J Appl Phycol (2015) 27:1535–1540
DOI 10.1007/s10811-014-0440-1

From Sir Joseph Banks to the world's seaweed colloid industry: the discovery of original material and typification of the marine red alga *Gloiopeltis tenax*

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Received: 23 September 2014 / Revised and accepted: 15 October 2014 / Published online: 8 November 2014

Abstract Specimens of a seaweed sent to Sir Joseph Banks in England at the beginning of the nineteenth century by a collector in China were described as a new species, *Fucus tenax*, by the English botanist and antiquarian Dawson Turner. This seaweed has been extensively used in Japan, China and Korea as a source of glue and gum and has been more recently employed in a wide range of specialised applications, including the conservation of antiquarian objects. Banks raised with Turner the possibility that similar species in Britain could be used for the extraction of 'gelatine'. This was a very early recognition of the potential use of marine phycocolloids from seaweeds and ultimately led to a marine hydrocolloid industry with projected wholesale sales in excess of US$1.56 billion in 2014. Specimens of *Fucus tenax* Turner [the generitype of *Gloiopeltis* J. Agardh, now *Gloiopeltis tenax* (Turner) J. Agardh] discovered in the Natural History Museum, London (BM), and the Eton College Natural History Museum (ECNHM) are considered to be the material upon which the descriptions and illustrations published by Turner (Ann Bot 2:376–378, 1806; Typis J 2:72–134, 1808–1809) were based, and a lectotype (BM) and provisional isolectotypes (ECNHM) are designated here to facilitate future molecular studies of species of the genus.

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Keywords Dawson Turner · *Fucus tenax* · Funoran · *Gloiopeltis tenax* · Hydrocolloid industry · Isolectotype · Lectotype · Marine phycocolloids · Sir Joseph Banks

Introduction

At the beginning of the nineteenth century, Dawson Turner (1775–1858), a banker, botanist and antiquarian from Yarmouth in Norfolk, England, wrote an account of 'A new interesting species of *Fucus*', which he named *Fucus tenax* Turner (Turner 1806, p. 376, pl. 13; Fig. 1a) based on specimens collected in China (*in mari Sinensi*) sent to him by Sir Joseph Banks (1743–1820). Turner (1806), noting that the seaweed was used extensively by the Chinese as a gum and glue, commented:

> I am entirely indebted to that great patron of all science Sir Joseph Banks, who sent me the plant some time since, and at the same time suggested whether it might not be possible to find some British species possessed of the same quality [meaning property].

and

> There are indeed few of the submersed Algae which are not possessed of some degree of viscidity, and many of our British Fuci will in great measure, if not entirely, melt, when boiled in water over a quick fire, especially *F. ciliatus* [now *Calliblepharis ciliata* (Hudson) Kützing] and *crispus** [now *Chondrus crispus* Stackhouse], both which, on cooling, form into a gelatine resembling glue in appearance, but, unfortunately, by no means in tenacity, of which they are altogether destitute; nor have I found them applicable to any purpose, except to the fixing of those sea weeds on paper, which do not of themselves possess a sufficiently adhesive quality.

The asterisked footnote read:

> *The experiments on these plants were made by Mr. J. D. Downes, of Yarmouth, who also discovered their use in affixing other Fuci on paper.

Sir Joseph Banks (1743–1820), English naturalist, botanist and patron of the sciences, accompanied Captain James Cook (1728–1779) on his first exploratory voyage around the globe on His Majesty's Bark *Endeavour* (1768–1771), visiting, amongst other places, Brazil, Tahiti and, most famously, the eastern coast of Australia where landfall was first made at Botany Bay [now part of Sydney Harbour, New South Wales]. In his subsequent role, overseeing the development of the Royal Botanic Gardens at Kew, Banks dispatched plant hunters to various countries. William Kerr (?–1814), a Scottish gardener at Kew, was sent to China in 1803 as His Majesty's Collector at Canton [now Guangzhou], a role he played for 8 years. The first cargo of plants sent back by Kerr via the East India Company was inspected by Banks and the King, George III, in August 1804 (Carter 1988). This timing fits with the first description of *Fucus tenax* (Turner 1806), but, thus far, no evidence exists to identify with confidence the collector of the specimen sent by Banks for Turner to peruse.

