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SHORT COMMUNICATION

Unforeseen importance of historical collections as baselines to determine biotic change of coral reefs: the Saba Bank case

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Abstract

Botanical and zoological collections may serve as archives for historical ecological research on the effects of global change and human impact on coral reef biota. Museum collections may harbour old specimens of reef-dwelling species that have become locally extinct. Such collections also help to determine whether early records of invasive species can be obtained from times when they were not yet recognized as such. A case study (2006) involving Saba Bank, Caribbean Netherlands (former Netherlands Antilles), suggests that the coral reef fauna here may have become impoverished when compared with data obtained during an earlier expedition in 1972. However, the 1972 sampling may have been incomplete, as it was performed by professional divers who were not trained taxonomists, whereas the collecting in 2006 was done by experienced marine biologists who knew the taxa they were sampling. As Saba Bank has been under stress due to the anchoring of large vessels, and invasive species have been a potential threat as well, future studies are needed to obtain more insights into the changing reef biota of Saba Bank. Using this Saba Bank example, we want to address the importance of natural history collections as reservoirs of valuable data relevant to coral reef biodiversity studies in a time of global change. As such, these collections are still underexplored and underexploited.

Introduction

Early ship-based scientific expeditions to species-rich coral reef areas were organized to explore marine biodiversity and to discover unknown species. Fieldwork consisted of collecting specimens indiscriminately by grabs and trawls or was conducted by divers without taxonomic training (Fig. 1). These sampling procedures may have missed many rare species and cryptic taxa. The collected specimens were usually sorted and preserved on board and eventually deposited in museum collections. Material available for study by taxonomists was identified and described in large series of botanical and faunistic monographs, which generated insights in the species richness of the seas and oceans (Ekman 1953; Hoeksema 2007). This was especially the case regarding expeditions to coral reefs in the centre of maximum marine species diversity, the so-called Coral Triangle (South-East Asia), which harbours high species concentrations of reef corals and organisms that depend on corals for food, shelter and substrate (Bellwood & Hughes 2001; Hughes *et al.* 2002; Roberts *et al.* 2002; Barber & Bellwood 2005; Bellwood *et al.* 2005; Hoeksema 2007; Bellwood & Meyer 2009a,b; Briggs 2009).

Nowadays, collecting is primarily done by marine systematists themselves and is therefore a better representation of the fauna present, such as during the Snellius-II Expedition to Eastern Indonesia in 1984 (Best *et al.* 1989; Hoeksema & Moka 1989; van Soest 1989; Hoeksema &

