Species Identification of Coral Jewellery by Genetic Testing: Case Studies, Experiences and Prospects

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ABSTRACT: This article reviews and details how DNA testing can be used to identify species of precious coral used in jewellery. Since certain species are listed by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), the correct identification of coral species is of utmost importance. We present case studies of loose and mounted coral samples tested at the Zurich Institute of Forensic Medicine in collaboration with the Swiss Gemmological Institute SSEF. Our findings also highlight the limitations of traditional gemmological testing in coral species identification (e.g. cases of misidentification, and new species discovered), and confirm the need for DNA analysis for accurate outcomes.

The Journal of Gemmology, **39**(7), 2025, pp. 688–696, https://doi.org/10.15506/JoG.2025.39.7.688

Precise identification of coral varieties used in jewellery has commonly been a difficult task for gemmologists. The red, pink and white corals (e.g. Figure 1) best known in the trade originate from colonial polyps that produce a solid and evenly calcitic internal skeleton. Taxonomists assign these corals to the Coralliidae family (Bayer 1956; Ardila *et al*. 2012; Tu *et al*. 2015). Their geographic provenance includes the Mediterranean Sea and adjacent Atlantic Ocean for the species *Corallium rubrum* (known in the trade as Mediterranean or Sardinian coral), and the Pacific Ocean for *C. japonicum* (called oxblood or aka coral) and various red-to-pink-to-white corals, with or without uniform colour distribution, from the *Pleurocorallium* and *Hemicorallium* genera (CIBJO Coral Commission 2024a, b). Depending on how a particular piece was cut, surface structures and growth rings characteristic for Coralliidae corals may be visible and provide useful hints for separating them from other corals and imitations (Henn 2006; Cooper *et al*. 2011). In addition, the application of Raman spectroscopy has become well established for authenticating colour origin in corals (Smith *et al*. 2007; Karampelas *et al*. 2009; Bersani & Lottici 2010; Macchia *et al*. 2016).

Furthermore, some studies have reported that chemical analysis using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) can distinguish different precious coral species based on trace-element composition, particularly for Ba and Pb (Vielzeuf *et al*. 2021; Xian *et al*. 2025). The present authors are also testing the use of LA-ICP-MS, but more work is needed—especially the integration of appropriate standard reference materials—in order to better apply the method to coral analysis.

Visual and morphological characteristics are important for characterising precious coral samples, including not just colour but also the homogeneity of colour distribution, the presence or absence of a white core or spots, and the surface lustre of a sample (Henn 2006; Cooper *et al*. 2011). However, none of the coral species used in the jewellery trade

Figure 1: Precious corals come in a wide range of colours, as shown in this assortment of gems and jewellery, and include a variety of species that cannot be identified by colour alone. The coral branch at central left is approximately 7.6 cm long. Photo by Luc Phan, SSEF.

can be identified with certainty by standard gemmological methods, as all precious coral colour variants (white, pink, orange and red) can occur in multiple species (Lendvay *et al*. 2020).

To fill this gap, the Swiss Gemmological Institute SSEF and the genetics department of the Zurich Institute of Forensic Medicine developed a DNA-based analytical technique, using coral samples from gemmological collections and objects confiscated by customs (Cartier *et al*. 2018; Lendvay *et al*. 2020; Cartier & Lendvay 2023; Lendvay 2024). The method is minimally destructive (requiring <10 mg coral skeletal material), so it is applicable for testing high-end jewellery (Cartier 2020, 2021)—with prior agreement from the client. Although other groups have announced DNA testing services for coral in the past (DANAT 2019; IGR 2019), their methodology—including the quality control of DNA data and the reference data sets used—have not been published.

In this article, we review our DNA testing methodology and demonstrate its use on representative examples of antique and modern high-end coral jewellery items submitted for DNA testing by clients of the Swiss Gemmological Institute SSEF.

