994; NRC, 1995, 2001; Kriwoken, 1996; Price, 2002; Roberts *et al*., 2003; Leslie, 2005; Norse and Crowder, 2005; Shears *et al*., 2008). Further, Grassle and Stocks (1999) proposed that marine ecosystem understanding depends on sound species-level data on distribution, abundance and life history of organisms. Accordingly, harnessing the Internet, database software and GIS tools has stimulated marine inventory at regional to global scales (Costello and Vander Berghe, 2006).

A national marine conservation area surrounding Gwaii Haanas National Park Reserve and Haida Heritage Site is proposed by Parks Canada Agency in the Haida Gwaii (Queen Charlotte Islands) region, British Columbia (Figure 1). Parks Canada's marine mandate under the *Canada National Marine Conservation Areas Act* of 2002 is to conserve representative samples of marine regions in which ecosystem structure and function are maintained while permitting multiple sustainable uses such as fishing (commercial, recreational, aboriginal subsistence), aquaculture and tourism. Other objectives include facilitating visitors' experiences and informing Canadians about their natural and cultural marine heritage. For marine conservation areas, the connectivity and dynamism of marine systems underscores the relevance of looking outside protected area boundaries to the necessary scale of appropriate ecosystem understanding of the contiguous region.

The CBD was one of the first international agreements to recognize the role of indigenous peoples and their knowledge in conserving biodiversity. In Canada, traditional aboriginal knowledge is recognized as a necessary consideration in the nation's oceans strategy (DFO, 2002) that arose from the Oceans Act of 1997 and as an application principle of the Fisheries Act. Key to any management structure for Gwaii Haanas' marine area will be the Canada-Haida (local indigenous group) cooperative management already in place for the Gwaii Haanas' lands since 1993. This was an early cooperative management agreement in the Parks Canada system. Aboriginal peoples have unique status within the

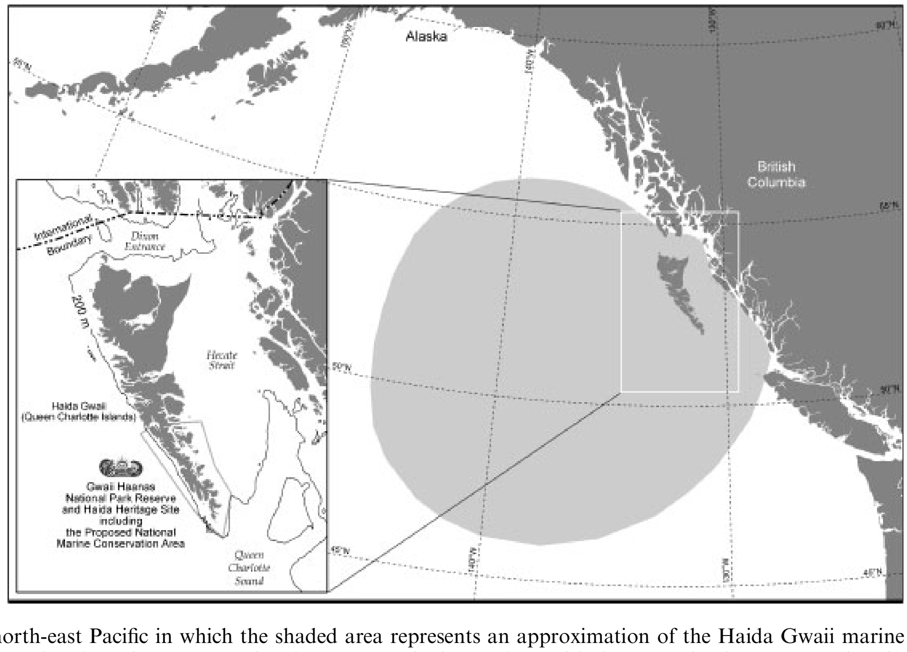

Figure 1. Map of the north-east Pacific in which the shaded area represents an approximation of the Haida Gwaii marine region. In the inset, the proposed Gwaii Haanas National Marine Conservation Area Reserve is shown along with the 200 m depth contour at the edge of the continental shelf.

