Ethnobotany of Hawaiian figure sculpture

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Received: 24 July 2019 / Accepted: 10 December 2019 / Published online: 28 December 2019
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Abstract

Anecdotal theories about traditional uses of Polynesian woods in relation to social and religious practices were tested using comparative wood identification. The woods used to make 135 figure carvings from the Hawaiian archipelago were identified and compared with 23 figure carvings from elsewhere in Polynesia (especially Tahiti and the Marquesas). Prior to this study, the majority of Hawaiian images were believed to have been made from wood of *Metrosideros polymorpha*, the commonest forest tree on the archipelago. The results confirm that *Metrosideros* was relatively popular in Hawaii (13% of Hawaiian carvings, compared with 4% in central and south-eastern Polynesia). However, more unexpectedly, over 18 different genera were utilized for figure carvings in Hawaii. The genus *Cordia* accounted for 20% of Hawaiian figure carvings identified here, compared with 26% elsewhere in Polynesia, and *Thespesia* for 4%, compared with 30% in Marquesas. Use of some woods, such as species of *Acacia*, was not previously recorded for this purpose, including the first record of *Artocarpus* wood for large Hawaiian temple images. Many species—especially those that were less popular for ritual figure carving—were also used for various other purposes, including food, canoe building and medicines. This study demonstrates that the early Polynesian settlers brought with them traditions of using certain trees, but also took advantage of elements of the extensive indigenous flora.

Keywords Ethnobotany · Figure sculpture · Hawaii · Pacific Islands · Wood

Introduction

Hawaiian figure sculpture represents perhaps the pinnacle of a tradition of woodcarving that spread throughout the Pacific with the early Polynesian colonists, and later died out after European contact. Its forms, symbols and conventions are inextricably linked to a social and religious framework. Many ideas and beliefs, later modified by characteristically Hawaiian cultural and environmental demands during a long period of isolation, were originally taken to Hawaii by seafaring Polynesians, probably from central eastern Polynesia, during the early settlement period that lasted until about 1400 AD (Kirch 2018).

There are about 150 existing examples of Hawaiian wood carvings with human figures, now dispersed in museums and private collections throughout the world, some of them

traceable to Captain Cook's own collections. Apart from some anecdotal information (e.g. Rock 1913, Kaeppler et al. 1993), relatively little is known about the woods used for the images. Previous laboratory wood identifications of Hawaiian figure carvings were primarily concerned with testing for possible non-authentic images (Claerhout 1981). More evidence is available for other parts of Polynesia, such as Tahiti and the Marquesas, both for wooden images (Orliac 1984a, b, c, 1986a, b, 1990b), and ocean-going canoes (Banack and Cox 1987). For example, the wood of a 1000-year-old canoe from the Society Islands was identified as *Terminalia* (Donaldson and Singh 1990), and many figure carvings from Easter island were carved from wood of *Sophora toromiro*, a tree endemic to this remote Polynesian island, including the iconic wooden hand that is now in the British Museum collection (Attenborough 1990; Orliac 1990a; Orliac and Orliac 2017).

A more intensive study was necessary to evaluate existing preconceptions about the use of certain woods to represent particular gods and practices. This paper presents a survey of the woods utilized for carved wooden images from Hawaii and other parts of Polynesia. We explore ethnobotanical aspects and also discuss whether the preferred woods were introduced to Hawaii by the early aboriginal settlers or were dispersed by other means. In a similar survey of parts of

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Africa, Dechamps (1977, 1982) found that carvers in some regions preferred particular woods (including *Erythrina* and several Rubiaceae) for making religious images, despite other woods being more readily available. In some cases, this preference was due to the particular properties of the woods concerned, but in others because the woods had some ritual significance; indeed, the two factors may well be interlinked.

Material and methods

Material was obtained from wooden images in the British Museum (London, UK), the Bishop Museum (Honolulu, Hawaii), and several other museums, galleries and private individuals (Table 1). Only human figure carvings were sampled, many of them listed by Cox and Davenport (1988). They represent many different types of object, including large temple images and ceremonial bowls (Fig. 1). The condition of the sample varied depending partly on the durability of the particular type of wood used, and partly on the conditions in which it had been kept or found.

Preparation of material

For identification, a sample of wood was removed from each image. Samples were necessarily extremely small, 2–5 mm across, preferably more or less cubic. It is usually possible to remove a sample this size without any loss being apparent, for example, from a previously damaged region, or from the base of an upright carving, or from inside the mouth of a very large image. Sections of the samples were cut in three planes: transverse (TS), tangential longitudinal (TLS) and radial longitudinal (RLS), using a Reichert sliding microtome with a freezing stage attachment that enabled the fragments to be held in place and properly aligned for sectioning. Sections were then mounted directly onto microscope slides in dilute glycerine. Observations (Figs. 2 and 3) were made using a light microscope (Leica SM–Lux) and compared with named reference material in the extensive collection of permanent microscope slides located at the Royal Botanic Gardens, Kew, which is supplemented by specimens from Kew's wood collection.