CORAL DNA AND ITS ANALYSIS

Specialised tissues within the coral colony produce an internal skeleton (Grillo *et al*. 1993), which does not contain living cells and is built from a mixture of calcitic minerals and organic material, such as proteins and carotenoids—the last two providing colouration (Merlin & Delé-Dubois 1986; Cvejic *et al*. 2007; Perrin *et al*. 2015). Each cell of the living coral tissue contains DNA, and during skeleton formation, traces of this DNA are incorporated into the skeletal material. In most cases, the amount of DNA trapped in the skeleton is sufficient for genetic analyses to be carried out from as little as around 6 mg of material (Lendvay *et al*. 2020, 2025a).

Sampling for DNA testing is done with a device that is similar to a dentist's drill, which uses a small metal burr. A tiny amount of coral skeletal material is either drilled from the inner surface of a pre-existing drill hole (in the case of beads, Figure 2), or is removed from the bottom or back side of a sample (for figurines or cabochons). The coral powder is placed in a buffer solution that dissolves the calcite and degrades the proteins to release the DNA. The DNA molecules in the solution are immobilised on

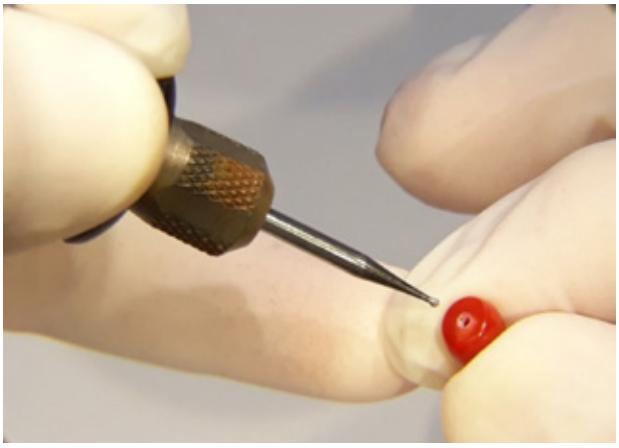

Figure 2: Sampling of coral for DNA testing involves the use of a drill to remove a small amount of skeletal material, such as from the drill hole of a bead (here, approximately 6 mm in diameter). Photo by N. V. Morf.

a silica membrane and washed with an ethanol-containing buffer solution to yield a pure DNA extract. This extract then undergoes enzymatic amplification of specific target regions of the DNA using polymerase chain reaction (PCR) technology. The sequence of the DNA bases (a long strand consisting of adenine, cytosine, guanine and thymine, represented by the letters A, C, G and T, respectively) that are characteristic of the sampled coral is then determined by capillary electrophoresis (for more details, see Lendvay *et al*. 2022). Finally, this DNA sequence is compared to a reference database to identify the particular species. Our database contains an extensive number of samples, including data from the scientific literature and in-house analysed coral samples from scientific surveys and museum collections (Lendvay *et al*. 2022, 2025a, b). If a coral object contains multiple pieces (e.g. beads in a necklace), then generally three representative samples are chosen for analysis. The laboratory work is carried out in special rooms accredited according to ISO 17025 standards for working with trace amounts of DNA, and special attention is taken to avoid contamination during the entire procedure.

CASE STUDIES

Corals Showing Various Shades of Red

Most corals in the jewellery trade range from orange and pink to bright red and deep red. These generally originate from three species—*Corallium rubrum*, *C. japonicum* and *Pleurocorallium elatius*—which are sometimes not easy to distinguish based on their appearance. In particular, the darker shades of *C. rubrum* can be mistaken for *C. japonicum*, while its lighter shades can resemble the colour of *P. elatius*.

We tested a precious coral jewellery set containing a brooch, necklace, bracelet and pair of earrings made entirely from orangey red coral, in a style that is typical of nineteenth century jewellery (Figure 3). Visually, the species expected was either *C. rubrum* or *P. elatius*. DNA testing of the central cabochon in the brooch and of one bead each in the necklace and bracelet all indicated *C. rubrum*, supporting the

Figure 3: A nineteenth-century jewellery suite containing orangey red coral was DNA tested on three pieces and found to consist of *Corallium rubrum* material. The cabochons range from 13.15 to 28.80 mm long. Photo by Luc Phan, SSEF.

possibility that this set was manufactured in the coral trading centre of Torre del Greco (Italy) using locally or regionally fished material.