Canadian constitution (Constitution Act of 1982) that includes access to living natural resources and a growing role in national park planning and management (Berg *et al*., 1993; Manseau *et al*., 2005). Respect for traditional knowledge is ethically warranted when contemplating long-term area management (Berkes, 1999; Turner *et al*., 2000). Respecting such knowledge in biodiversity conservation is a recent phenomenon (Gadgil *et al*., 1993), particularly within marine conservation (Drew, 2005). A potentially useful area of contact for information sharing between western natural science and indigenous knowledge is that of indigenous taxonomies (Berkes, 1999).

This paper is a case study on the development and potential utility of a literature-based (1880s to 2000), collection-based and GIS-based marine invertebrate species inventory (intertidal, benthic, pelagic and parasitic species) that represent >90% of the region's recorded marine animal species — the remainder being vertebrates. No records of marine invertebrate species from the region occur before 1878. Given that perhaps only 10–15% of Earth's species diversity is known (Raven *et al*., 1991), the scope for additions is enormous. The general state of knowledge on marine invertebrates from the whole north coast of British Columbia region is poor (Lambert, 1994; Sloan *et al*., 2001; Pellegrin *et al*., 2007; BCMCA, 2008). The objective of this case study is to demonstrate the creation of a geo-referenced marine invertebrate species inventory that provides a starting point in regional biodiversity knowledge in aid of marine area conservation. This inventory is part of a science review assisting public consultations towards establishing the proposed Gwaii Haanas National Marine Conservation Area Reserve (Sloan *et al*., 2001; Sloan, 2006). Discussion includes lessons learned from species database assembly, structure and quality assurance, as well as first steps towards inclusion of indigenous knowledge. Further, suggestions are made for rendering the inventory additive to integrate other types of information to an area's species diversity.

INVENTORY SCOPE

The Haida Gwaii region is defined as the contiguous waters surrounding Haida Gwaii including Dixon Entrance, Hecate Strait, Queen Charlotte Sound and westward into the North-east Pacific to approximately 145° W, but not Vancouver Island, the mainland British Columbia and Alaska coasts or their associated islands and inlets (Figure 1). This region is of marine biogeographical interest as it represents a transition area for various plant (Sloan and Bartier, 2000) and invertebrate (Sloan *et al*., 2001) groups, although it is not a biogeographic crossroads (*sensu* Spector, 2002) in the north-east Pacific comparable with, for example, Point Conception (34.5° N) in southern California (Coan *et al*., 2000).

This inventory was based on as complete a survey as possible of literature and collections starting from the first known science report (Dawson, 1880). All invertebrate taxa from the family to the subspecies levels from all published and unpublished documents, institutional collections with regional material and unpublished observations from individuals were included. Few field collections from various research projects around Gwaii Haanas were included. A four-dimensional (latitude/longitude/depth/date) GIS database was created to represent the entire regional marine invertebrate science history. Species names are widely accepted standards backed by the convention of the International Code of Zoological Nomenclature (Bowker, 2000). Approximately 25 000 invertebrate records (2503 species — 23 phyla) from 2900 collection or observation sites (Figure 2) from the intertidal to >3600 m depth were included. Records are biased towards shallow water as approximately 80% of sites were from <200 m depth. The accumulation of taxa over time illustrated in Figure 3 shows a tendency to level off that is most marked at higher taxonomic levels such as family.

All species records from the study area were included initially, regardless of whether they were represented by

