GB NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME

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	Name of Organism:	***Sargassum muticum*** **(Yendo) - Fensholt**
	Objectives:	Assess the risks associated with this species in GB
	Version:	FINAL 04/04/11

N	QUESTION	RESPONSE	COMMENT
1	What is the reason for performing the Risk Assessment?		The natural geographical range of *Sargassum muticum* (known hereafter as *S. muticum*) is the Asian coasts of the Pacific Ocean where it is known to occur in China, Japan and Korea. It was introduced to the Pacific coast of Canada in 1944 and by 1973 had spread south to Mexico and north to Alaska. In 1973 it was first found on the south coast of England as predicted by Druehl (1972). *S. muticum* has since spread north to Norway and south to Portugal and the Mediterranean Sea.
2	What is the Risk Assessment area?	GB	*S. muticum* is a non-native species able to colonise natural and man-made habitats and is known to influence local community structure and possibly also species richness.
3	Does a relevant earlier Risk Assessment exist?	NO OR UNKNOWN (Go to 5)	Many accounts of the impact of *S. muticum* have been written since its discovery in Europe in 1973. Literature on the species is voluminous. (e.g. Critchley *et al.* 1990, Davison 1999).
4	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?		
A	**Stage 2: Organism Risk Assessment SECTION A: Organism Screening**		
5	Identify the Organism. Is the organism clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	YES (Give the full name & Go to 7)	The genus Sargassum is taxonomically difficult, but *S. muticum* is a distinct entity. *Sargassum muticum* (Phaeophyceae, Fucales, Sargassaceae).
6	If not a single taxonomic entity, can it be redefined?		
7	Is the organism in its present range known to be invasive, i.e. to threaten species, habitats or ecosystems?	YES (Go to 9)	*S. muticum* is globally invasive, notably in Atlantic and Mediterranean Europe (also Pacific coast of N. America). Where it occurs it is often visually dominant, a community characterising organism that locally changes community structure and species dominance (e.g. Strong *et al.* 2006, Harries *et al.* 2007). It is a relatively unobtrusive component of the algal flora in its native area of Japan (Norton 1977b, Critchley 1983e)
8	Does the organism have intrinsic attributes that indicate that it could be invasive, i.e. threaten species, habitats or ecosystems?	YES or UNCERTAIN (Go to 9)	A persistent perennial plant with distinct seasonal growth that occurs in rock pools and shallow standing water and subtidal waters, rarely on intertidal rocks (it has very limited tolerance to desiccation), usually in more sheltered rather than severely wave-exposed situations. Its pseudo-perennial lifestyle together with fast growth rate, large frond size and dense local colonisation make it an effective competitor with native algae where environmental conditions are favourable. The species may form blanketing growths as a canopy layer. *S. muticum* can disperse by the release of gametes and formation of zygotes in the water column (see Deysher & Norton 1982) - zygotes are retained on the receptacle for several days after fertilisation and are released as small germlings which sink relatively rapidly with most of them settling within 2-3m of the parent plant; this gives rise to dense stands of *Sargassum* and expansion at the margins (probably not a mechanism for longer range dispersal), and by detached drifting plants (these cannot reattach but if reproductively active they can remain viable for a significant length of time and release germlings at a more distant location). It is also a fouling species. *S. muticum* germlings grow at a faster rate than other native British macroalgae and may represent competitive success. This could help minimise the time during which very young germlings are susceptible to faunal micrograzing (Hales & Fletcher, 1989).
9	Does the organism occur outside effective containment in the Risk Assessment area?	YES (Go to 10)	*S. muticum* was first discovered in Scotland after 31 years spread in England, Wales and Ireland, and from past pattern will spread throughout the north of the UK by natural means. Control by eradication was not successful with the original population on the Isle of Wight.
10	Is the organism widely distributed in the Risk Assessment area?	YES & Future conditions/management procedures/policies are being considered (Go to 19)	*S. muticum* occurs throughout southern England, and has also been found in Wales and Ireland, and recently on the west coast of Scotland (see Hardy & Guiry 2006 - although not up to date).