Identifications

For an identification to be made, the sample must closely match the reference material, using characters observable in all three planes of section. Identifying features of some of the more commonly used woods are given in Figs. 2 and 3. Most identifications were made to genus level, because species availability is not comprehensive in all cases. Rock (1913) provided an invaluable source of information on trees available to the islanders, and taxonomic names were updated where appropriate from Imada et al. (1989) and also from

the International Plant Names Index (IPNI <https://www.ipni.org/>). Some of the identifications are tentative (marked with an asterisk in Table 1) because the sample was in particularly poor condition and fragmented on sectioning. A few samples that did not precisely match any available reference material are not included here.

Results

Wood identifications

Common names in italics are native Hawaiian, unless otherwise stated. A list of identifications is given in Table 1.

Acacia (Leguminosae–Mimosoideae)

This genus accounts for five Hawaiian carved images (Fig. 1f), and none from elsewhere in Polynesia. There are two native species of *Acacia* in Hawaii, both of which are endemic. *Acacia koa* (called *koa* or *koa ka*) is a substantial forest tree that was once widespread on all the Hawaiian Islands, including large stands on ancient lava flows (Rock 1913; Elevitch 2006). It yields wood of high quality, which was once used to make the largest war canoes (Holmes 1993). It is therefore not surprising that it was used for a few of the Hawaiian images, as it was strong and readily available on the archipelago, though not on other eastern Polynesian islands. The other native *Acacia* species on Hawaii, *A. koaia* (*koa'i'a* or *koa oha*), sometimes considered a subspecies of *A. koa*, is a smaller tree with a more restricted distribution from monodominant canopies in dry forest (Mueller-Dombois and Fosberg 1998); its relatively harder and more closely grained wood was used for making spears and paddles (Rock 1913). The wood of both species is broadly similar, with vessels often solitary and short narrow rays, but *A. koaia* typically has much thicker-walled fibres. Based on the differences in the samples examined here, both woods are probably represented in this survey (Table 1).

Aleurites (Euphorbiaceae)

Only two samples from Hawaii were made from wood of *Aleurites*, and none from elsewhere in Polynesia based on our analysed samples. *Aleurites moluccanus* Willd. (candle-nut, *kukui*) is a very common Hawaiian forest tree and also an important component of the tropical Pacific island flora. The wood of *A. moluccanus* has thin-walled fibres with relatively narrow heterocellular rays containing cuboidal crystals. Polynesian settlers extensively used oil from the nuts of this species, and also utilized other parts of the plant (Rock 1913), so they certainly transported it from Hawaii; studies of ancient sediments in Kauai demonstrated that it was not present there before human settlement, but is subsequently represented by

Table 1 Polynesian images and identifications.