The whereabouts of the original material upon which Turner based his description and illustrations (Turner 1806, pl. 13; 1808–1809, pl. 125; Fig. 1a, b) have been uncertain, with the result that *Fucus tenax* Turner has remained untypified.

Gloiopeltis

Gloiopeltis J. Agardh (1842: 66, 68) is a genus of red algae referred to the family *Endocladiaceae* (Gigartinales, Florideophyceae), and species of the genus are presently known solely from the North Pacific; from the Philippines, China, Korea, Japan and Russia; and from Alaska to Baja California, México. Currently, three species are recognised (Guiry and Guiry 2014): *Gloiopeltis tenax* (Turner) Decaisne, *Gloiopeltis complanata* (Harvey) Yamada and *Gloiopeltis furcata* (Postels & Ruprecht) J. Agardh, all of which are widely distributed in the western North Pacific; only *G. furcata* is known from the eastern North Pacific and from the Aleutian Islands south to Baja California, México (Guiry and Guiry 2014 and included references). Suringar (1870) named several new species (*Gloiopeltis capillaris*, *Gloiopeltis cervicornis* and *Gloiopeltis intricata*) from Japan that have since been reduced to synonymy (see Guiry and Guiry 2014), and he illustrated the great variation in specimens of each of his Japanese species (Suringar 1870, pl. XVII–XX).

The generitype of *Gloiopeltis* J. Agardh is widely considered to be *G. tenax*, but J. Agardh (1842: 68) firmly stated 'Typo *Fuco tenaci* Turn. tab. 125' [referring to pl. 125 in Turner (1808–1809)]. Accordingly, the generitype is actually *Fucus tenax* Turner. Additionally, the combination *Gloiopeltis tenax* has been universally ascribed to J. Agardh on the grounds that the combination was presumed to have been made when the generic name was proposed (J. Agardh 1842, p. 68, footnote), but this is not the case as pointed out by Silva et al. (1987, p. 27), who noted that the combination was not made until a few months later by Decaisne (1842, p. 360). As McNeill et al. (2012) have emphasised, the type of a genus must be an included name (Art. 10.2 ICN) and 'The type of a name of a genus…is the type of the name of a species.' (Art. 10.1 ICN, McNeill et al. 2012) so that the type of the genus is the lectotype of *Fucus tenax* Turner.

Species of *Gloiopeltis* grow on intertidal rocks from small perennating basal crusts, the seasonal cylindrical to compressed erect axes irregularly subdichotomously branching and becoming hollow in some specimens. The season of maximum erect growth is winter and early spring when rapid elongation ('within 2 months' in Amoy [now Xiamen], China; Tseng 1933, p. 49) of fronds occurs. In many places in the North Pacific, the species is zone-forming in the mid-intertidal or at least forms extensive growths on intertidal boulders and bedrock.

Because of their extensive usage and widespread distribution, species of the genus have come to have a wide range of common names, including, in China, Ch'i-ts'ai and Hung-ts'ai (both 'red vegetable'), Kaau-ts'oi ('gelatinous vegetable') and Lu-kio-ts'ai ('vegetable with the horns of a stag') (Tseng 1933; Madlener 1977), and, in Japan, Fukuro-funori (Arasaki and Arasaki 1983), from which the name 'funoran' for the extract is derived. According to Swider and Smith (2005), in Japan, *G. tenax* is known as *mafunori*, *G. complanata* as *hana-funori* and *G. furcata* as *fukuro-funori*.

Funori has been in use in Japan since at least the latter part of the seventeenth century (Chapman and Chapman 1980, p. 143; Swider and Smith 2005) as an adhesive, as a sizing agent for textiles and paper and as a thickener for mortar and plaster (Tuvikene et al. 2014). Collection of funori seems to be mostly confined to the southern parts of Japan, with people in some areas 'planting' boulders in the *Gloiopeltis* zone to increase the harvest (Chapman and Chapman 1980, p. 146).

