



Organism Impact Assessment

Styela clava
(Clubbed Tunicate)

October 2006

Version 20/10/2006

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CONTENTS

1.0 Background	3
1.1 <i>Styela clava</i> Herdman, 1881.....	3
1.1.1 Biology and Ecology	3
1.1.2 International Distribution	4
1.2 Pathways and vectors of introduction	5
1.2.1 Pathways and vectors—New Zealand.....	5
1.3 Establishment.....	6
1.4 Spread.....	6
1.4.1 Population Growth.....	7
1.5 New Zealand Core Values	7
2.0 Ecological Risk Analysis	8
2.1 Likelihood.....	9
2.1.1 Maori cultural and spiritual subcomponents	Error! Bookmark not defined.
2.2 Consequence	10
2.3 Risk Estimation	13
2.4 Uncertainty.....	14
2.4.1 Biology and Ecology	14
2.4.2 Vectors	14
2.4.3 Impacts	14
2.5 Risk Description.....	15
References	17

1.0 Background

The clubbed tunicate, *Styela clava* (*Styela*) (sea squirt), has been detected at Lyttelton Harbour (Christchurch), Waitemata Harbour (Auckland), and the Hauraki Gulf (Waiheke I., Mahurangi, Wilson Bay).

Specimen records from Waitemata Harbour and nearby areas of Hauraki Gulf suggest that *Styela* has been present in New Zealand waters since at least 2002 (B. Hayward, pers. comm.). It is unknown how widely this organism is distributed around New Zealand.

In some portions of its introduced range, *Styela* has caused, and continues to cause, significant environmental and economic impacts through high-density fouling of commercial equipment, competition with native and farmed species for resources (i.e., food and space), and overgrowth of shellfish. Given this invasion history, *Styela* may pose a serious threat to New Zealand's marine ecosystems, biodiversity, and aquaculture industry. The preliminary organism impact assessment (OIA) presented here is aimed at providing managers and decision-makers with an evaluation of the potential threats *Styela* poses to New Zealand's environmental, economic, social, and cultural core values.

1.1 *Styela clava* Herdman, 1881

Kingdom: Animalia
Phylum: Chordata
Subphylum: Tunicata
Class: Ascidiacea (sessile tunicates)
Order: Pleurogona
Family: Styelidae

Styela is a member of the subphylum Tunicata—filter-feeding invertebrates with a free-swimming larval stage. These larvae exhibit the four characteristics of chordates (notochord, dorsal nerve cord, pharyngeal “gill” slits, and a post-anal tail), demonstrating an evolutionary relationship with the three other chordate subphyla (lancelets, hagfish, and vertebrates). *Styela* belongs to class Ascidiacea, comprised of sessile tunicates; their free-swimming larvae attach to an underwater surface, and spend the duration of their lifespan anchored to the settling site.

Styela is a tough, leathery club-shaped organism that grows up to 160 mm long. It has an elongated cylindrical body on top of a stalk of variable length. It can be brownish-white, yellowish-brown or reddish-brown. The body has visible rounded swellings on the upper portion and rounded longitudinal ridges on the lower half.

1.1.1 Biology and Ecology

Habitat Preference: *Styela* is apparently a secondary fouling species, preferentially settling on surfaces already encrusted with other organisms; experiments demonstrated larval settlement on test panels submerged for more than 3 months, and only on surfaces bearing a well developed biota (Holmes 1976).

On natural substrates such as algal fronds, peat, rocks, stones, mussels and oysters (Buzier 1980; Minchin & Duggan 1998; Lützen 1999), *Styela* tends to attain densities of 50–100 individuals/m² (Lützen & Sorensen 1993; Minchin & Duggan 1998). However on artificial substrates in docks, aquaculture farms and sluice walls it has been shown to attain densities of 500–1000 individuals/m² (Holmes 1976; Sandee et al. 1980; Minchin & Duggan 1998). Lambert & Lambert (1998) reported that non-indigenous ascidians often form the dominant component of the sessile filter-feeding invertebrate fauna on many harbour and marina structures.