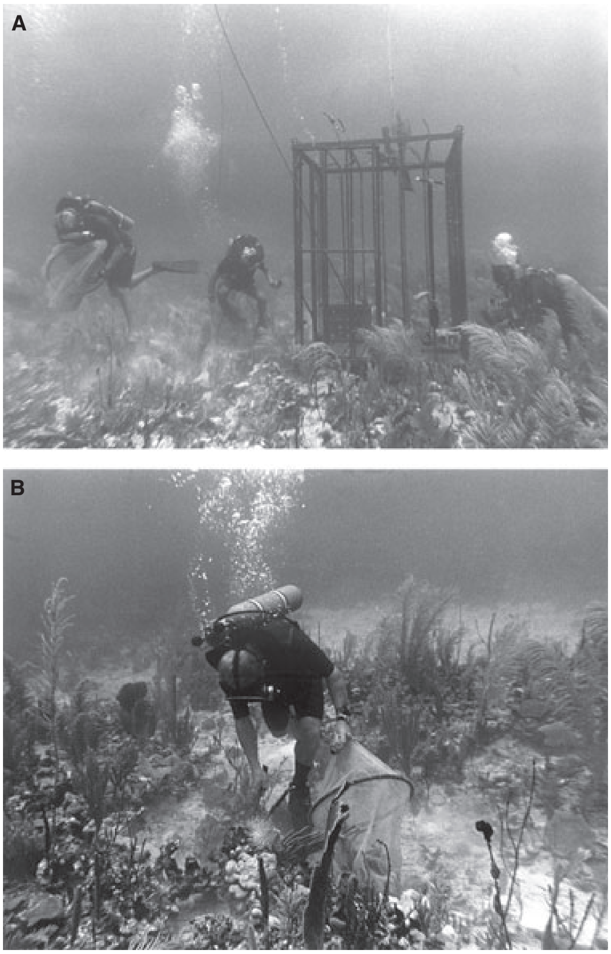

Fig. 1. Royal Dutch Navy divers collecting stony corals, octocorals and sponges at Saba Bank (Caribbean Netherlands) in 1972 (source: NCB Naturalis archives). (A) The shark cage served as a lift for the collected specimens. (B) A diver with his collecting gear.

Best 1991) and the 'Oceanic Reefs' Expedition to the Seychelles in 1992–93 (Fransen 1994; den Hartog 1994; Hoeksema & Best 1994; ten Hove 1994; van Ofwegen & Slierings 1994; Randall & van Egmond 1994; van Soest 1994). Nevertheless, well maintained botanical and zoological museum specimens may serve as proof that species that nowadays are absent in a particular area, actually did occur there in the past (Hoeksema & Koh 2009; van der Meij *et al.* 2009, 2010). It is remarkable that ecological studies dealing with long-term changes in biodiversity hardly ever mention this approach (Jackson *et al.* 2001; Edwards *et al.* 2010; Magurran *et al.* 2010). We want to promote the idea that well documented natural history collections, besides remaining indispensible in taxonomic research, are likely to play a growing role in global change studies. This is particularly relevant for coral reefs, which are the most diverse and threatened pristine marine ecosystems of the world, but which also lack baseline studies because underwater observations only started relatively recently (Gardner *et al.* 2003; Pandolfi *et al.* 2003; Knowlton & Jackson 2008). Consequently, in coral reef sciences there is a tendency of shifting baselines, which implies that certain reef conditions are attributed to recent impacts, overlooking the importance of historical disturbances (Sheppard 1995; Bellwood *et al.* 2004). It may therefore be difficult to reconstruct what circumstances have led to the currently recognized decline of coral reefs and when this decline started (Aronson & Precht 2006), with the possible exception of cases where suitable fossil reef deposits are available (Aronson & Precht 1997; Edinger *et al.* 2001; Aronson *et al.* 2002; Hughes *et al.* 2003; Greenstein & Pandolfi 2008). We argue that natural history collections of reef organisms can be useful in reconstructing recent changes over time when relevant long-term time datasets are not available (*e.g.* Connell *et al.* 1997, 2004; Hughes & Connell 1999; Bak *et al.* 2005).

Discussion

Biological collections and global change studies

Some of the oldest natural history museums and herbaria harbour samples of coral reef fauna and flora that have been stored there for over 100 years. These specimens can be important as reference material for historical studies of marine environments such as coral reefs and inland bays that undergo sedimentation (Hoeksema & Koh 2009; Schwerdtner Máñez 2010). Furthermore, documented cases include reefs that have completely disappeared due to sand mining or have become damaged by destructive fisheries, pollution or land-based activities, as in Jakarta Bay (Cleary *et al.* 2006, 2008; de Voogd & Cleary 2008). However, museum specimens collected there before these reefs disappeared, may represent species that occurred there in the past (van der Meij *et al.* 2009, 2010). Furthermore, cryptic and sibling species recorded from an area for the first time, could have been represented in collections from the same area and elsewhere for a long time without being noticed previously (Knowlton *et al.* 1992; Knowlton 1993, 2000; Luttikhuizen & Dekker 2010; van der Meij & Visser 2011).

Biological collections may also be important as reference material in relation to global change-related impacts on coral reefs, such as El Niño Southern Oscillation (ENSO) events, ocean acidification, sedimentation and red tides, which may have long-lasting damaging effects on specific reef areas or particular species, especially when they occur in combination with harmful human activities (Hoeksema & Cleary 2004; Hoegh-Guldberg *et al.* 2007; Carpenter *et al.* 2008; Munday *et al.* 2009; Veron *et al.* 2009; Samini

Namin *et al.* 2010; Sheppard *et al.* 2010). Elevated seawater temperatures and major subsequent coral reef bleaching events have occurred at various coral reef localities in 1982/1983, 1997/1998, and since 2010 (Brown & Suharsono 1990; Hoeksema 1991; Glynn 1993; Feingold 2001; Glynn *et al.* 2001; Hoeksema & Matthews 2011).