Hawaii	
<i>Acacia</i> Mill.	BI, 10348 (image; probably <i>A. koaia</i> Hillebr.); BM, Oc.6285.a-b (probably <i>A. koaia</i>); H, 3464 (probably <i>A. koa</i> A. Gray); CM, E150.1200 (Oldman 302); P, <i>s.n.</i> (figure)
<i>Aleurites</i> J.R.Forst. & G.Forst.	BI, C.03525; *PM, E.17530 (temple image)
<i>Antidesma</i> L.	P, *Heathcote <i>s.n.</i> , NY
<i>Artocarpus</i> J.R.Forst. & G.Forst.	BI, 7654 (large kona-style temple image); BI, 08486 (image); BI, D.3718; BI, C.8485; PM, E.12071 (large standing image of Ku); P, Seattle figure <i>s.n.</i>
<i>Cheirodendron</i> Nutt. ex Seem.	P, *Carpenter <i>s.n.</i>
<i>Cordia</i> L.	BI, 132; BI, 04044 (image); BI, 07655 (image); BI, 9072; BI, 07658 (image); BI, D.02300 (image from drum support); BI, 01 HNPk; BI, 02 HMPk; BI, D.2772 (image with helmet); BI, D.01535; BI, 07656 (image); BM, Oc. 1944 02.716 (figure with human hair); BM, Oc.HAW.46 (kava bowl with two carved figures); BM, Oc.HAW.48 (eating bowl with three figures); BM, Oc.4682 (spear rest); BM, Oc 1977 08.1 (drum with figures); *BM, Oc.1657 (human figure on all fours); EM, spear rest; CU, 22.917; RI, E.2733; IU, 84.41; CM, E.150.1185 (Oldman 301); DM, VI 256; DM, VI 257; DM, VI 8375; P, Sothebys 1988 <i>s.n.</i> (small figure); P, Adler <i>s.n.</i>
<i>Dracaena</i> Vand.	*BI, 258050; *BI, 258052; BI, 3189
<i>Diospyros</i> L.	BI, 01361 (erect human figure standing on block); *BI, 08034 (image); CM, E.150.1162 (Oldman 315); PR, 1936.26.10 (kona-style stick image)
<i>Erythrina</i> L.	BI, 259049; BI, 258051; BI, 258053; BI, 258054; BM, Oc.+249 figure with helmet); BM, Oc.HAW.76 (figure; both separate head and body)
<i>Eugenia</i> L.	BI, 7883 (Bloxam temple image with stick); BM, Oc.1656 (kona-style temple image); BM, Oc1855,1220.48 (male figure); RSM, 1891-26; BI, 272689 (large temple image); M, 91.50 (' <i>Aumakua</i> image)
<i>Hibiscus</i> L.	P, <i>s.n.</i>
<i>Metrosideros</i> Banks ex Gaertn.	BI, B.067; BI, B.01342; BI, B.1805; BI, 9068; BI, B6923; BI, B104; BI, 00159 (image); BI, TL 1978.35; BI, B2139; BI, B6922; BM, Oc,LMS.223 (kona-style temple image figure on stick); BM, Oc,HAW.74 (standing figure); BM, Oc,HAW.75 (figure); CU, 22.916; NO, 77.149 (standing male figure); PR, 1866.1.1407 (figure with helmet); PR, 1954.4.33 (standing figure)
<i>Myrsine</i> L.	BI, 01365 (image); BI, 01364 (image); BM, Oc.1440 (stick figure)
<i>Rauvolfia</i> L.	*BI, 01362 (figure bending over); DM, VI 8381
Rhamnaceae: <i>Colubrina</i> Rich. ex Brongn. or <i>Alphitonia</i> Reisseck ex Endl.	BI, 7659 (<i>Lono</i> stick image); *BI, <i>Ka'upulchu</i> (1 July 1984; MA, 1979.206.1625; PR, 1884.65.42 (8/9806) (small kona-style stick image; probably <i>Alphitonia</i>); *DM, VI 7241; P, Quin (211/210)
Rubiaceae (various genera)	BI, B.6976 (possibly <i>Canthium</i> Lam.*); BI, 06693 (image; Kamehameha War God); *BI, 01360 (image); BI, X59; BI, 09518 (image); BI, C.8814 (slab-type temple image); CM E.150.1197; BM, Oc.4681 (spear rest or rod holder) (possibly <i>Psychotria</i> L. *); B, D.6.173; H, 351.1; D, 1880-1606 (possibly <i>Bohea</i> Gaudich.*); *DM VI 8379; *DM VI 8388; *DM VI 8366; Munich, L.955; RSM, UC 384; RSM, 19230
<i>Santalum</i> L.	BI, B.2749; BI, 1921.014.124A (image); H, 3075.1
<i>Thespesia</i> Sol. ex Corrêa	BI, 07657 (image); BI, C.2773; *BI, 01341 (image); *BM, Oc,VAN.313 (spear rest); D, 1880-1607
Tahiti	
<i>Artocarpus</i>	BM Oc,TAH.61 (small standing figure)
<i>Calophyllum</i> L.	BM Oc,LMS.98 (deity figure)
<i>Cordia</i>	BM, Oc,TAH.62 (standing female figure); BM, Oc1955,10.1
<i>Fagraea</i> Thunb.	*BM, Oc,TAH.60 (canoe ornament with two figures); *BM, Oc,+1997.a
<i>Metrosideros</i>	BM, Oc,TAH.63 (standing female figure)
<i>Thespesia</i>	BM, Oc.7047.a; BM, Oc,TAH.78.a (small male figure); BM, Oc1939,11.1 BM, Oc.7049
<i>Caesalpinia</i> L.	*BM Oc,TAH.136 (figure)
Marquesas and Cook Islands	
<i>Cordia</i>	BM, Oc1925,1119.183; BM, Oc1925,1119.184; BM, Oc1925,1119.185; BM, Oc1925,1119.186
<i>Fagraea</i>	*BM Oc1899,-.160
<i>Thespesia</i>	BM, Oc.1972 (canoe prow); BM, Oc,LMS.194 (canoe ornament); BM: Oc1976,01.1
<i>Casuarina</i> L.	BM Oc,LMS.169 (standing male figure, Rarotonga)
Tonga	
<i>Fagraea</i>	*VHD <i>s.n.</i>
Easter Island (Rapa Nui)	
<i>Sophora</i> L. (toromiro)	BM, Oc,EP.32 (carved wooden hand), Attenborough figure <i>s.n.</i> ; EU, 2-headed female; EU, male (moai tongata); PM, E5306 (<i>Moai kavakava</i> figure); PM, E5308; PM, E69449
<i>Caesalpinia</i> L.	*EU female