Predominantly a littoral species, *Styela* has been observed as deep as 40 m (Dauvin et al. 1991), and up to 30 cm above the extreme low water spring tide level, when situated under rocks (Holmes & Coughlan 1975). It typically occurs in subtidal areas shielded from wave action, to a depth of 15–25 m (Abbot & Johnston 1972; Buzier 1980), being especially abundant 10–200 cm below the sea surface on floating structures such as pontoons (Lützen 1999). *Styela*'s local distributions tend to be patchy (Berman et al. 1992; Cohen et al. 2000; Davidson et al. 2005)

Environmental Tolerances: *Styela* can withstand a great temperature range: 2–23 °C in the laboratory (Holmes 1969), and 10–23 °C in the field (Hobsons Bay, Australia; Holmes 1976). More extreme values were observed in the Eastern Scheldt, Belgium, with a range of -2 to 22 °C. Even though *Styela* is able to withstand low temperatures, growth is slow, if not arrested, below 5 °C (Lützen 1999). *Styela* are capable of surviving in and salinities of 20–32 ppt, and can withstand fluctuations beyond these ranges (Holmes 1976; Christiansen & Thomsen 1981; Lambert & Lambert 1998; Lützen 1999).

Reproduction and Growth: *Styela* requires water temperatures of at least 10 °C to reproduce (Parker et al. 1999). In Canada, Davidson et al. (2005) did not see larvae in the water column until the water temperature reached 15 °C. Although Parker et al. (1999) observed peak spawning once the water temperature had reached 17 °C, they noted that ripe ova were observed in late February, indicating that gonad maturation must have occurred below 8 °C. However, they went on to tentatively conclude that spawning is the only temperature-dependent process in the reproductive cycle of *Styela*.

Embryonic and larval development occur in temperatures from 15–18° C (Parker et al. 1999). The larval stage is relatively short, lasting approximately 24 hours, and the embryos are believed to not be buoyant. Most larvae released from an individual settle within a short distance of the parent (≤ 10 m; Grosberg 1987; Stoner 1990).

Styela grow rapidly, however there is a great deal of geographic variability in 1) the age/size at which reproductive maturity occurs (2 months, 25 mm, Prince Edward Island, Canada; 7 months, 75–95 mm, Denmark), 2) spawning frequency (apparent maximum is every 24 h), and 3) length of reproductive season (5–10 mos.). There is no clear pattern in the geographic variation of these traits, making it difficult to generalize about *Styela*'s life-history characteristics. Adults have no known predators (Holmes 1976; Lambert & Lambert 1998; Lützen 1999; J. Davidson, pers. comm.), and documented lifespans are 15 months (England; Holmes 1976) and 2–3 years (California, USA; Lambert & Lambert 1998).

1.1.2 International Distribution

Native to the North Western Pacific, *Styela* has been introduced to various locations in the Northern hemisphere including the English Channel, the Irish Sea, New England, the Baltic Sea, and Nova Scotia (Lützen 1999). In the Southern Hemisphere it has been introduced to Victoria, Australia (Port Philip Bay).

Styela's discontinuous geographic distribution must be explained by accidental transfer (Lützen 1999). For example, circumstantial evidence suggests that *Styela* was introduced to the South of England by vessels returning from the Korean War in 1952 (Coughlan 1969). Coughlan (1985) and Minchin & Duggan (1988) both presumed the isolated *Styela* populations in Ireland, western England, and Bretagne to have been introduced on hulls of coastal tankers and ferries. The California population of *Styela* is believed to have established in the 1920's, either through transport on ship hulls, in ballast water, or inadvertently with the importation of oysters (*Crassostrea gigas*) from Japan (Lambert & Lambert 1998).

1.2 Pathways and vectors of introduction

Primary pathways for *Styela* transport and introduction are international shipping, international yachting, and aquaculture. Vectors specific to these pathways include hull fouling (transport and subsequent spawning of attached individuals), shellfish (aquaculture translocations of *Styela*-fouled oysters), and ballast water (transport and release of larvae) (Lützen 1999).