Tseng (1933, p. 49) explains how valuable the resource in Amoy, China, was in the 1930s:

> The rocks are jealously guarded and no one is permitted to pick up a single seaweed from another person's grounds. If such a case is discovered, the person will be fined by the village committee a sum of $50.00 [sic] and besides will have to set off a quantity of fire-crackers as a means of confessing his offence against the owner.

Mitchell and Guiry (1983) have described how Turner's early observations on *F. tenax* had indirectly led to the use of

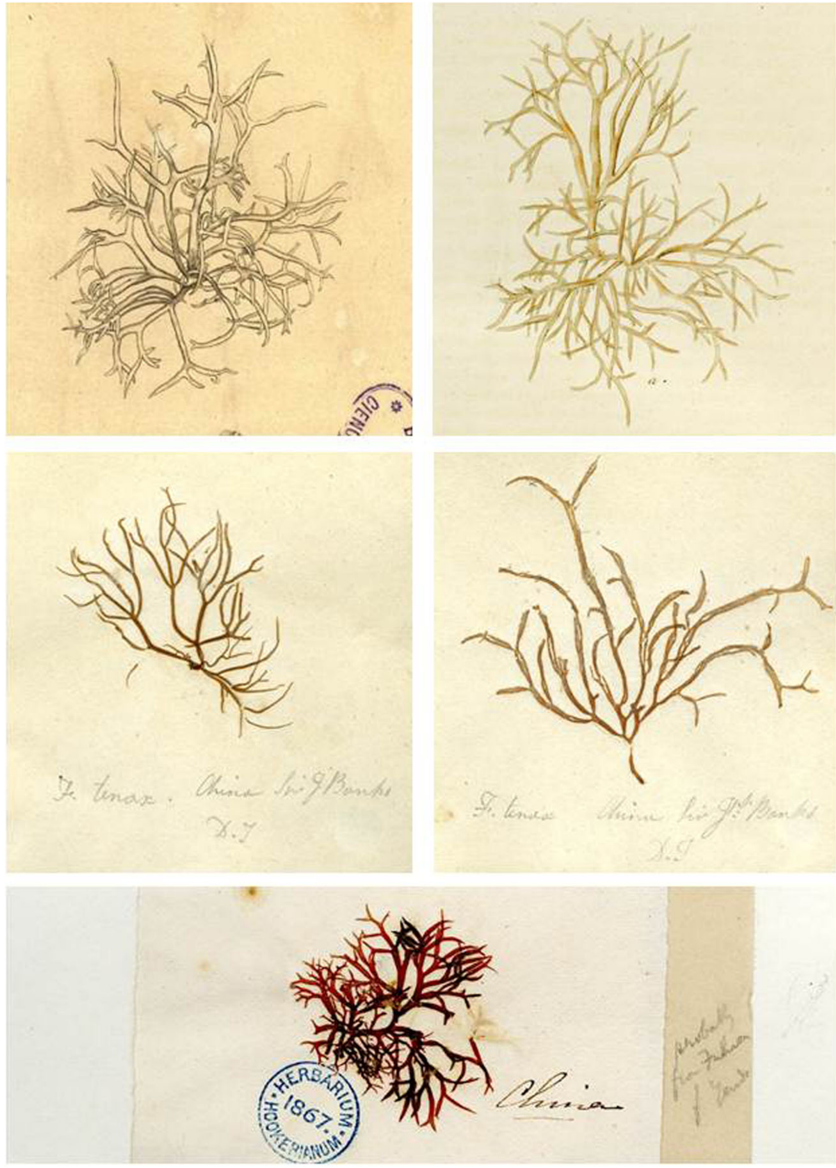

Fig. 1 Original illustrations and original material of *Fucus tenax*. **a** *Fucus tenax*, pl. 13 in Turner (1806). **b** *Fucus tenax*, pl. 125 in Turner (1809). **c** *Fucus tenax*, annotated 'DT', in the William Hincks herbarium in ECNHM and considered here as original material. **d** *Fucus tenax*, annotated DT, in the William Hincks herbarium in ECNHM and considered here as original material. **e** Specimen of *Gloiopeltis tenax* (BM000518758), probably annotated by Antony Gepp and here designated as lectotype. *Scales*: 1 cm = 1.55 cm