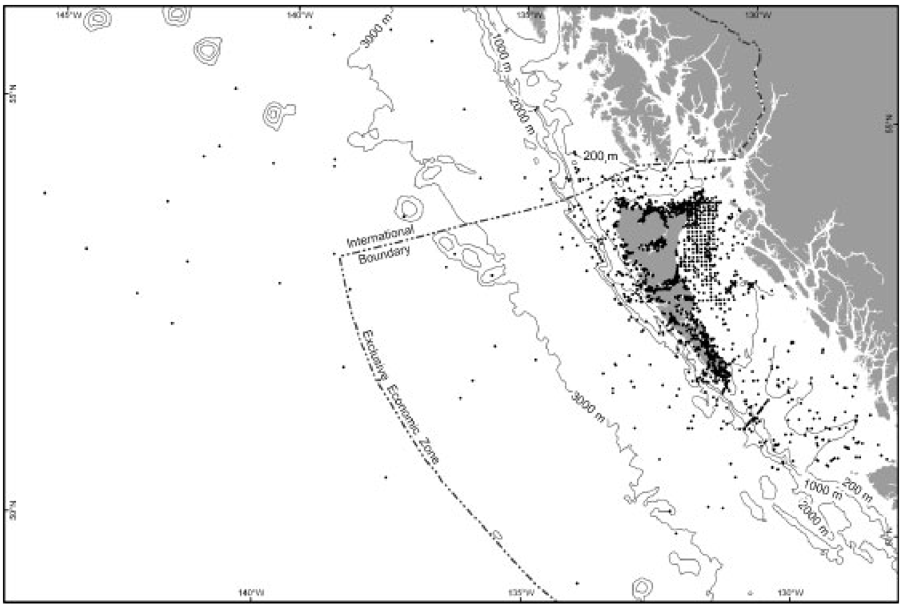

Figure 2. Map of all sample or observation sites in the Haida Gwaii marine region from which invertebrate species (intertidal, benthic, pelagic, parasitic) have been recorded (from the 1878 to 2000) in the geographic information system database.

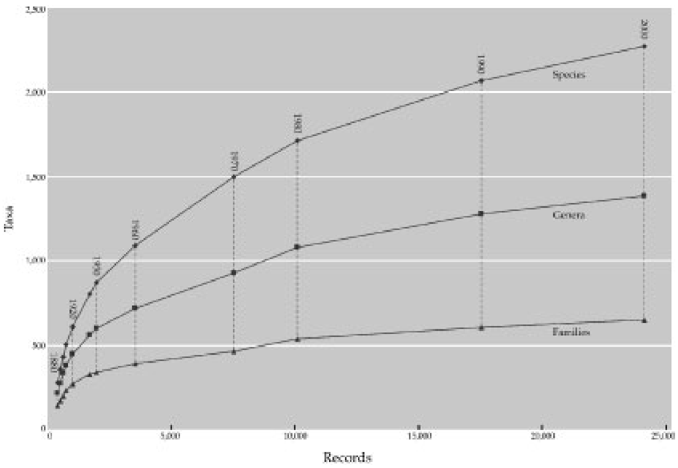

Figure 3. Marine invertebrate taxa accumulation curves from sampling in the Haida Gwaii marine region from the first record in 1878 to 2000. Observations without reliable dates were excluded, thus the total number of species used (2276) differs from the total in the database (2503).

specimens in professionally curated collections. However, some question the merit of including species not in such collections, because these species are unverifiable (Hawksworth and Mibey, 1997). To maintain rigour, each record was assigned an identification reliability criterion, in order as follows: (1) species for which the type specimen(s) come from the region; (2) species for which there are catalogued museum specimens; (3) species mentioned in internationally peer-reviewed publications; (4) species mentioned in grey literature reports and unpublished surveys; and (5) species for which there are known or suspected problems. The first two criteria cover species that are represented by specimens in collections and are differentiated in the database from all the other species.

Geo-referenced specimens in curated collections are the foundation of most regional species lists (Hawksworth and Mibey, 1997; Ponder, 1999; Meier and Dikow, 2004) used to assess biodiversity within protected areas (Funk *et al*., 1999; Brooks *et al*., 2004; Graham *et al*., 2004; O'Connell *et al*., 2004), and to document species declines (Shaffer *et al*., 1998). Sixteen of 21 North American and eight overseas institutions contacted had study area material that collectively represented 68% of all species recorded. However, no museum had all their Haida Gwaii specimens digitized into databases. Contracts with the three largest collection holders (all Canadian) were made to acquire those data. Further, most museums had unsorted, unidentified specimens from the Haida Gwaii region. This information is also included in the database. Given the incomplete museum collection digitization (perhaps 10% globally, Graham *et al*., 2004), it is not surprising that only about 33% of all described marine species are available online from reliable master lists (Costello and Vander Berghe, 2006).

North-east Pacific invertebrate checklists (Austin, 1985; Kozloff, 1996) covered at least 80% of recorded regional taxa. Additions and updates were made based upon literature either omitted from or published since these checklists. More recent monographs (e.g. Coan *et al*., 2000), and individual papers with updated taxonomy and systematics were used whenever possible. For marine regions without comprehensive checklists, a starting point could be the rapidly growing internet-based information on individual groups.