Hull fouling is considered the most common vector for this taxon, given that retention time for ballast water usually exceeds *Styela*'s window for larval settlement (12–28 h), and that differences in water temperatures between offshore and port environments can act as a spawning cue for hullbound individuals (Lambert & Lambert 1998, and references therein; Lützen 1999; Minchin & Gollasch 2003). It is still not known whether a rheophobic species like *Styela* can survive on ships in continuous service (Lützen 1999). Until 1999 the only record from a ship's hull was from a vessel moored for almost a year in Cork Harbour (Minchin & Duggan 1988).

Styela is believed to have been transferred with aquaculture stock and equipment. Minchin & Duggan (1988) suggest it may have been transferred to Ireland by attachment to imported Pacific oysters (*C. gigas*). The initial report of *Styela* in Denmark came from an oyster bed where spat from the English Channel (an area where *Styela* are known to reside) were previously re-laid. The Danish population may have also derived from imported Pacific oysters from California. Any fouled artificial substrate has the potential to be colonized by *Styela*, and mobile gear/structures left submerged in an affected area are potential vectors for the species.

Styela can also be transported through natural means. It is believed that the isolated populations of the southeast North Sea became established by drifting on *Sargassum muticum* (Lützen 1999). This alga, to which *Styela* frequently attaches, becomes detached from the holdfast towards the end of its growth cycle and can float some considerable distance. *S. muticum* is not found in New Zealand waters, however a close relative (*S. verruculosum*) is found in the South Island around Banks Peninsula.

1.2.1 Pathways and vectors—New Zealand

Aquaculture stock and equipment are typically not imported to New Zealand from regions where *Styela* is known to occur, hence international shipping and yachting are the likely pathways of the New Zealand incursion. Given the relatively

low likelihood of *Styela* persisting in ballast tanks, and that New Zealand regulates ballast water exchange for international vessels entering the country, hull fouling appears to be the tunicate's primary vector to New Zealand.

Currently, there exists no national-level hull fouling regulation of vessels entering New Zealand; Ministry of Agriculture and Forestry (MAF) inspectors can recommend that a vessel have its hull cleaned, but this is not compulsory. As such, the arrival of *Styela*-fouled vessels from abroad provide opportunities for the further introduction of this species to New Zealand.

1.3 Establishment

Styela seems to be well-established in the Hauraki Gulf (present since at least 2002), and the likelihood of this tunicate persisting in other areas of New Zealand appears to be extremely high: the temperature and salinity ranges within New Zealand's marine waters broadly overlap *Styela*'s environmental tolerances, and based on monthly water temperatures (Coakley 1970; Grieg *et al.* 1988), successful spawns may be expected to occur in Lyttelton between November and April, and potentially year-round in Hauraki Gulf. Spawning of *Styela* on fouled hulls is the likely source of both the Hauraki Gulf and Lyttelton Harbour incursions, as differences in water temperatures between offshore and port environments can act as a spawning cue for hullbound individuals (Lambert & Lambert 1998, and references therein; Lützen 1999; Minchin & Gollasch 2003).

1.4 Spread

Styela larvae are free-swimming, but weakly so, and their local spread is largely influenced by hydrodynamics (Holmes 1976; Borque *et al.* 2005 and references therein). Local dispersal is generally gradual and is not considered a primary means by which *Styela* may spread beyond areas of introduction (Lambert & Lambert 1998).

Spread to other areas in New Zealand is possible via several vectors:

- Although New Zealand regulates ballast water exchange for international vessels entering the country, no such standards exist for internal movements; ballast water uptake from an affected area and subsequent discharge < 24 h later may introduce viable *Styela* larvae to an unaffected port.
- *Styela* larvae may settle on a variety of potential transport vectors (ships, equipment, conveyances), most typically those with macrofouling; larvae may also settle on apparently unfouled aquaculture stock and gear. Translocating objects on which larvae have settled is a likely means of further spread, via subsequent maturation and spawning of individuals. Translocation of objects fouled with reproductive adult *Styela* poses similar opportunities for spread.
- Facilities processing shellfish fouled by *Styela* may release viable individuals via operational discharge. Effluent draining onto marine waters may introduce *Styela* into previously uncolonized areas.