Asterisk indicates tentative identification, either due to poor wood preservation or similarities between species (indicated in text). Collection sources: *B* Bremen Museum; *BI* Bishop Museum, Honolulu, USA; *BM* British Museum, London, UK; *CM* Canterbury Museum, New Zealand; *CU* Cambridge University Museum, UK; *D* Dublin museum, Ireland; *DM* Dahlem Museum, Berlin, Germany; *EM* Exeter Museum, UK; *H* Honolulu Museum, USA; *IU* Indiana University, USA; *M* Five Continents Museum, Munich, Germany; *MA* Metropolitan Museum of Art, NY, USA; *NO* New Orleans Museum of Art, USA; *P* private collections; *PM* Peabody Essex Museum, Salem, USA; *PR* Pitt-Rivers Museum, Oxford, UK; *RI* Providence, Rhode Island, USA; *RSM* Royal Scottish Museum, Edinburgh, UK; *VHD* Volkerkundemuseum, Hermitage, Dresden, Germany. *s.n.* sine numero (lacking number)

macrofossils (Burney et al. 2001). The trunk wood was sometimes used for canoes in Hawaii, though it is ‘soft and absolutely not durable’ (Rock 1913, p. 257). Brown (1935) also recorded that the wood was used for canoes in the Austral Islands and Rapa. The relative paucity of records for figure carving could reflect this lack of durability, either because most samples have already deteriorated or—perhaps more likely—because the native islanders preferred to use more durable woods for their ritual images.

Antidesma (Euphorbiaceae)

Another species of Euphorbiaceae, *Antidesma*, accounted for one of the Hawaiian samples. This is the first record of its use for images, though the hard, reddish brown wood of the Hawaiian tree species *A. platyphyllum* H. Mann (*hame* or *haa*), which is now used for cabinet work, was used by the natives to make anvils (Rock 1913). The wood of *A. platyphyllum* has small angular vessels with minute pitting, thick-walled fibres and strongly heterocellular rays.

Artocarpus (Moraceae)

Our study shows that three large Hawaiian temple figures, all previously thought to have been made from *Metrosideros*, were all made from wood of *Artocarpus* (‘ulu, breadfruit), including the large standing image of the Hawaiian god Ku located in the

Peabody Essex Museum. In total, six Hawaiian samples and a small standing figure from Tahiti in the British Museum were made from *Artocarpus* wood, which has characteristic anatomy with large solitary vessels with associated axial parenchyma and fairly broad rays. Our study represents the first record of its use for Hawaiian figure sculpture (see also Kaeppeler et al. 1993), though Rock (1913) noted that it was used in the construction of houses and canoes in Hawaii, and Rose et al. (1993) recorded its use for *Kāhili* poles. *Artocarpus* wood was also utilized for one of the Tahitian images (Table 1), and Orliac (1986a) recorded its use for a Marquesan house post carved with a figure. Kahn and Coil (2006) found that house posts made from *Artocarpus* wood were restricted to use in high-rank habitation sites in prehistoric Tahitian society.

Originally from South East Asia, *A. altilis* (Parkinson) Fosberg (breadfruit) is of considerable economic importance for its highly nutritious fruit; it was introduced throughout Polynesia for this reason. It is known as *uru* in Tahiti and the Austral Islands, and *kuru* in Rarotonga. Other parts of the plant were also utilized, including the bark for making barkcloths (Tamburini et al. 2019). Whistler (1988) reported that on Tokelau, the wood is used for canoes and firewood.

Cheirodendron (Araliaceae)

A single Hawaiian sample was made from wood of *Cheirodendron* (Table 1), which is readily identifiable by its

Fig. 1 Examples of wooden carved images sampled in this study. **a** Kava bowl with two carved figures (Oc.HAW.46) made from wood of *Cordia*. **b**, **c** Front and back of stick figure (Oc.1440), made from wood of *Myrsine*. **d** Kona-style temple image (Oc.1656), made from wood of *Eugenia*. **e** Spear rest (Oc.VAN.313), made from wood of *Thespesia*. **f** Wooden deity figure in two pieces (Oc.6285.a-b) made from wood of *Acacia*. Images copyright of the Trustees of the British Museum

Fig. 2 Transverse sections (TS) and tangential-longitudinal sections (TLS) of some of the more commonly-used woods. **a, b** *Thespesia populnea* (**a** TS, **b** TLS), dense wood with short tangential bands of axial parenchyma (in TS) and short heterocellular rays (in TLS). **c, d** *Metrosideros polymorpha* (**c** TS, **d** TLS), solitary vessels associated with axial parenchyma (in TS) and narrow uniseriate or biseriate heterocellular rays (in TLS). Scale bars = 200 μ m. Images P.J. Rudall, from microscope slide collection at the Royal Botanic Gardens, Kew

small vessels with characteristic scalariform pitting and fairly broad rays. There are probably two species of *Cheirodendron* in Hawaii: *C. trigynum* A. Heller (*olapa*) and *C. platyphyllum* Seem. (*lapalapa*). A bluish dye was extracted from the leaves and bark, but the only use previously recorded for the wood is for firewood, which reportedly burns when green (Rock 1913).