DATABASE STRUCTURE

Database structure follows taxonomic conventions established by the Association of Systematic Collections and adopted by ITIS. The attributes of the database's 10 information tables are listed in Appendix A. To enable further enquiry, records were linked with all relevant literature, the higher systematic affiliations were provided to assist grouping into related units and any observations underpinned by specimens in collections were identified. Also indicated was whether species have been introduced into the region (Sloan and Bartier, 2004) or have some listed at-risk status.

Also included were southern Haida dialect words for invertebrates obtained from the Skidegate Haida Immersion Program (SHIP) of the Skidegate Haida Language Authority. This was done to facilitate including other traditional Haida knowledge into the database in the future. Known Haida names for 56 species or species groups are listed. These species represent the most important marine invertebrate food species used historically by the Haida and most of the shallow water species fished commercially in the region.

Figure 4 illustrates relationships between the information tables of the database. Relationships between tables are either mandatory or optional, e.g. an *observation* must come from a *site*, but an observation may, or may not, be linked to one or more *specimens* because not all observations are backed by collection specimens. Relationships are also either one-to-one (1:1), one-to-many (1:N) or many-to-many (N:M). For example, for each site in time and space, there is only one set of physical properties (1:1); one site can have many observations (1:N); and one site can be referenced by many sources and one *source* can include many sites (N:M).

Database quality was controlled using both automated and manual methods. Automated methods included searching the attribute fields listed, either alone or in combination, in order to identify anomalies and logical inconsistencies (e.g.

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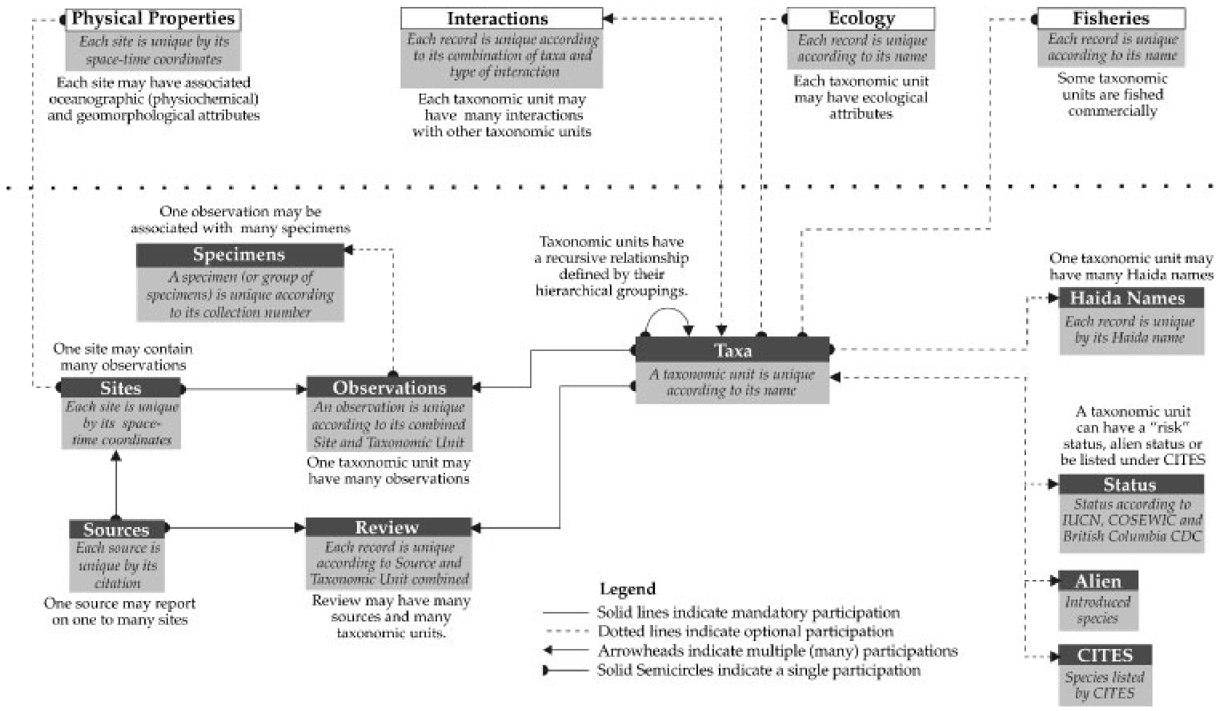