In such cases, museum specimens can be used to show that endangered species have survived or may even display much greater distribution ranges than previously assumed. For example, after the 1982–83 El Niño warming event, only dead specimens of the hydrocoral *Millepora boschmai* de Weerdt & Glynn, 1991 were collected at their type locality, the East Pacific coast of Panama, and therefore the authors considered the species extinct (Glynn & de Weerdt 1991; de Weerdt & Glynn 1991). Only a year later, five living corals were observed in the same area (Glynn & Feingold 1992). However, specimens of *M. boschmai* collected alive from Indonesia (by BWH) had been available for study since 1984 but had remained unnoticed until a taxonomic revision of Indonesian *Millepora* corals was made (Razak & Hoeksema 2003). This discovery indicates the unpredicted value of collecting specimens for museum collections for possible use in global change studies.

It is important that museum collections remain accessible for research, and therefore collections should be well maintained and catalogued, which is usually done by a curator. It is even better if a collection is improving as it is involved in ongoing research and additional material is deposited for future research. Examples of natural history museums that have been actively involved in reef coral research for about 25 years are NCB Naturalis in Leiden (*e.g.* stony corals, soft corals, sponges, commensal shrimps, parasitic snails, reef-dwelling foraminifera) and the Museum of Tropical Queensland in Townsville (stony corals). Other museums, such as the National Museum of Natural History of the Smithsonian Institution in Washington, D.C., receive voucher specimens from various reef scientists on a regular basis, providing there are active scientists on staff who take care of the material.

A case study: reef surveys at Saba Bank

Saba Bank, part of the Caribbean Netherlands (former Netherlands Antilles), is a large submerged atoll covered by species-rich benthic assemblages, which are under threat by anchoring oil tankers (Hoetjes & Carpenter 2010; McKenna & Etnoyer 2010). So far, relatively little explorative research has been carried out on the reef assemblages here in relation to neighbouring areas (Klomp & Kooistra 1999). However, a recent survey (2006) showed that zoological collections made at Saba Bank during a previous expedition in 1972 (van der Land 1977) have become valuable baselines to indicate possible losses of local coral and sponge fauna. The collections of both expeditions are available as reference material in the collections of NCB Naturalis (Leiden) and the Smithsonian Institution (Washington, DC), respectively.

Five stony coral species collected from a total of 17 reef sites in 1972 were not found in 2006, *i.e. Diploria clivosa* Ellis & Solander, 1786, from one site, *Madracis asperula* Milne Edwards & Haime, 1849, from five sites, *Mycetophyllia lamarckana* Milne Edwards & Haime, 1848, from four sites, *Scolymia lacera* Pallas, 1766, from one site, and *Solenastrea bournoni* Milne Edwards & Haime, 1848, from one site (van der Land 1977; McKenna & Etnoyer 2010). Three of these five missing species were rare (each at one site), and the three other ones (at four and five sites, respectively) moderately rare in comparison with the most common species, *Siderastrea radians* Pallas, 1766, which was observed at 13 Saba Bank sites in 1972 (van der Land 1977). Some of the species lacking in 2006 may have been listed as unidentified corals in the later survey (McKenna & Etnoyer 2010) because, in addition to 43 listed species, 10 records from 2006 are of uncertain identity, which implies that both collections should be re-examined jointly for a better comparison.