- Arrival of *Styela*-fouled international vessels provides continuing opportunities for further establishment of this species. Multiple introductions within a given area can 1) increase the probability that a population will become established, 2) buffer an established population against extinction, via recruitment, and 3) be a source of additional genetic variation, with which populations may better adapt to introduced areas (Rouget & Richardson 2003, and references therein; Kolbe *et al.* 2004); these points also apply to the transport of *Styela* within New Zealand.
- Patterns of vessel movements into and within New Zealand are poorly known, as are the relative risks of hull fouling posed by various sectors.

1.4.1 Population Growth

Throughout its distribution, *Styela* has demonstrated different patterns of population growth. In some areas, populations have not spread and remain isolated (since 1972 in Hobson's Bay, Australia, and 1973 in San Diego Bay, USA; Holmes 1976, Lambert & Lambert 1988). A gradual spread was observed on the South Coast of England, where it was over 15 years before *Styela* was reported outside this region (Coughlan 1969).

In less than ten years after its initial introduction to the United States (1973, Long Island Sound, New York), *Styela* had spread over a broad geographic area, from Connecticut to Maine (Berman *et al.* 1992). Dense monocultural strands containing thousands of individuals occur at many sites in New England, yet apparently identical nearby habitats have very few or no *Styela* (Berman *et al.* 1992).

A small population was observed in a Netherlands harbour in 1974, remaining in isolated locations until large populations suddenly appeared two years later (Christiansen & Thomsen 1981). From that time, the species spread throughout the area, achieving population densities of up to 500 individuals/m² on artificial substrates. This is possibly the first observation of explosive development of a *Styela* population after its initial introduction.

In Prince Edward Island (PEI), Canada, *Styela* was first recorded in the Brudenell River in January 1998 (Bourque *et al.* 2005), and in 2001 underwent a population explosion, growing in dense clumps of up to 1000 individuals/m² on docks, buoys, and other hard surfaces (Fisheries and Oceans Canada 2002).

1.5 New Zealand Core Values

All non-native species alter the dynamics of ecosystems to which they are introduced (Cohen *et al.* 2000, and references therein). The magnitude and extent (e.g. spatial, temporal) of change depends upon biotic and abiotic characteristics of the receiving environment, and the ecology and life-history of the introduced species (Mack *et al.* 2000; Sakai *et al.* 2001). *Styela*'s potential effects are considered with respect to the five outcomes outlined in The Biosecurity Strategy for New Zealand (Biodiversity Council 2003): Environmental, Commercial, Maori cultural and spiritual values, Human health, and Social. The basic elements of the core values (outcomes) are:

- Environmental—the biological and physical characteristics of an ecosystem, such as biodiversity, endangered species, and protected areas.
- Commercial—ecosystem elements that provide a current or potential economic gain or loss, e.g. industry infrastructure, fishing areas.

- Maori cultural and spiritual values—ecosystem elements that comprise marine fishing/harvest areas and sacred places, influence quality of life, etc.
- Human health—elements of the ecosystem that may impact aspects of human health such as mortality, morbidity, disability, quality of life, and lifespan.
- Social—ecosystem elements that influence aesthetic and recreational use, e.g. through iconic significance or local sense of value.

The subcomponents of these core values relevant to *Styela* can vary spatially, temporally, and among stakeholder groups; as the risk analysis process is iterative, these components should be re-evaluated as the OIA is revised. Based on our initial review of *Styela*'s biology, ecology, and invasion history, we identified core value subcomponents that the organism may impact (Table1).

Table 1. Core value subcomponents potentially impacted by *Styela clava*.

Core Value	Subcomponent	Description
Environmental	Biodiversity	Flora and fauna that exist in a given area
	Habitat	Biotic and abiotic structures that provide habitat for flora and fauna
	Protected areas	Marine reserves—biotic and abiotic components; intrinsic value
	Protected species	Marine wildlife—seabirds, reptiles, coral, fish, and mammals
	Trophic interactions	Energy flow within an ecosystem; food webs; predator-prey relationships
Commercial	Aquaculture	Shellfish and salmon farming
	Vessels/moorings	Maintenance/cleaning costs
Maori cultural & spiritual	Mataitai, taiapure, kaimoana	Traditional fishing grounds, local fisheries, seafood
	Taonga	Treasured species/resources
	Kaitiakitanga	Environmental stewardship
	Manaaki tangata	Obligation to care for guests
	Mana	Sense of identity, pride, strength of spirit
Human health	Morbidity	Asthma; personal injury
Social	Aesthetics/diving	Natural character of an area; status as a dive destination
	Recreational harvest	Public fishing, collecting species