An antique multi-gem necklace with numerous polished and faceted coloured stones, all drilled and suspended on three rows of pearls, contained some red-orange coral beads (Figure 4). Interestingly, the necklace not only included amethyst, citrine, red-to-brown garnet and pink tourmaline of presumably Indian and/or Sri Lankan origin, but also a mix of light blue sapphires from Sri Lanka (metamorphic type) alternating with dark blue basaltic sapphires probably from a historically known occurrence in Southeast Asia, and bright green emeralds from Colombia. Following DNA testing, the red coral in this multi-stone necklace was found to be *C. rubrum*. This coral was also subjected to radiocarbon age dating, giving a high probability for a formation age around the sixteenth century.

A strand of graduated medium-to-large round red precious coral beads (Figure 5) was submitted for testing with the client's assumption that they were made from *C. rubrum*. Instead, our results revealed that all three (randomly) tested beads originated from the so-called *C. japonicum* species complex, which includes red *C. japonicum*, pink *C. tortuosum* and white *C. nix*. By considering both the DNA information and the colour, we could specify the material as *C. japonicum*. The results of DNA testing of this necklace, which contradicts the initially expected species, demonstrates the limits of both visual assumptions and basic gemmological testing in assigning species to precious coral samples.

Finally, we analysed a sautoir containing orange coral that was attributed to the renowned French jewellery designer Suzanne Belperron, from the 1930s (Figure 6). We tested two beads in the strand and a large carved coral bead encapsulated within a disc of rock crystal, and all three samples were found to belong to the *P. elatius* species complex. The reason for referring to a 'species complex' here is that the well-known Japanese pink coral (*P. elatius*) is very closely related to four other *Pleurocorallium* species. These include the Japanese *P. konojoi*, well known as white coral used in jewellery, and three other species from the East China Sea only recently

Figure 4: This antique necklace contains red-orange coral, along with various other gem materials. The tested coral (marked with an arrow ; approximately 10 mm long) was identified as *Corallium rubrum* material, and was radiocarbon dated to the sixteenth century. Photo by Alice Chalain, SSEF.

Figure 5: Three randomly selected beads in this graduated strand (9.40–20.00 mm in diameter) were found to consist of *Corallium japonicum*, rather than the expected *Corallium rubrum*, according to a combination of DNA testing and colour. Photo by Alice Chalain, SSEF.

Figure 6: This sautoir, reportedly from the 1930s, contains orange coral beads (6.35–11.60 mm in diameter) and carvings (12.25–23.00 mm long). DNA testing of two beads and the carving set within a disc of rock crystal indicated a member of the *Pleurocorallium elatius* species complex. Photo by Michael Bichsel, SSEF.

discovered and described. These are *P. carusrubrum* (red), *P. gotoense* (white) and *P. uchidai* (red), each of which is known only from a single specimen. Due to their genetic similarities, they are not distinguishable from *P. elatius* based on their DNA segments analysed to date. To remain scientifically sound, in our reports we identify red precious corals of this group as '*P. elatius* species complex'.

CITES-listed Species or Not?

Conclusively revealing the specific species of a precious coral sample has significance other than just elucidating the origin and history of a piece of jewellery. There is general agreement amongst scientists that the fishing of precious corals over the past centuries has caused strong population declines in several species (Bruckner 2016; Cannas *et al*. 2019). Among other measures to regulate coral fisheries (such as restricting the minimum size, total volume and location of corals that can be harvested), four species from the Pacific Ocean are included in CITES Appendix III: *C. japonicum*, *P. elatius*, *P. konojoi* and *P. secundum* (https://checklist.cites.org/#/en). These require a CITES export permit or a CITES certificate of origin (or re-export certificate) when they are transported and traded internationally. Therefore, manufacturers and traders may wish to conclusively identify the species of precious coral before it is traded.