Figure 4. Schematic diagram of the marine invertebrate database structure used to accommodate the relationships between the information tables listed in Appendix A. Note that the Taxonomic Units information table includes a recursive relationship allowing a taxon's systematic hierarchy to be revealed up to the phylum level. Separated by a dotted line in the top portion of the figure are potential database enhancements accommodating relationships between the existing information tables and new tables of *physical properties*, *interactions*, *ecology*, and *fisheries*.

observation sites on land). For example, it is possible to identify all non-coastal sites listed as intertidal by performing a GIS search that combines proximity to the coast with the *type* field within the sites table. Some errors were due to data entry and some were from the source documents. Therefore, overall quality assurance is not possible without hand-work in pursuit of anomalies, particularly in the earlier literature. This is one of the most daunting tasks in species inventory, but one that is best performed at the outset.

SOURCES OF ERROR

Any exhaustive species compilation will warrant numerous caveats on its limitations. Challenges for the invertebrate data include records not backed by voucher specimens, a wide variety of information sources, an array of habitats from splash zone to deep-sea, a range of sampling methodologies from deep-sea trawls to intertidal collection by hand and an appreciable proportion of pre-1940s literature with incomplete information. Even within the grey literature, reliability varies greatly depending on the expertise of investigators making the identifications, and this ranges from taxonomic specialists to amateur naturalists. Further, sample locations can experience multiple sampling events (perhaps by differing methods) during different surveys over time. The results of this fieldwork can languish unpublished, or published only in part, for decades. Therefore, the details of sampling can become scattered in the literature and redundancy or incompleteness may not always be apparent. It may take decades for taxonomists to fully process a collection.

Incorrect identifications are likely common, particularly in non-specialist reports. Misidentification occurs in museum collections after accession of whole, but unreviewed, collections. For example, the Royal British Columbia Museum acquired Parks Canada's collections from early 1990s surveys. Among the specimens were two snails, both of which were significant range extensions for these particular species. However, upon re-examination, the specimens were identified as species well known from Haida Gwaii (Sloan *et al*., 2001). Only thorough review by taxonomic specialists for each group will ultimately provide reliable identification. Thus the Gulf of St Lawrence invertebrate survey took >20 years to draw (globally) upon the experts to review specific organism groups (Brunel *et al*., 1998).

A specimen's species name can undergo multiple changes over time, reflecting reclassification due to systematic changes or taxonomic lumping or splitting. As a result, species names can become disconnected or lost. A list of alternative names (synonyms or misidentifications) was made, many of which came from Austin (1985). However, some names in publications before the 1950s were disconnected from modern names and were difficult to track. These required intermediate references before they could be appropriately placed in the database. A potential solution is the rapidly improving access to taxonomic information published prior to the digital age, that is, serials with digitized back-issues.

Errors associated with sample locations were common. For example, there are two Moresby Islands in British Columbia and it is not always apparent which one was being referred to. Other, more complicated situations occur, such as species from regional crab diet analyses that yielded unique species records. Here, the problem was that the species occurrences were not

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linked to individual sample (trawl) sites. In this case, we used the approximate mid-point within the geographic range of all the sample locations for all the species records. Other instances are misspelled or incorrect location names, or vague location descriptions.

There were lost data underlying some published species information. Examples are from papers including regional marine invertebrates for which raw sample location data were allegedly in the Depository of Unpublished Data, Canadian Institute of Scientific and Technical Information, Ottawa, but these data were not present in files, in addition specimens can go missing and prove to be untraceable after dispersal into various collections, especially before the 1940s. As Graham *et al.* (2004) noted, such problems can be detected if they represent geographical outliers or they can be corrected if the specimen and original field notes can be checked. Again, accessing the very rapidly growing body of digital collections records online will probably help.

NATIONAL ADOPTION

Gwaii Haanas' marine invertebrate and marine plant databases were the first from Pacific Canada to be lodged with Fisheries and Oceans Canada's Centre for Marine Biodiversity, Bedford Institute of Oceanography, Nova Scotia [http://www.marinebiodiversity.ca]. This centre was established as part of Canada's national science plan for marine biodiversity (Zwanenburg *et al.*, 2003). The Gwaii Haanas data then became part of Canada's contribution by the Centre to the global Ocean Biogeographic Information System (OBIS), and ultimately into the Global Biodiversity Information Facility. The Gwaii Haanas databases can now be queried on-line by theme, geography or in combination thereof, through a 'Geoportal' (Maguire and Longley, 2005) maintained by OBIS.