Cordia (Boraginaceae)

It is well known that Hawaiians preferred *kou* wood for their bowls; they reportedly planted *Cordia* trees for this purpose (Malo 1951). The wood was valued both in Hawaii and the Marquesas for its beautiful grain and soft but durable heartwood. The wood anatomy is characterised by its relatively thin-walled fibres and abundant axial parenchyma and broader rays containing crystalline deposits (Fig. 3a, b). Our study has demonstrated a greater importance than predicted for *kou* wood in the smaller carved images. In total, 27 of the Hawaiian samples and six from elsewhere in Polynesia were made from *Cordia*. An image found in a cave in Kawaihae, Hawaii, formerly believed to be made of *koa* (*Acacia*), is made of *kou* wood. The British Museum Hawaiian figure images carved from *kou* wood are diverse; they include a figure with human hair, a figure on all fours, a drum, a spear rest and two bowls (Fig. 1a). The Polynesian images include a standing female figure.

Cordia subcordata Lam. (called *kou* in Hawaii or *tou* elsewhere in Polynesia), an evergreen shoreline tree, is the only species of *Cordia* on the Hawaiian archipelago, and widespread in the Old World tropics, though Hawaiian populations have been devastated by insect damage (Jenkins 1989). In the Marquesas, this species was used to carve figures, drums and bowls, though for the latter, both *Thespesia* and *Calophyllum* were preferred (Orliac 1986b, Brown 1935). Whistler (1988) recorded that *Cordia subcordata* provides the finest wood on the Tokelau Islands, north of Samoa in Western Polynesia, where the plant is known as *kanava*, and is used to make plank canoes, drums and cooking utensils.

Diospyros (Ebenaceae)

Four Hawaiian samples were made from wood of *Diospyros*, a large genus of over 700 species, including the commercial ebonies. They include an erect human figure in the Bishop Museum and a kona-style stick image in the Pitt-Rivers museum. The wood of *Diospyros* has small vessels and dense unicellular rays containing cuboidal crystals. There are two species of *Diospyros* in Hawaii, both known locally as *lama* (Rock 2013; though this name refers to *Aleurites* elsewhere in Polynesia; Elevitch 2006): *D. ferrea* (Willd.) Bakh., which also occurs in Fiji, and *D. hillebrandii* (Seem.) Fosberg, which is endemic to Hawaii. Both species are listed by Rock (1913)

Fig. 3 Transverse sections (TS) and tangential-longitudinal sections (TLS) of commonly-used woods. **a, b** *Cordia subcordata* (**a** TS, **b** TLS), relatively thin-walled fibres and abundant axial parenchyma (in TS) and broader rays (in TLS). **c, d** *Myrsine linearifolia* (**c** TS, **d** TLS), small-grained wood with angular vessels (in TS) and broad rays with crystal sand present in some ray cells (in TLS). Scale bars = 200 µm. Images P.J. Rudall, from microscope slide collection at the Royal Botanic Gardens, Kew

under their former synonyms *Maba sandwicensis* and *Maba hillebrandii*. *Diospyros ferrea* is a tree with hard reddish-brown wood, utilized for constructing temples and other religious purposes. According to Rock (1913), *lama* wood was used to represent the goddess *Laka*.

Dracaena (Asparagaceae)

Three Hawaiian samples from the Bishop Museum were here tentatively assigned to the relatively soft, pale wood of *Dracaena* (Table 1), though the fragmentary material available consisted largely of parenchymatous tissue. Larger samples would be needed to identify them accurately, but they differ radically from dicotyledonous woods in possessing a large amount of parenchyma interspersed with discrete vascular bundles. *Dracaena aurea* Mann (*halapepe*) is an arborescent Hawaiian monocotyledon that can grow up to 35 ft tall; it is widely reported as endemic to the island of Kauai, but according to Rock (1913), it once grew in large stands on the other islands. The ‘wood’ of *D. aurea* (a tissue produced by a secondary thickening meristem rather than a bifacial vascular cambium) is soft and white; it was used by the natives for carving images (Rock 1913). In fact, wood of *D. aurea* is not readily distinguishable from the secondary tissues produced by another monocot species, *Cordyline fruticosa* (L.) Chev.,

which was widely introduced throughout Polynesia by early colonisers, both as a food plant and for the leaves, which were worn for ritual purposes. However, *C. fruticosa* is not an arborescent species, and the secondary tissue is not known to have been used for carving.

Erythrina (Leguminosae–Papilionoideae)

Seven Hawaiian samples were made from wood of *Erythrina*; none from elsewhere in Polynesia. *Erythrina sandwicensis* Degener (known as *wiliwili*) is endemic to Hawaii, though other species of the genus are common on shorelines of other Pacific islands. The wood is easy to carve as it is very soft and light, and is therefore useful for making canoe outriggers. Its anatomy is highly characteristic, with solitary vessels associated with broad regular bands of axial parenchyma that is distinctly stratified in tangential longitudinal section. In the Marquesas, trunks of *E. variegata* were used to make light canoes (Brown 1935).

Eugenia (Myrtaceae)

Six Hawaiian samples were made from wood of *Eugenia* (Fig. 1d); none from our samples from elsewhere in Polynesia. The wood is very dense, with thick-walled fibres and

heterocellular rays. *Eugenia malaccensis* L. (mountain apple or 'ohia-'ai; formerly *Syzygium malaccense* [L.] Merr. and Pery) was introduced to the Hawaiian archipelago by early Polynesian settlers for its many uses, particularly its edible fruits. Rock (1913) reported that it was also a sacred tree, and the wood was used to carve images.