As an example, in a batch of orange-red carved loose coral beads submitted for testing, we performed DNA analysis of three beads (Figure 7) and found two to be *C. rubrum* (not CITES listed), while the third bead belonged to the *P. elatius* species complex. DNA testing thus showed that these beads originated from multiple sources and contained both non-CITES-listed and CITES-listed corals.

Figure 7: DNA analysis of these three coral beads from a batch submitted for testing revealed that two samples (**a**, 7.09 mm in diameter; and **b**, 13.15 mm in diameter) are *Corallium rubrum* but the third (**c**, 11.15 mm in diameter) is from the *Pleurocorallium elatius* species complex, which includes the CITES-listed *P. elatius*. Photos by Luc Phan, SSEF.

Precious Coral Species Diversity, Including a New Species

The precious corals of the Coralliidae family belong to three genera: *Corallium, Hemicorallium* and *Pleurocorallium*. Corals used in jewellery are commonly described as coming from eight species within these genera: *C. rubrum*, *C. japonicum*, *H. regale*, *H. laauense*, *H. sulcatum*, *P. elatius*, *P. konojoi* and *P. secundum* (CIBJO Coral Commission 2024a, b). Thus, we would expect to find these species in coral jewellery items submitted for testing. As of August 2025, there was a total of 49 accepted species in the three genera listed above. The number of known coral species is increasing due to our ever-growing understanding of organisms in deep-sea environments; indeed, more than one-third (19) of these species have been described since 2010 (i.e. Simpson & Watling 2010; Nonaka *et al*. 2012, 2023, 2025; Tu *et al*. 2012, 2015, 2016; Nonaka & Hayashibara 2021; Hu *et al*. 2025). It is, therefore, conceivable to expect that coral species other than the eight mentioned above could be detected in jewellery.

We tested three beads of an exceptional light pink 'angel skin' necklace consisting of 67 regularly graduated round coral beads (Figure 8). The term *angel skin* (or *pelle d'angelo* in Italian) is commonly used to refer to coral with a delicate, 'flesh-pink' colouration. The material is generally considered to come from an uncommon albino form of the species *P. elatius*. Based on their colour and other characteristics, the beads in this necklace were initially expected to originate from *P. elatius*. However, the DNA sequences we obtained from all three beads were identical, although they were different from the reference DNA data for the eight coral species commonly known to be used in jewellery (CIBJO Coral Commission 2024a, b). To gather more information, we performed additional analyses on the DNA extracted from one of the beads and, to our surprise, it turned out to be a member of the *P. norfolkicum* species complex. However, *P. norfolkicum* itself is known only from an area (near New Caledonia) where

Figure 8: An 'angel skin' coral necklace, which was initially expected to originate from *Pleurocorallium elatius*, was revealed by DNA testing not to have originated from any of the species previously recognised in the coral trade. Instead, it turned out to be a member of the *Pleurocorallium norfolkicum* species complex, likely from the Vietnam region. The beads range from 10.55 to 26.75 mm in diameter. Photo by Alice Chalain, SSEF.

commercial coral fishing has not occurred. In a search to find the genetic type identical to the one in the angel-skin coral necklace, we screened additional samples from various coral fishing grounds, and found a single matching specimen originating from a commercial fishery in Vietnam which was taxonomically unidentified (see Lendvay *et al*. 2025a). In summary, we concluded that the beads in this necklace originated from a coral species previously not considered to be used in the precious coral trade, and that they likely originated from Vietnam or a nearby area in the northwest Pacific (Lendvay *et al*. 2025a).