DISCUSSION

A geo-referenced historical (literature- and collections-based) invertebrate species inventory can be a useful early step in biodiversity knowledge gathering towards marine area conservation. Invertebrates represent most (>90%) of marine areas' recorded multicellular animal species diversity, although likely only a fraction of what is actually there (Raven *et al.*, 1991; Snelgrove, 1999). Mobilizing existing inventory information is acknowledged as foundational for assessing conservation status and sustainable use (Stork and Samways, 1995; Hawksworth and Mibey, 1997; Samper, 2004). A digitized historical species inventory reveals aspects of a region's marine science history, cost-effectively unearths publically-funded information (Zeller *et al.*, 2005), facilitates regional biogeographic comparisons (Arvanitidis *et al.*, 2002) and focuses future efforts to fill key data gaps while avoiding redundancy of collecting effort. There is also the intrinsic (right-to-exist) non-use value of biodiversity that underpins humanity's ethical duty of stewardship (Ehrlich and Ehrlich, 1992; Barr *et al.*, 2003). The value of inventory is magnified by geo-referencing species occurrences that enable other spatial data (biological (Salomon *et al.*, 2001) or physical/chemical (Zacharias and Roff, 2000)) to be layered for analyses with species data towards biogeographic and ecosystem characterization (Graham *et al.*, 2004; Gregr and Bodtker, 2007; Shears *et al.*, 2008). The tendency for cumulative records of regional invertebrate taxa to level off over time shown in Figure 3 may represent a limitation of the unsystematic historical nature of sampling. Further inclusion of sampling, based just on opportunity, may now be a lower yield strategy for capturing biodiversity compared to more focused sampling according to habitat or substrate type and with a full range of appropriate sampling technologies.

There is potential for enhancement of the database to incorporate regional ecosystem processes and properties. One potential goal would be to use the spatial taxonomic information to support better regional ecosystem-based management through developing insights into ecosystem structure and function (Frid *et al.*, 2008). Illustrated in the top of Figure 4 are elements that could augment the database as follows:

Physical Properties—oceanographic or geomorphological data often recorded with *sites*.

Interactions—trophic and/or nutrient flows between different *taxonomic units*.

Ecology—ecological attributes of *taxonomic units*, e.g. pelagic, parasitic.

Fisheries—fishery-dependent or -independent data types on target species or species groups (e.g. a *taxonomic unit* could be a species or a higher unit such as a Family).

Given the critically important public consultation process in contemporary marine conservation (NRC, 2001), the ideas of species and species diversity are more recognizable to the public within the continuum of scale that characterizes aquatic biodiversity (Angermeier and Schlosser, 1995). Notions of consequences of biodiversity loss and of links between biodiversity well-being and managing for sustainable ecosystems remain relatively less understood by the general public (CoML, 2007). If taxonomy provides a vocabulary to discuss the world (Knapp *et al.*, 2002), then the public's concerns over environment and biodiversity are usefully symbolized, in part, through the well-being of species. This includes the culturally charismatic species such as mammals, birds and vascular plants (but not most invertebrates) and species-at-risk. The issue of focal species in marine conservation is reviewed elsewhere (Zacharias and Roff, 2001). Over the longer term, of course, public learning and discourse towards a broader (than species) ecosystem-based conservation and understanding is needed.