Hibiscus (Malvaceae)

A single Hawaiian sample was made from wood of *Hibiscus*. The cosmopolitan species *H. tiliaceus* L. (*hau*) is one of the commonest lowland trees, and is a source of fibre for cordage and tapa (Tamburini et al. 2019). It is widespread throughout Polynesia as an invasive coastal plant. The light, soft wood was used for canoe outriggers in Hawaii (Rock 1913), as elsewhere in Polynesia. In Tahiti, *Hibiscus* wood was also widely used for making door posts (Kahn and Coil 2006). The wood of *H. tiliaceus* is known to overlap somewhat in structure with that of *Thespesia populnea* (Dotte-Sarout and Kahn 2017), but in reference material available to us, *H. tiliaceus* has relatively thin-walled fibres and taller rays.

Metrosideros (Myrtaceae)

The genus *Metrosideros*, which is of ancient and widespread distribution in the Pacific, accounted for 17 of the Hawaiian samples, including some large standing figures and temple images, and a standing female figure from Tahiti. Traditionally, *Ohi'a-lehua* was thought to be the most important wood for carving images in Hawaii, particularly for Kuka'ilimoku figures (Kaepler et al. 1993). Our survey strongly supports the predicted relative importance of this wood in Hawaii. The endemic Hawaiian species *Metrosideros polymorpha* Gaud. (called *ohi'a-lehua* or *lehua*) is the commonest forest tree on the archipelago (Rock 1913; Mueller-Dombois and Fosberg 1998); it is closely related to *M. collina* (Forster) A. Gray, a cosmopolitan species with attractive red flowers. The dark red wood of *M. polymorpha* is hard and durable, with thick-walled fibres and narrow heterocellular rays (Fig. 2c, d). It was an important timber source on Hawaii, used especially for carving (Rock 1913). Elsewhere in Polynesia, *Metrosideros* wood was favoured for making houses and boats in Rapa (Brown 1935).

Myrsine (Myrsinaceae) (kolea)

Three Hawaiian samples, including a British Museum stick figure (Fig. 1b, c), were made from wood of the genus *Myrsine*, which includes several endemic species in the archipelago. The wood anatomy is highly characteristic, with small angular vessels with minute intervacular pitting and broad rays that are very long in tangential longitudinal section (Fig. 3c, d). According to Rock (1913), a species with

handsome pink wood, *M. lessertiana* A.DC., was exploited by the native Hawaiian islanders to make house posts and beams.

Rauvolfia (Apocynaceae)

Two Hawaiian samples were made from wood of this genus. *Rauvolfia sandwicensis* A.DC. (called *hao*) is the only Hawaiian species; it closely resembles *Ochrosia compta* K. Schum. (*holei*), both in morphology and wood anatomy, with small vessels, scattered axial parenchyma and heterocellular rays. The wood, called 'Hawaiian ironwood' because of its durability, is close-grained and dark yellowish in colour (Rock 1913).

Rhamnaceae: Colubrina and Alphonsea

Six samples from Hawaii were made from *kauila* wood, representing two species of Rhamnaceae that grow in Hawaii, *Colubrina oppositifolia* Brongn. and *Alphonsea ponderosa* Hillebr.; these species are both called *kauila* and are not readily distinguishable from each other using wood anatomy. The wood of both species has mostly solitary vessels with small intervacular pitting and narrow, rather homocellular rays. The samples include a small kona-style stick image in the Pitt-Rivers museum in Oxford. The relatively durable *kauila* wood was also used for making spears and *Kāhili* poles (Rock 1913; Rose et al. 1993); it was traditionally considered important for Hawaiian images, and its name is represented in one of the important religious ceremonies.

Rubiaceae (including Psychotria L.)

Rubiaceae is a large, predominantly tropical family of flowering plants, of which the majority of tropical species are trees and shrubs. Seventeen Hawaiian samples were here assigned to Rubiaceae, which includes a range of genera and species on the archipelago that are difficult to distinguish from each other using wood anatomy. About 13 genera are represented in the Hawaiian flora, of which seven are arborescent and include species that could have been used for wood carving: *Bobea*, *Canthium*, *Coprosma*, *Gardenia*, *Hedyotis* sect. *Gouldia*, *Morinda* and *Psychotria*. However, Rock (1913) recorded only two species of Rubiaceae as providing useful timber, both for making various implements and canoe parts: *Bobea elatior* Gaud. ('*ahakea*) and *Canthium odoratum* Seem. (*walahe'e* or *alahe'e*). Some other species were used in other ways; for example, *Morinda citrifolia* L. (*noni*) was used for making medicines and dyes (Tamburini et al. 2019). Elsewhere in Polynesia, Whistler (1988) also recorded some Rubiaceae woods in use in Tokelau: *Morinda citrifolia* (Indian mulberry or *nonu*) and *Guettarda speciosa* (*puapua*) were

used to make adze handles and canoe outriggers and *Gardenia taitensis* (*tiale tiale*) was used for netting needles. We have tentatively assigned some of the images in our survey to *Canthium*, *Psychotria* and *Bohea* (Table 1), which all possess small, often solitary vessels with minute intervacular pitting, short bands of apotracheal parenchyma and heterocellular rays.