DISCUSSION

There is no trade ban on precious corals (unlike ivory), so the aim of coral DNA testing is to provide greater transparency so that merchants and jewellers know what they are trading (down to the species level) and can communicate this to their customers. Genetic analysis has proven to deliver unequivocal results for identifying the species (or species complex) of precious corals. It has advantages over LA-ICP-MS, a method sometimes also used to identify coral species (Vielzeuf *et al*. 2021; Xian *et al*. 2025), since trace-element data can only distinguish three species on the basis of Ba and Pb concentrations—*C. rubrum*, *C. japonicum* and *P. elatius*—but the technique cannot differentiate these species in all cases. To our knowledge there are no conclusive trace-element chemical data currently available for additional species, and as this study shows, visual characterisation alone may sometimes not be sufficient for conclusive species identification, even for well-studied species.

Our experience has shown that DNA testing can successfully be employed as a routine tool for coral identification. We use an average of 5.9 mg of coral powder from a sample, with amounts ranging from 2.2 to 12.4 mg. According to our initial explorative experiments, DNA testing is always successful with 100 mg of coral skeletal material, but it was not consistently successful when using just a few milligrams (Lendvay *et al*. 2020). A plausible explanation for the unsuccessful analyses may be that degradation of the DNA in certain samples hindered the enzymatic amplification of the DNA in the PCR step. Corals are often dead when they get fished; the best-known examples of such sub-fossil corals are the millennia-old 'Sciacca' corals of *C. rubrum* fished near Sicily (Bavestrello *et al*. 2021). A significant proportion of the corals fished in Japan are also already dead, having lived long before the beginning of coral fishing (Okumura *et al*. 2021). The DNA in the skeletons of corals that have lain dead on the seabed for centuries is likely much more decayed than the DNA in corals fished alive, which could account for the large differences in the DNA content observed in coral jewellery material (Lendvay *et al*. 2020). Nevertheless, as shown by the results of the multi-gem necklace in Figure 4 (with a sixteenth-century radiocarbon age), DNA testing can be successful from minute amounts of skeletal material from antique jewellery.

FUTURE PROSPECTS

The species and general provenance of precious corals can be identified by genetic testing. The accuracy of such identifications will surely benefit from the future work of taxonomists and marine biologists. The description of species hitherto unknown in jewellery (including the sequencing of specific DNA fragments) will provide reference data on the genetic characteristics and geographic distribution of additional taxa. Especially desirable is further taxonomic work in the Western Pacific, Japan, and Taiwan, a region with diverse precious coral beds that are currently being exploited commercially.

In the future, it may also be possible to identify the geographic origin of individual species of coral in more detail, such as for *C. rubrum* (e.g. Figure 9) from the Mediterranean region and adjacent Atlantic Ocean. This will require more detailed genetic data from populations covering the past and present range of harvested species.

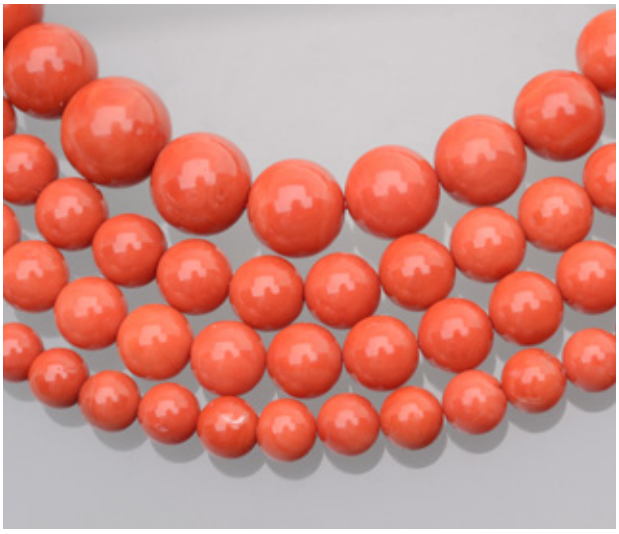

Figure 9: Necklaces of *Corallium rubrum* containing beads of different sizes (6.62–12.00 mm in diameter) typify material from the Mediterranean region and adjacent Atlantic Ocean, although their precise geographic origin cannot currently be determined. Photo by Luc Phan, SSEF.

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