Chondrus crispus Stackhouse as a source of gelling material in Dublin from 1829 and ultimately to the coining of the names 'carrageen' (from a common Irish place name, *Carraigín*, the diminutive of the Irish word for a rock, *carraig*), 'carrageenin' and ultimately 'carrageenan'. *C. crispus* is still known widely as 'Irish Moss' and was, in its turn, the origin of the carrageenan industry, now the most valuable and largest of the seaweed colloid industries (Table 1).

Discovery of original material of ***Fucus tenax***

During a major refurbishment of the Natural History Museum at Eton College (ECNHM) between 1994 and 2000, an old plant collection was rediscovered and named the William Hincks Herbarium (Fussey et al. 2006). It contains approximately 300 seaweed specimens, most of which lack collector and locality information. However, amongst the collection, there are two specimens (Fig. 1c, d) labelled '*F. tenax* China Sir J. Banks' with the initials 'DT', considered to be those of Dawson Turner based on comparison of the handwriting on sheets with specimens annotated by him at the BM (e.g. *Taonia atomaria* (Woodward) J. Agardh BM000701458 and BM000701460). In the study of Fussey et al. (2006, p. 29), these initials were incorrectly read as 'DN' and attributed to David Nelson, the botanist who sailed aboard HMS *Discovery* with Captain James Cook on his third circumnavigation. A search of the Natural History Museum (BM) material from Turner's herbarium (formerly at Kew Gardens where it was incorporated into *Herbarium Hookerianum*) revealed a specimen (Fig. 1e, BM000518758) that had been considered as possible type

Table 1 Growth in seaweed hydrocolloid market from 1999 to 2014. The figures for 2014 are estimates based on growth from 2009 to 2013. Data courtesy of Dr. Harris J. Bixler (pers. comm.)

Seaweed hydrocolloid	1999 MT (US$)	2009 MT (US$)	2014 (est.) MT (US$)
Agar	7500 (128)	9600 (173)	10,600 (191)
Carrageenan	42,000 (291)	50,000 (527)	60,000 (626)
Alginate	23,000 (225)	26,500 (318)	30,000 (339)
Total	72,500 (644)	86,100 (1018)	100,600 (1156)

MT metric ton or tonne, a unit of measurement used in the US industry and equivalent to 1000 kg

material but annotated, probably by Antony Gepp, as follows: 'probably not one of the original specimens which was sent to Dawson Turner by Banks (not the one fig[ure]d in *Ann[als of] Bot[any]* 1806, p. 376)'. Gepp also made a note on the specimen: 'probably from Fukien' [on the southeastern coast of China, now called Fujian f ['fide' = according to] Yendo [Kichisaburo Yendo (1874–1921)], a Japanese phycologist who visited the Museum to examine corallines]. Antony Gepp (1862–1955) was employed as a phycologist at the Natural History Museum from 1886 to 1927, but he continued working there after his retirement (Natural History Museum 2014).

In our opinion, the BM specimen (Fig. 1e) resembles the plants illustrated in pl. 13 (Fig. 1a) in the study of Turner (1806) and even more so pl. 125, fig. a (Fig. 1b) in Turner (1808–1809). The latter illustration is by W.J. Hooker ['W.J.H. Esq^{r} del^{t}.' at the bottom left of the plate identifies William Jackson Hooker (1785–1865), who married Dawson Turner's eldest daughter, Maria (1797–1872; Dawson 1961), in 1815 and who provided 230–234 of the Fuci's 258 plates (cf. Richardson 2002 and Wynne 2003)]. Our considered opinion is that the specimens at BM and at ECNHM are part of the materials upon which the description of *F. tenax* Turner was based. We propose to designate here the specimen at BM (Fig. 1e) as the lectotype on the basis that its provenance is well established and because of its close resemblance to the original 1806 illustration. We designate here the two specimens at ECNHM (Fig. 1c, d) as provisional isolectotypes as they are likely to be part of the same collection although their provenance is not as well established.