***Santalum* (Santalaceae)**

Three Hawaiian samples were made from wood of the sandalwood genus, *Santalum*. Perhaps surprisingly, given its subsequent importance for export, there is no previous record of *Santalum* timber having been used for native ritual carvings in Hawaii. Wood of *Santalum* is hard, yellow and fragrant, with small, round solitary vessels, thick-walled fibres and short, narrow rays. There are probably four species of *Santalum* on the Hawaiian archipelago (Imada et al. 1989), of which *S. freycinetianum* Gaud. is known as 'ili-ahi or la'au 'ala (fragrant wood).

***Thespesia* (Malvaceae)**

The genus *Thespesia* accounted for five of the Hawaiian samples (Fig. 1e), compared with seven from elsewhere in Polynesia, including an early (pre-1774) small male figure from Tahiti. One species, *T. populnea* (called *milo* in Hawaii, *mio* or *miro* elsewhere in Polynesia) is the only Hawaiian representative of the genus; this species is also widespread in other parts of Polynesia (Elevitch 2006). In Hawaii, wood of *Thespesia* was used primarily to make bowls or small objects such as spear rests (Fig. 1e) (Rock 1913; Jenkins 1989). It had great ritual significance in south-eastern Polynesia, where it was popular—together with *Cordia*—for carving religious images (Orliac 1990b). In Tahiti and the Marquesas, *T. populnea* featured in ancient religious ceremonies and was also used to make bowls, for which it was preferred to *Calophyllum*, as it does not readily crack or split on drying (Brown 1935). The wood of this species is somewhat similar to *Hibiscus tiliaceus* but has relatively thick-walled fibres and small rays (Fig. 2a, b).

Discussion

Our study highlights unexpected levels of importance of some woods for Hawaiian temple images, particularly for *Cordia* and *Thespesia*. Most images were formerly believed to have been made from *Metrosideros* (*ohia lehua*) (Kaeppeler et al. 1993). Many other woods were not previously recorded for this purpose. Some recorded species were also used as a food source (e.g. *Artocarpus* breadfruit), so would probably have been readily available close to areas of habitation. Some

others (e.g. *Acacia koa*) were common forest trees, used for other purposes, such as canoes. Several Rubiaceae were well known to the islanders for their medicinal value.

Comparison of the Hawaiian woods with our (admittedly small) sampling from central and south-eastern Polynesia shows that *Cordia* alone maintained its relatively high level of usage (20% of Hawaiian carvings were of *Cordia*, compared with 26% from elsewhere). *Thespesia*, a popular wood for this purpose in Tahiti and the Marquesas (30%), was used for only about 4% of the Hawaiian images, and therefore could have declined in relative importance compared with elsewhere in Polynesia. On the other hand, *Metrosideros*, which was relatively little used elsewhere in Polynesia (about 4%), accounts for about 13% of the Hawaiian total. Orliac's (1986a, b) results support this finding, as she recorded the use of *Artocarpus*, *Casuarina*, *Cordia* and *Thespesia* for figures from the Marquesas. It is clear that the early settlers brought with them traditions of using certain trees, particularly *Thespesia* and *Cordia*, which persisted to some extent on the Hawaiian archipelago. However, they were not completely bound by these traditions, but took advantage of elements of the extensive indigenous flora, such as *Acacia* (4% of the total number of Hawaiian images), and various genera of Rubiaceae (13%), which were probably not utilized for this purpose elsewhere.

An intriguing aspect of this survey is the absence of certain woods. In particular, *Calophyllum inophyllum* (*kamani*)—a common shoreline tree in Hawaii—is absent from the Hawaiian records here, perhaps because it is relatively difficult to carve. Jenkins (1989) reviewed earlier speculations as to why certain large trees, despite being readily available, were not used for wood by the Hawaiians, who had considerable knowledge about their properties. The Hawaiians apparently did not favour the use of *Calophyllum* (*kamani*) wood for figure sculpture, though they used it occasionally for other purposes, including calabashes or poi bowls (Rock 1913; Jenkins 1989). It was also used in Tahiti and the Marquesas for calabashes, but was not as popular as the *mi'o* (*Thespesia*) for this purpose, as it tends to distort or split on drying. Elsewhere in Polynesia, the ready availability of *Calophyllum* wood made it an important resource. Occasionally, it was used symbolically as a piece of uncarved wood. Whistler (1988) recorded that on Tokelau, *Calophyllum* wood was used to carve many items, including bowls and handicrafts. In Rarotonga, *Calophyllum* was used for making both images and canoes (Cheeseman 1903), and according to ancient legends of Tahiti and the Marquesas, it was favoured for making idols (Brown 1935; Orliac 1990b).