The sponges collected in 1972 and 2006 were examined together in one study: 29 of 81 Saba Bank sponge species were sampled in 1972 but not in 2006 (Thacker *et al.* 2010). Some of the sponge species missing in the 2006 survey were rather common in 1972. Two of these were sampled at five different sites in 1972, *Amphimedon caribica* (Pulitzer-Finali, 1986), *Ptilocaulis walpersi* Duchassaing & Michelotti, 1864, one at four sites, *Tedania (Tedania) ignis* Duchassaing & Michelotti, 1864, and four of them at three different sites (*Cinachyrella arenosa* van Soest & Stentoft, 1988, *Dragmacidon explicatum* Wiedenmayer, 1977, *Hyrtios violaceus* Duchassaing & Michelotti, 1864, and *Leucetta floridana* Haeckel, 1872). In comparison, the most commonly collected sponge species in 1972, *Aplysina cauliformis* Carter, 1882, was sampled at 11 of the 17 dive sites (Thacker *et al.* 2010).

The octocoral fauna of Saba Bank was sampled during both expeditions but the collections have not yet been compared (Etnoyer *et al.* 2010). As material from both expeditions is available for study, there is an opportunity to compare the octocoral collections for a study of possible changes in faunal composition and to describe new species, such as *Lytreia* spec. nov., *Pterogorgia* spec. nov., and additional ones that are expected to be found during future surveys (Etnoyer *et al.* 2010). Should new fieldwork be organized, it is recommended to search also for cryptic organisms associated with octocorals, such as parasitic gastropods belonging to the Ovulidae (Reijnen *et al.* 2010) and commensal shrimps belonging to the Palaemonidae (Snijders & Fransen 2010). The inclusion of symbionts in biodiversity surveys would give a more complete image of the biodiversity. A search for symbionts would show that corals and sponges are not only important for structuring the reefs but also as indispensable biotic components in the habitat of associated organisms.

Another important aspect of the comparison of collections consists in the earliest records of invasive species. The Indo-Pacific coral species *Tubastraea coccinea* Lesson, 1829, has been recorded in the Atlantic since 1943, in the Caribbean as well as in Brazil, and was probably introduced by ship traffic and imported oil platforms (Cairns 2000; Ferreira 2003; Fenner & Banks 2004; de Paula & Creed 2004; Creed & de Paula 2007). Specimens of a second species, *Tubastraea tagusensis* Wells, 1982, originally known from Galápagos, have been collected in Brazil together with the first species in 2000 (de Paula & Creed 2004; Creed 2006; Lages *et al.* 2010). A third Indo-Pacific coral species, *Tubastraea micranthus* Ehrenberg, 1834, was observed in 2006 in the Atlantic on an oil rig in the Gulf of Mexico (Sammarco *et al.* 2010). Although *T. coccinea* is so far the only *Tubastraea* species recorded from Saba Bank, recorded in 1972 and 2006 (van der Land 1977; McKenna & Etnoyer 2010), additional field surveys and collection studies may indicate further invasive coral species.

Another invasive species in the Caribbean (since 1992), the notorious piscivorous red lionfish *Pterois volitans* Linnaeus, 1758, has not been recorded yet from Saba Bank (Toller *et al.* 2010; Williams *et al.* 2010), although it is one of the best documented invasive species in the Caribbean (Miloslavich *et al.* 2010). We do not know whether specimens are being deposited in museum collections.

Despite the assumed undersampling by the 1972 expedition, which was performed by Dutch Navy divers and not by scientists (Fig. 1), the collection of unique species at that time, as compared to the 2006 survey, supports the conclusion of recent studies that future research is needed to establish the importance of Saba Bank as a regional species reservoir. We need to ascertain if species represented in old collections are still present or if the species composition has changed due to habitat degradation and by invasive species. Furthermore, it would not be surprising if undescribed species from Saba Bank are still represented in natural history collections, such as two species of octocorals (Etnoyer *et al.* 2010). We may assume that despite a long history of taxonomic research in the Caribbean, the marine biota of the region is not yet well known (Miloslavich *et al.* 2010).

Conclusions

Natural history museums hold historical collections of botanical and zoological specimens, which together form an important tool in biodiversity research. At the time of collecting, the main purpose of the samples was to verify identifications to serve as reference material in the descriptions of species and as type material in case they represented new taxa, or as back-up records in biological survey reports and biogeographical analyses. We anticipate that museum collections will become increasingly important by contributing necessary baseline data in historical ecological studies concerning global change studies. This is particularly relevant when vulnerable ecosystems are involved, such as species-rich coral reefs.

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