Engaging in species inventory reveals an enduring irony in conservation. On one hand, the CBD has initiated an unprecedented demand for species occurrence data (Samper, 2004), information management tools are now in place to manage and share these data globally (Costello and Vanden Berghe, 2006) and there is broad consensus that biodiversity is integral to ecosystem properties and services (Hooper *et al.*, 2005; Worm *et al.*, 2006; CoML, 2007). On the other hand, taxonomy and natural history expertise that underpin collection of species-level data continues to languish. Raven *et al.* (1991) questioned the ability of taxonomy to contribute, in timely and effective ways, to ecosystem understanding in this era of rapid habitat degradation and biodiversity loss. That is, the rate of species loss from rich habitats such as coral reefs, far exceeds the rate of describing species from those ecosystems. Despite the need for appreciable growth in taxonomy (especially for invertebrates) there has been relatively little progress since the mid-20th century (Hedgpeth *et al.*, 1953), with a few exceptions (Rodman and Cody, 2003). This overall lack of progress remains an impediment to advances in biodiversity knowledge and conservation biology (Froese, 1999; Snelgrove, 1999; Godfray, 2002; Dayton, 2003; Golding and Timberlake, 2003; Ronquist and Gärdenfors, 2003; Zanetell and Rassam, 2003; Brooks *et al.*, 2004; Pressey, 2004) including in the marine realm (NRC, 1995, 2001; Hixon *et al.*, 2001; Norse and Crowder, 2005; CoML, 2007).

Protected areas should function as long-term ecosystem and biodiversity baseline reference sites (Vane-Wright *et al.*, 1991; Arcese and Sinclair, 1997; Dayton *et al.*, 2000; Hager and Nudds, 2001; Roff, 2005) and conservation managers need to know species diversity within their areas (O'Connell *et al.*, 2004; Boone *et al.*, 2005). The spatial context of protected areas and their potential roles as reference sites are well served by sound GIS-based species occurrence data. In the early 1990s, the US National Park Service reviewed the state of species inventories and found most invertebrate groups, except some arthropods (Debinski and Brussard, 1994), poorly represented in parks (Stohlgren *et al.*, 1994). In the late 1990s, the US National Park Service initiated a long-term Inventory and Monitoring Program [http://www.nature.nps.gov/im/] with an essentially terrestrial focus and a system-wide priority on vertebrates, vascular plants and species of special interest (Boone *et al.*, 2005). Invertebrate inventories (mostly for arthropods) were identified as voluntary on a park-by-park basis, although the importance of invertebrate and non-vascular plant inventories was acknowledged for marine areas of US national parks. With a few exceptions (McGuinness, 2001), however, there remains a marked cultural bias against invertebrates that tend to be overlooked in conservation management in favour of higher-profile groups such as vertebrates and vascular plants (Wilson, 1987; New, 1998; Lunney and Ponder, 1999; McGuinness, 2001; Clark and May, 2002).

Given the national recognition for uses of traditional knowledge in marine natural resource management (DFO, 2002; Manseau *et al.*, 2005) and of the cooperative management expected for Gwaii Haanas' proposed marine area, respecting Haida knowledge is central. As outlined in Drew (2005), benefits can include fostering a sense of engagement and ownership within the cooperative management partnership. Specifically, using Haida names in the invertebrate database is an early step in the process towards inclusion of traditional aboriginal knowledge into the total body of knowledge in support of future management. Given the pragmatics of subsistence, only a small fraction of invertebrate species are usually reflected in aboriginal taxonomies compared with larger proportions of culturally more important groups such as vertebrates (Raven *et al.*, 1991; Berkes, 1999). Aboriginal taxonomies are used for communicating about species whose biology is already known rather than for retrieval of biodiversity information (Raven *et al.*, 1991). Names are linked to the traditional uses Haidas made of marine invertebrates (Ellis and Wilson, 1981). Therefore, animals' names enable cross-cultural information sharing on conspicuous invertebrate species or groups. Next steps include recording of Haida place names (AMB, 2008) that will aid geo-referencing Haida information types such as songs, stories, subsistence take areas and species' traditional ecological information. These could be rendered into GIS layers for spatial evaluation along with natural science layers.

This historical invertebrate species baseline represents most of the Haida Gwaii marine region's species diversity, and can be used to help characterize ecosystems after other types of GIS layers are superimposed. Although there are taxonomic problems in some species identifications, there may be sufficient information to make spatial generalizations when, for example, understood in the context of depth and substrate.