2.0 Ecological Risk Analysis

Ecological risk analysis is the process of evaluating the likelihood of an organism's impact, identifying the potential consequences, determining risk, and assessing uncertainty. Each of these elements can be addressed using qualitative, semi-quantitative, or quantitative methods, or a combination thereof—the specific approach used depends upon data quality and availability, and/or the level of detail

required. In this initial analysis, we employ a qualitative approach (categories of likelihood, consequence, and risk) given the relative lack of data on *Styela*.

2.1 Likelihood

Likelihood is the probability of an impact occurring. Herein, we express likelihood under five categories (Table 2).

Table 2. *Styela* assessment likelihood categories.

Likelihood	Description
Highly Unlikely	Impact may occur only in very rare circumstances
Unlikely	Impact could occur in some circumstances, but is generally not expected to
Possible	Impact could occur
Likely	Impact could occur in most circumstances
Almost certain	Impact is expected to occur in most circumstances

Based on *Styela* background information, we assigned likelihoods of the organism's potential impact on core value subcomponents (Table 3), and identified possible mechanisms of effect (Section 2.2).

Table 3. *Styela* assessment likelihood categories. Maori cultural and spiritual subcomponents are addressed in Section 2.1.1

Subcomponent	Likelihood
Biodiversity	Possible — <i>Styela</i> has demonstrated the potential to reduce local biodiversity, but impacts vary geographically.
Habitat	Possible — <i>Styela</i> can overgrow biotic & abiotic structures, but the degree to which this occurs varies geographically.
Protected areas	
• Biotic & abiotic components	Possible —A function of potential effects on biodiversity and habitat structure/composition.
• Intrinsic value	Possible — <i>Styela</i> will affect the integrity of marine reserves by simply being present.
Protected species	
• Corals, spotted black grouper	Possible —A function of potential effects on habitat structure/composition, biodiversity, and trophic interactions.
• Seabirds, marine reptiles and mammals	Highly Unlikely — <i>Styela</i> 's effects are not expected to propagate at an ecosystem level and impact upon these taxa.
Trophic interactions	Possible — <i>Styela</i> predation on plankton may alter resource availability and use for other organisms.

Aquaculture	Likely —Has an invasion history (Canada), and is exhibiting similar behaviours in the Hauraki Gulf (Waiheke Is.).
Vessels/moorings	Highly Unlikely — <i>Styela</i> fouling of vessels and moorings is not expected to be a maintenance issue.
Maori cultural & spiritual Morbidity	Possible —A function of potential effects on the ecosystem elements upon which Maori values are based.
• Asthma	Highly Unlikely —Potential human health impact on shellfish processors only under very specific conditions.
• Personal injury	Possible —Added weight of <i>Styela</i> on aquaculture gear may cause lifting-related back strain.
Aesthetics/diving	Possible —A function of potential effects on biodiversity and habitat structure/composition.
Recreational harvest	Possible —A function of potential effects on biodiversity and habitat structure/composition.

2.2 Consequence

Consequence is “the adverse outcome or impact of an event” (Australian Government Department of Health and Ageing 2005). We reviewed existing literature on *Styela*’s biology and ecology (Section 1.0, and references therein) to identify the tunicate’s potential effects on New Zealand core values. Possible impacts include:

- Biodiversity
 - *Styela* is capable of forming monospecific stands on natural substrates, potentially outcompeting native taxa for space. “Blankets” of *Styela* may reduce habitat (substrate) complexity, in turn reducing biodiversity.
 - Large solitary ascidians such as *Styela* have high filtration rates, and may outcompete native filter-feeders for phytoplankton and/or zooplankton.
- Habitat
 - Monospecific aggregations may alter habitat quality and/or availability for other encrusting organisms.
- Protected areas
 - *Styela* may affect the integrity of marine reserves by reducing local biodiversity (through predation, competition), changing habitat structure (e.g., monospecific aggregations), or by simply being present.
- Protected species
 - *Styela* may compete with black corals (Order Antipatharia) and red corals (Order Corallidae) for food and space. *Styela* could reduce local biodiversity (through predation, competition) and change habitat structure (e.g., monospecific aggregations), potentially impacting on spotted black grouper (*Epinephelus daemeli*). If *Styela* alters trophic interactions at an ecosystem level, effects could cascade to seabirds, marine mammals, and marine reptiles.
- Trophic interactions