11	Does at least one species (for herbivores, predators and parasites) or suitable habitat vital for the survival, development and multiplication of the organism occur in the Risk Assessment area, in the open, in protected conditions or both?		*S. muticum* colonises preferentially pools, lagoons and shallow standing water and subtidal waters in sheltered and slightly wave-washed situations. It has broad environmental tolerances, can establish on pebbles as well as bedrock. There are many habitats around the Scottish coast (particularly the west) that are suitable for establishment.
12	Does the organism require another species for critical stages in its life cycle such as growth (e.g. root symbionts), reproduction (e.g. pollinators; egg incubators), spread (e.g. seed dispersers) and transmission, (e.g. vectors)?		The original spread of *S. muticum* to Europe was probably by transplantation of insufficiently quarantined oysters as predicted by Druehl (1972); subsequently its spread has been both by natural (fertile drift - Bjaerke, 2005, Brown *et al.*, 2006) and anthropogenically influenced means (Brown *et al.*, 2006).
13	Is the other critical species identified in question 12 (or a similar species that may provide a similar function) present in the Risk Assessment area or likely to be introduced? If in doubt, then a separate assessment of the probability of introduction of this species may be needed.		
14	Does the known geographical distribution of the organism include ecoclimatic zones comparable with those of the Risk Assessment area or sufficiently similar for the organism to survive and thrive?		*S. muticum* has a wide temperature tolerance and has colonised Atlantic European coasts from southern Norway and Sweden to Portugal (Boudouresque *et al.*, 1994); it is becoming more common in the Mediterranean Sea, but is largely absent from cold arctic waters. Experimental studies have shown that *S. muticum* is eurythermal and able to tolerate and develop under a wide range of temperatures from 5 C to 30 C (*cf* Hales & Fletcher, 1989) but optimally at 25 C. Its occurrence in Alaska and the west coast of Canada indicates that it is able to cope with the Scottish climate.

15	Could the organism establish under protected conditions (e.g. glasshouses, aquaculture facilities, terraria, zoological gardens) in the Risk Assessment area?		*S. muticum* is not uncommonly associated with harbours, marinas and associated structures, and sheltered inlets; it may possibly colonise aquaculture facilities in Scotland. It has spread to marine SSSIs, SACs and MNRs in the UK. It is potentially a minor navigation hazard from tangling propellers and fouling fishing gear (Critchley *et al.* , 1986).
16	Has the organism entered and established viable (reproducing) populations in new areas outside its original range, either as a direct or indirect result of man's activities?		Populations established throughout Atlantic and Mediterranean Europe, (and Pacific coast of N. America), (Boudouresque *et al.* , 1994). The original point of introduction in a new oceanic region has been generally associated with translocation of cultivated oysters (Druehl, 1973; Brown *et al.* , 2006).
17	Can the organism spread rapidly by natural means or by human assistance?		Populations can actively spread by natural means (Bjaerke, 2005) although the original seeding involved insufficiently quarantined oyster transplantation (Druehl, 1973). Natural spread has been both rapid and slow (it is currently absent from the east coast of England) and is dependant on local conditions such as the predominant direction of drifting plants and the availability of suitable habitats. Its appearance at remote locations is usually associated with shellfish cultivation (e.g. Kraan, 2006).
18	Could the organism as such, or acting as a vector, cause economic, environmental or social harm in the Risk Assessment area?		*S. muticum* potentially can form excessive nuisance growths, but has not caused any loss of species save for changes in community structure or dominance and the character and appearance of the lower shore and shallow subtidal communities. High recruitment density of *S. muticum* may prevent settlement of other algae, and dense canopies may shade out other species (Critchley *et al.* 1986; Staehr *et al.* , 2000). It may cause economic damage to aquaculture industry in Scotland by fouling installations and nets.
19	This organism could present a risk to the Risk Assessment area and a detailed risk assessment is appropriate.	Detailed Risk Assessment Appropriate GO TO SECTION B	The monitoring of the spread of *S. muticum* and impact on local marine communities would provide greater understanding of the impact of this species.
20	This organism is not likely to be a harmful non-native organism in the Risk Assessment area and the assessment can stop.		From effects seen in England and elsewhere, the spread of *S. muticum* throughout Scotland will have a noticeable impact at intertidal and shallow subtidal levels on the communities of rock-pools, lagoons, and shallow standing waters where there is mixed substrata and shelter.