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APPENDIX A

Attributes of each data table in the invertebrate database

Field name	Description of properties
Sources Table	
Source_ID	A Unique Number identifies each source (article, report, book, collection, etc.)
Citation	A bibliographic citation of the source
Sites Table	
Site_ID	A Unique Number identifies each site
Source_ID	A link to the Sources table
Original Site	The site identifier (e.g. number, name, code) from the original source, if it exists
Location Described	Text describing site, if available
Original Latitude	Latitude as originally recorded or as recorded by us from original notes
Original Longitude	Longitude as originally recorded or as recorded by us from original notes
Horizontal Datum	North American Datum (NAD) 1927 or 1983, if known
Adjusted Latitude	Adjusted latitude, e.g. if site turns out to be on land; repositioning was based upon text description of the site, or any other information permitting a common-sense repositioning
Adjusted Longitude	Adjusted longitude, e.g. if site was on land see above
Estimated Accuracy	An estimate (in metres) of accuracy of the site's location
Observation Date	Date, or range of dates, which observation was taken
Depth	Estimated depth (m), or range of depths, at which observation was taken
Type	Ecological notes on observation site: benthic/intertidal/subtidal/river-estuary/pelagic/parasite/fish stomach/bird stomach/crab stomach
Comments	Notes on ecological traits of the site, e.g. sea grass meadow, sea urchin barrens, sponges in cave, SCUBA diving, etc.
Observations Table	
Observation_ID	A number that uniquely identifies each observation
Site_ID	Together with Taxon, forms a Unique Alphanumeric Code—links to Sites table
Taxon	Together with Site, forms a Unique Alphanumeric Code—links to Taxa table
	A number on our scale of 1 to 5 as follows: 1) Species for which the type specimen(s) come from the Haida Gwaii region 2) Species for which there are other museum specimens; 3) Species mentioned in internationally peer-reviewed and historical publications; 4) Species mentioned in 'grey' literature reports and unpublished surveys; and 5) Species observations for which there are known or suspected problems.
Specimens Table	

Observation_ID	Unique Number — links to the Observations table
Collection	The acronym of the institution in which the specimen(s) is held
Catalogue	Museum's catalogue number for that specimen
Accession	Museum's accession number for that specimen
Lot	Museum's lot number for that specimen
Type Status	Type status of the specimen, e.g. paratype, holotype, etc.
Number	Number of specimens of that taxon
Notes	Miscellaneous text on specimens, e.g. gender, reproductive state, unpublished record
Haida Names Table	
Taxon	Unique Alphanumeric Name provides a link to the Taxa table
Haida Name	The Haida language name (spelling/orthography) according to the Skidegate Haida Language Authority, Skidegate Haida Immersion Program (SHIP)
Orthography Notes	Notes on the orthography used because some databases cannot accommodate (recognize) the orthographic symbols selected by SHIP
Notes	Text on interpretation of the Haida name, e.g. shrimp name derived from 'to run backwards'
Taxa Table	
Code	Unique Alphanumeric Code — our in-house code for linking to other tables
Parent[a]	The scientific name of the taxon's parent
Taxon[b]	Unique Scientific Name
Level	Sub-specific epithet Full species name
Authority	The name of the original describer of the species and the date when published, if available
Common Names	Common name(s) associated with the taxon
Comments	Miscellaneous text on whether the identification is questionable and ecological notes, e.g. parasite, rarity, seagrass meadow, etc.
Review Table	
Taxon	Provides a link with the Taxonomic Units table
Source_ID	Provides a link with the sources table
Notes	Notes concerning reliability, significance (e.g. type specimens)
Status Table[c]	
Taxon	A unique name that provides a links with the Taxa table
CDC_Global_Rank	The taxon's global ranking according to the Nature Conservancy
CDC_Subnational_Rank	The provincial rank according to the BC CDC
CDC_Status	BC CDC status (Red, Blue)
COSEWIC	COSEWIC Status
Aliens Table[d]	
Taxon	A unique name that identifies alien taxa; links with the Taxa table
CITES Table[e]	
Taxon	A unique name that identifies the CITES taxon; links with the Taxa table
Appendix	The CITES appendix on which the Taxon is listed

[a]Each taxa has a taxonomic parent and this relationship is recursively defined in the table so that, for example, any subspecies can be linked to its phylum or all the subspecies can be determined for a phylum.
[b]Consistent with the *International Code of Zoological Nomenclature*.
[c]British Columbia provincial listing (CDC — Conservation Data Centre), Canadian federal listing (COSEWIC — Committee on the Status of Endangered Wildlife in Canada), international listing (IUCN — World Conservation Union).
[d]Species that have been introduced into the region.
[e]Convention on the International Trade in Endangered Species (CITES) listing.

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