Dispersal of 'preferred' woods

The early Polynesian colonists were notoriously skilled at exploiting available plant resources, including woods, and

were able to recognise useful plants. They were restricted to a limited flora on many of the islands they colonized, and often took with them seeds of important crop plants (e.g. Dotte-Sarout and Kahn 2017). Wood charcoal studies in Eastern Polynesia have demonstrated that particular woods were preferred for specific ritual purposes (Kahn and Coil 2006). However, despite Brown's (1935) belief that many of the important timber species (such as *Thespesia* and *Cordia*) were introduced to south-eastern Polynesia by the early Polynesian settlers, many of them could have been sea dispersed (for a more detailed discussion, see Mueller-Dombois and Fosberg 1998, pp. 474–477). Seeds of some species (e.g. *Thespesia populnea*) will germinate even after prolonged exposure to sea water (Hemsley 1891). Merrill (1954) plausibly criticized Brown's (1935) list of 'intentionally' introduced species, which includes several of the genera recorded here (*Artocarpus*, *Aleurites*, *Colubrina*, *Cordia*, *Eugenia/Syzygium*, *Fagraea*, *Hibiscus*, *Morinda* and *Thespesia*), regarding all the 'strand' species as potentially sea-dispersed. These strand species, which grow in sandy coastal areas, include *Colubrina asiatica*, *Cordia subcordata*, *Erythrina indica*, *Hibiscus tiliaceus* and *Thespesia populnea* and also possibly *Morinda* (Rubiaceae) and *Calophyllum*, though Merrill conceded that these species could have been introduced. Indeed, recent fossil evidence from caves on the south coast of Kauai shows that *Cordia* fruits are already abundant in pre-human sediments, though *Aleurites* was present only in post-settlement deposits (Burney et al. 2001), suggesting that at least some species were introduced.

On the other hand, some species whose woods were apparently highly valued elsewhere in Polynesia, such as *Fagraea* and *Casuarina*, were not introduced to Hawaii until recent times. *Fagraea* (*pua* in the Marquesas and elsewhere) is a native tree in parts of Polynesia, but it is a modern introduction to Hawaii; it is used for carving images in Tahiti, the Marquesas and Tonga. Orliac (1984a, b, c, 1990b) identified the woods of several carved figures from Moorea, near Tahiti, as *Fagraea*, and noted that in Tahiti, *pua* was sacred to the god Tane. Cheeseman (1903) observed that *Fagraea* wood, which is hard and durable, was used in Rarotonga for 'all classes of carved work, and especially for the elaborately carved handles of the ceremonial axes reserved for the use of chiefs'. Similarly, *Casuarina equisetifolia* (known as *toa* in the Marquesas, Tahiti and elsewhere) is common throughout East and West Polynesia and Australia; its wood is extremely hard and difficult to carve, but it was used in the Marquesas to make figure carvings (Orliac 1986b, 1990b), war weapons and barkcloth beaters, in Tahiti for images of the warrior god 'Oro (Brown 1935), and in Rarotonga 'for any purpose for which extreme hardness and durability are required' (Cheeseman 1903), including the Rarotongan image examined in this survey. These species were clearly not preferred for figure carving where other suitable woods are available.

Conclusions

In terms of land mass, the Hawaiian archipelago is among the most extensive and isolated of the Polynesian island groups. It must have represented an unusually diverse and stable environment, with an abundance of plant resources. The early Polynesian settlers imported traditions of particular woods used for carving ritual images, but they also took advantage of the extensive indigenous flora. About 50% of the Hawaiian records listed here are compatible with earlier reports of these woods having been used for Hawaiian wooden figure sculpture (e.g. from Rock (1913)). Our study represents the first record of *Artocarpus* wood for large Hawaiian temple images. Comparison of Hawaiian woods with those from central and south-eastern Polynesia shows that *Cordia* alone maintained its relatively high level of usage (20% of Hawaiian carvings examined here were made from wood of *Cordia*, compared with 26% from elsewhere). *Thespesia* appears to have declined in importance relative to other parts of Polynesia, but *Metrosideros*, which was widely available in Hawaii, assumed greater significance for figure carvings.

Acknowledgements Dorota Starzecka (British Museum) initiated this project and coordinated collection of material, with help and support from Adrienne Kaeppler (Smithsonian Institute, Washington, DC). Many museums, galleries and individuals (listed in Table 1) kindly allowed us to sample fragments of wood from their images. The Bishop Museum, Hawaii, supplied some of the woods used for reference material in this project, supplementing material available in the extensive wood collection at the Royal Botanic Gardens, Kew. Catherine Orliac (Museum National d'Histoire Naturelle, Paris) made helpful comments on an earlier draft of the manuscript. David Lorence (National Tropical Botanical Garden, Hawaii) and Peter Green (Royal Botanic Gardens, Kew) provided advice on botanical names and literature. We also thank an anonymous reviewer for constructive and helpful comments on the manuscript.

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