B	SECTION B: Detailed assessment of an organism's probability of entry, establishment and spread and the magnitude of the economic, environmental and social consequences			
	Probability of Entry	**RESPONSE**	**UNCERTAINTY**	**COMMENT**
1.1	List the pathways that the organism could be carried on. How many relevant pathways can the organism be carried on?	few - 1	LOW - 0	*S. muticum* was transferred to Europe by transportation of insufficiently quarantined oysters (Farnham *et al.* , 1973). It is known to have been transferred from the UK to the Netherlands on oysters (Critchley & Dijkema 1984); oyster transplantation is blamed for introduction to Denmark (Staehr *et al.* 2000), the Mediterranean (Knoepfler-Peguy *et al.* 1985), Republic of Ireland (Loughnane & Stengel 2002) and Northern Ireland (Boaden 1995). Its subsequent spread was by natural means involving the movement of zygotes, and fertile drift material (often large portions of a plant) by water movement. Plant fouling of boat hulls is another potential means of spread (Farnham *et al.* , 1973; Knoepfler-Peguy *et al.* 1985, Mediterranean; Kraan 2005, Ireland).
1.2	Choose one pathway from the list of pathways selected in 1.1 to begin the pathway assessments.		MEDIUM -1	Farnham *et al.* (1973) suggested that shipping rather than *Crassostrea* may have been a vector for the original introduction of *S. muticum* to England (Solent) although C*rassostrea* was reared under quarantine hatchery conditions in nearby Chichester Harbour. Subsequent local spread was probably involved both natural and anthropogenic (boat fouling) means.
1.3	How likely is the organism to be associated with the pathway at origin?	likely - 3	LOW - 0	*S. muticum* must be present to effect release of gametes and formation of zygotes, and to produce detached fragments that form drift material.
1.4	Is the concentration of the organism on the pathway at origin likely to be high?	moderately likely - 2	HIGH -2	Uncertain, a few plants or germlings could initiate a population but some years are required to build up a sufficient breeding stock to allow for expansion by natural means (Critchley *et al.* 1983).
1.5	How likely is the organism to survive existing cultivation or commercial practices?	likely - 3	LOW - 0	See DEFRA report No FC1017/CSA7049 - Development of Best Practice in Relation to Movement of Bivalve Shellfish Stock. (Brown *et al.* , 2006). S. muticum has survived the effects of trawling, cutting, suction and chemical herbicide (Bjaerke 2005). See also Critchley *et al.* (1986).
1.6	How likely is the organism to survive or remain undetected by existing measures?	unlikely - 1	LOW - 0	A very obvious species that will be detected in the course of marine surveys except perhaps in the early stages of colonisation when plants are small and populations sparse; initial populations occurring at subtidal levels may also be overlooked. Once established, populations survive indefinitely.
1.7	How likely is the organism to survive during transport /storage?	very likely - 4	MEDIUM -1	Longevity of fertile drift fragments (often large) is probably considerable (up to 3 months has been suggested) see Arenas *et al.* (2002), Staehr *et al.* (2000). Longevity and dispersal of gametes and zygotes is probably limited.
1.8	How likely is the organism to multiply/increase in prevalence during transport /storage?	very likely - 4	MEDIUM -1	Drift plants will remain fertile or become fertile while travelling considerable distances, and may shed gametes and form zygotes at new locations top produce new plants (Bjaerke 2005).
1.9	What is the volume of movement along the pathway?	minor - 1	MEDIUM -1	For drift plants probably spasmodic according to weather conditions (plants becoming detached or broken as a result of storms) (Arenas *et al.* , 2002; Bjaerke 2005; Brown *et al.* , 2006) .
1.10	How frequent is movement along the pathway?	often - 3	MEDIUM -1	Uncertain, but spread via water movement is common as drift material is frequently washed on to sea-shores (Bjaerke, 2005).