Gloiopeltis and the foundation of the modern seaweed colloid industry

Of the three generally recognised *Gloiopeltis* species, *G. furcata* seems to be the most widely distributed and collected for household use and commercial purposes (Fig. 2), whereas *G. tenax* and *G. complanata* are less commonly exploited, although it is often not clear from published and anecdotal reports as to precisely which species is being used. All three species occur in China (Xia Bangmei 2004, p. 50) and Japan (Yoshida 1998, p. 677). Further north, only *G. furcata* is reported from Peter the Great Bay (*Zaliv Petra Velikogo*, Perestenko 1980) and the Kamchatka Peninsula (*Poluostrov Kamchatka*), where it is described as 'one of the most common mass species of flora of the Russian Far East'. (Klochkova et al. 2009, p. 112, from Russian).

What Turner (1802, 1808–1809) originally termed the 'gelatine' from *F. tenax* is actually a carrageenan-like galactan (sulphated polysaccharide) generally referred to as 'funoran'. It has been traditionally employed in Japan as a thickener for mortar and plaster (Hirase, Araki, and Ito 1956; Hirase and Watanabe 1972); as a sizing agent in the paper and textile industries (Swider and Smith 2005; Takano et al. 1995); as a coating of high-end wallpapers (Klochkova et al. 2009); as a paste for pottery, handicraft and stationery; and as a household adhesive (Yasunaga et al. 2006). It is approved as a safe food thickener (Yu et al. 2010) and is used as a consolidant for matte paints (Geiger and Michel 2005), a blood anticoagulant and in the cosmetic industry (Sand and Glicksman 1973). More recently, *G. tenax* has been reported to have the potential as a natural antioxidant and antimicrobial agent in food processing (Zheng et al. 2012), and funoran has been tested in xylitol chewing gum for its efficacy in removing dental plaque and controlling dental caries (see Wang et al. 2014). Perhaps most usefully, funoran-like material obtained by simply dissolving funori sheets in warm water has been used in the successful conservation of ancient wood sculptures, particularly to consolidate flaking pigments and gilding, textiles and

Fig. 2 Woman collecting *Gloiopeltis* by hand at Oishi-zaki, Yura, Awaji Island, Hyogo Prefecture, Japan. 22 March 2007 © M.D. Guiry

various other conservation projects of historic and artistic works (see Swinder and Smith 2005). Because of its long history of use, minimal processing and ease of use, it is an ideal consolidant for many such purposes.

Conclusion

The selection of types for the various names that have been applied to species of *Gloiopeltis* will be critical for a much needed re-examination of the species relationships within the genus. This, in turn, will enable different gelling properties to be assigned to individual species with the potential for more quality control. It is likely (Hiroshi Kawai, Kobe University, pers. comm.) that molecular studies will show that many more species occur in the area of distribution of the genus. The putative species of the genus described by Suringar and others will require further typification to establish their species status.

Acknowledgments We are grateful to Dr. Harris J. 'Pete' Bixler (Ingredients Solutions Inc.) for the information in Table 1 on the production and sales of seaweed colloids; Professor Hiroshi Kawai (Kobe University, Japan) for information on unpublished data on the species of *Gloiopeltis*; Sir Michael Dixon for his ongoing advice regarding the ECNHM Collection; Dr. David Smith, Rebecca Tessier and Roddy Fisher for their work on the ECNHM herbarium and the online catalogue http://collections.etoncollege.com/home; and Dr. Neil Chambers, Executive Director of the Sir Joseph Banks Archive Project, for his suggestion concerning William Kerr.

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