1.11	How widely could the organism be distributed throughout the Risk Assessment area?	very widely - 4	LOW - 0	Most of the UK will be invaded by *S. muticum* as it is currently present in Scandinavia, Germany, Netherlands, France, Spain, Portugal, and common in south England (Boudouresque *et al.* , 1994), Wales and Ireland. *S muticum* is less tolerant of low salinity conditions (Hales & Fletcher, 1989).
1.12	How likely is the organism to arrive during the months of the year most appropriate for establishment ?	very likely - 4	LOW - 0	*S. muticum* is perennial but dies back in winter and has a flush of growth in spring and summer (*cf* Thomsen *et al* ., 2004). It will probably establish especially in the growing season (spring and summer) when swarms of germlings are released intermittently.
1.13	How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) or other material with which the organism is associated to aid transfer to a suitable habitat?	N/A		
1.14	How likely is the organism to be able to transfer from the pathway to a suitable habitat?	very likely - 4		Zygotes will settle in most suitable pool, lagoon and shallow standing water habitats. For successful establishment drift plants need to arrive at a location with suitable exposure levels and hard substrates not densely covered by algae (Arenas *et al.* 2002; Bjaerke 2005; Staehr *et al.* 2000).

	Probability of Establishment	RESPONSE	UNCERTAINTY	COMMENT
1.15	How similar are the climatic conditions that would affect establishment in the Risk Assessment area and in the area of current distribution?	similar - 3	LOW - 0	*S. muticum* is eurythermal, with maximum and minimum temperature tolerances that occur outside UK waters (*cf* Hales & Fletcher, 1989); lower sea temperatures in Scotland may reduce but not inhibit growth of *S. muticum* .
1.16	How similar are other abiotic factors that would affect establishment in the Risk Assessment area and in the area of present distribution?	similar - 3	LOW - 0	Habitat conditions throughout the UK are appropriate for colonisation by *S. muticum* although it is less likely to spread into estuaries and wave-exposed sites.
1.17	How many species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism species are present in the Risk Assessment area? Specify the species or habitats and indicate the number.	many - 3	LOW - 0	*S. muticum* occurs abundantly in rocky shore pools, lagoons, areas of shallow sheltered standing water and subtidal waters, sometimes in man-made habitats (ports and harbours), but is less tolerant of low salinity estuaries. It will grow on mixed substrates of cobbles and pebbles on sediment in sheltered and moderately wave-exposed situations. Such environments are widespread at lower shore and shallow subtidal levels in many Scottish sea lochs.
1.18	How widespread are the species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism in the Risk Assessment area?	widespread - 4	LOW - 0	Rocky shores with, pools, lagoons and areas of shallow water occur throughout the UK.
1.19	If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in the risk assessment area?	N/A		
1.20	How likely is it that establishment will not be prevented by competition from existing species in the Risk Assessment area?	very likely - 4	LOW - 0	*S. muticum* often forms blanketing growths but may be initially inhibited by an existing cover of algae; a disturbance event that displaces existing algae may create space for *S. muticm* to become established. When established it competes effectively because its holdfast is perennial, so keeping its 'space' from one growing season to the next. Its large size and rapid growth allows it to compete very effectively for light.
1.21	How likely is it that establishment will not be prevented by natural enemies already present in the Risk Assessment area?	very likely - 4	LOW - 0	*S. muticum* is well established in southern England and Wales and appears not to have significant natural enemies; although various grazers might feed on *S. muticum* (e.g. *Psammechinus* in Scandinavia (Pedersen *et al.* 2005, Thomsen *et al.* 2006) there is no evidence of them preventing establishment or controlling it. Critchley *et al.* (1986) showed that biological control agents were ineffective.
1.22	If there are differences in man's management of the environment/habitat in the Risk Assessment area from that in the area of present distribution, are they likely to aid establishment? (specify)	N/A		Managing marine habitats is not comparable with managing terrestrial habitats.
1.23	How likely is it that existing control or husbandry measures will fail to prevent establishment of the organism?	very likely - 4	LOW - 0	Eradication attempts failed in 1973 shortly after the discovery of *S. muticum* on the Isle of Wight and populations subsequently became well-established. Control of drift material is difficult as is control of propagules in the water column and their transportation. But some control of its spread with appropriately managed bivalve stock movement may be helpful (see Brown *et al.* 2006).
1.24	How often has the organism been recorded in protected conditions, e.g. glasshouses, elsewhere?	N/A		
1.25	How likely is the reproductive strategy of the organism and duration of its life cycle to aid establishment?	very likely - 4	LOW - 0	Fertile plants of *S. muticum* occur abundantly and drift material remains fertile facilitating the spread to new locations (Bjaerke 2005 and others).
1.26	How likely is it that the organism's capacity to spread will aid establishment?	very likely - 4	LOW - 0	*S. muticum* spreads relatively rapidly and easily establishes new populations (*cf* Staehr *et al.* 2000).
1.27	How adaptable is the organism?	very adaptable - 4	LOW - 0	*S. muticum* has a wide temperature tolerance and will occupy standing water habitats even where substratum is limited by colonising small cobbles and boulders.
1.28	How likely is it that low genetic diversity in the founder population of the organism will not prevent establishment?	very likely - 4	HIGH -2	*S. muticum* has spread extensively in Europe from probably a few originally seeded populations.
1.29	How often has the organism entered and established in new areas outside its original range as a result of man's activities?	few - 1	MEDIUM -1	It is not known how many original populations were established in Europe in the 1970s (probably a few), but *S. muticum* now occurs extensively along Atlantic coasts and in the Mediterranean Sea. Its appearance in many new locations has been linked to 'man's activities' (see Boudouresque *et al.* , 1994)
1.30	How likely is it that the organism could survive eradication campaigns in the Risk Assessment area?	very likely - 4	LOW - 0	Previous eradication campaigns have failed (see Davison 1999) with the exception perhaps of Lundy where there was some degree of success.
1.31	Even if permanent establishment of the organism is unlikely, how likely is it that transient populations will be maintained in the Risk Assessment area through natural migration or entry through man's activities (including intentional release into the outdoor environment)?	N/A		Permanent populations now well established.

	Spread	RESPONSE	UNCERTAINTY	COMMENT
2.1	How rapidly is the organism liable to spread in the Risk Assessment area by natural means?	very rapid - 4	LOW - 0	Dispersal by water movement has been very rapid; since 1973 the species has spread from France and the Isle of Wight to Norway and Portugal (first seen in 1992). See Boudouresque *et al.* (1994).
2.2	How rapidly is the organism liable to spread in the Risk Assessment area by human assistance?	very slow - 0	LOW - 0	Possibly oyster transplantation and ship fouling but also natural means.
2.3	How difficult would it be to contain the organism within the Risk Assessment area?	very difficult - 4	LOW - 0	Populations of *S. muticum* are already well established in Europe and in the UK. See Boudouresque *et al.* (1994).
2.4	Based on the answers to questions on the potential for establishment and spread define the area endangered by the organism.		LOW - 0	A wide area of Atlantic and Mediterranean Europe, *S. muticum* may also spread to N. Africa, certainly throughout the UK and Scotland. Following introduction to Pacific America in 1944 it subsequently spread to Alaska and Mexico, it will likely spread throughout the UK.

	Impacts	RESPONSE	UNCERTAINTY	COMMENT
2.5	How important is economic loss caused by the organism within its existing geographic range?	minimal - 0	MEDIUM -1	Probably little or none more a nuisance organism - unaware of published information.
2.6	Considering the ecological conditions in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, livestock health and production, likely to be? (describe) in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, likely to be?	minimal - 0	MEDIUM -1	Probably little or none. May locally grow in nuisance amounts and require clearance. May possibly foul fish farms and small boats, clog intake pipes and cause loss of amenity value (Critchley, 1986). Unaware of published information. Its impact on the sea-grass (*Zostera*) bed at its first site of discovery in Britain is inconclusive; monitoring has revealed its survival despite abundant growths of *S. muticum.*
2.7	How great a loss in producer profits is the organism likely to cause due to changes in production costs, yields, etc., in the Risk Assessment area?	minimal - 0	HIGH -2	Probably little or none (possible minor effects on tourism and amenity value and the need to clear beaches of rotting weed, and antifoul or clear marine structures such as fish farms) - unaware of published information.
2.8	How great a reduction in consumer demand is the organism likely to cause in the Risk Assessment area?	minimal - 0	HIGH -2	Probably little or none - unaware of published information.
2.9	How likely is the presence of the organism in the Risk Assessment area to cause losses in export markets?	unlikely - 1	HIGH -2	Probably little or none - unaware of published information.
2.10	How important would other economic costs resulting from introduction be? (specify)	minor - 1	HIGH -2	Probably little or none other than clearance of driftweed from tourist beaches - unaware of published information.
2.11	How important is environmental harm caused by the organism within its existing geographic range?	moderate - 2	LOW - 0	*S. muticum* appears not to have caused a loss of biodiversity but may determine community structure and dominance. On the positive side large plants create habitat for epibionts.
2.12	How important is environmental harm likely to be in the Risk Assessment area?	moderate - 2	MEDIUM -1	As previously. *S. muticum* can form blanketing growths.
2.13	How important is social and other harm caused by the organism within its existing geographic range?	minimal - 0	HIGH -2	Probably little or none but may occasionally occur in nuisance amounts requiring clearance - unaware of published information.
2.14	How important is the social harm likely to be in the Risk Assessment area?	minor - 1	HIGH -2	Probably little or none but may occasionally occur in nuisance amounts requiring clearance - unaware of published information.
2.15	How likely is it that genetic traits can be carried to native species, modifying their genetic nature and making their economic, environmental or social effects more serious?	unlikely - 1	LOW - 0	The genus *Sargassum* is not native to the northeast Atlantic - unaware of published information.
2.16	How probable is it that natural enemies, already present in the Risk Assessment area, will have no affect on populations of the organism if introduced?	very likely - 4	MEDIUM -1	Plant-animal interactions of *S. muticum* are not fully understood but note that it often occurs abundantly and its speedy germling growth may give the species a competitive advantage against grazing (see Critchley *et al.* 1986 for observations on biological control).
2.17	How easily can the organism be controlled?	very difficult - 4	LOW - 0	Eradication schemes have largely failed (see Bjaerke 2005). *S. muticum* is now naturalised and occurs widely and abundantly.
2.18	How likely are control measures to disrupt existing biological or integrated systems for control of other organisms?	moderately likely - 2	MEDIUM -1	Control of introduced species in the marine environment is difficult and has been successful only once (*Ascophyllum nodosum*, San Francisco California); damage caused is not known. Any action e.g. clearance would inevitably cause disturbance to surrounding communities.
2.19	How likely is the organism to act as food, a host, a symbiont or a vector for other damaging organisms?	moderately likely - 2	HIGH -2	Insufficient field data to determine this fully.
2.20	Highlight those parts of the endangered area where economic, environmental and social impacts are most likely to occur		LOW - 0	Widely throughout the UK as the species is well established throughout Atlantic Europe. The west coast of Scotland is potentially a very favourable area for *Sargassum* and may become a nuisance in relation to fish-farming.

Summarise Entry	very likely - 4	LOW - 0	*S. muticum* is a non-native species widely established throughout Europe; the sources for further spread are plentiful.
Summarise Establishment	very likely - 4	LOW - 0	*S. muticum* is well-suited to pool, lagoon, shallow water habitats in the UK, where firm substrates occur. Establishment is least likely where there is wave-exposure or low salinity.
Summarise Spread	rapid - 3	LOW - 0	It is not known how many original populations were established in Europe in the 1970s (probably a few), but *S. muticum* now occurs extensively along Atlantic coasts and in the Mediterranean Sea. Its appearance in many new locations has been linked to human activity.
Summarise Impacts	minor - 1	MEDIUM -1	Probably no negative impact on biodiversity but will change community (biotope) structure and dominance (having a visual impact where it forms dense beds). It is potentially a nuisance species.
Conclusion of the risk assessment	MEDIUM -1	MEDIUM -1	*S. muticum* will eventually become a naturalised species throughout the UK, as have other non-native algae (e.g. *Asparagopsis armata* , *Bonnemaisonia hamifera* , and *Codium fragile*).
Conclusions on Uncertainty	moderate - 2	LOW - 0	There have been many studies on the biology and ecology of *S. muticum* in the UK and elsewhere (see references below).

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