- *Styela* may alter the composition, distribution, and abundance of species in an ecosystem (via predation, competition), and thus alter energy flow. The likelihood of such trophic impacts and their potential mechanisms have yet to be identified.
- Aquaculture
 - *Styela* is capable of fouling gear and stock to a degree where handling times are increased and control efforts necessary, thus increasing operational costs. There is the potential for diminished returns due to poorer condition and increased discards of fouled stock.
- Vessels/moorings
 - *Styela* is not expected to cause any impacts beyond those typically associated with biofouling organisms (e.g., increased drag).
- Maori cultural & spiritual
 - *Styela*'s potential effects on habitat structure and biodiversity may directly or indirectly impact upon *taonga* and/or *kaimoana*. These impacts may ultimately influence iwi or hapu *manaaki tangata* and *kaitiakitanga* obligations, as well *mana*.
- Morbidity
 - Workers cleaning *Styela*-fouled shellfish in poorly ventilated conditions may develop an asthmatic condition.
 - Added weight of *Styela* on gear can cause lifting-related back strain.
- Aesthetics/diving
 - *Styela* may affect the integrity of dive destinations by reducing local biodiversity (through predation, competition) and changing habitat structure (e.g., monospecific aggregations), potentially reducing aesthetic value.
- Recreational harvest
 - *Styela* may alter the abundance and distribution of harvested species through predation, competition, etc.

Determining consequence involves evaluating the degree and rate of change, type of change, spatial and temporal extent of impact, potential cumulative effects, and reversibility (Australian Government Department of Health and Ageing 2005). Based on these considerations, we defined different degrees of consequence (Table 4) and then determined the level of *Styela*'s potential effects on core value subcomponents (Table 5).

Table 4. Categories of *Styela* consequence assessment. These categories are neither exclusive nor limiting; level of consequence can vary on the basis of duration, level of impact, and reversibility of changes (see section 2.5, Risk Description).

Consequence	Description
Insignificant	Minimal or no impact
Minor	Disruption to a core value subcomponent, but reversible and/or limited in time and space, or severity
Moderate	Widespread disruption to a core value subcomponent, but reversible or of limited severity or duration
Major	Extensive disruption to a core value subcomponent that persists over time or is not reversible

Table 5. Consequences of *Styela* effects on core value subcomponents.

Subcomponent	Consequence
Biodiversity	Insignificant to Moderate —May reduce local biodiversity, but tends to have a patchy distribution.
Habitat	Insignificant to Moderate —Can overgrow biotic & abiotic structures, but tends to have a patchy distribution.
Protected areas	
<ul style="list-style-type: none"> • Biotic & abiotic components 	Insignificant to Moderate —A function of biodiversity and habitat consequences; by virtue of competing with native species for space and food and/or altering habitat structure/availability, could reduce the conservation value of an area.
<ul style="list-style-type: none"> • Intrinsic value 	Minor to Major —May compromise the integrity of protected areas by simply being present.
Protected species	
<ul style="list-style-type: none"> • Corals 	Insignificant to Major —May reduce abundance and distribution through competition for space and food.
<ul style="list-style-type: none"> • Spotted black grouper 	Insignificant to Major —May reduce abundance and distribution by overgrowing key habitat and shifting trophic relationships/dynamics of prey species.
<ul style="list-style-type: none"> • Seabirds, marine reptiles and mammals 	Insignificant to Minor —At an ecosystem level, may alter trophic relationships that could ultimately influence the distribution of these taxa. Littoral-pelagic coupling likely to be weak, and/or limited in spatial scale.
Trophic interactions	Insignificant to Moderate —Large aggregations may alter local resource availability. Cumulative effects of introduced ascidians and other filter-feeders may cause a shift in trophic structure towards an ecosystem dominated by epibenthic/benthic biomass rather than pelagic biomass.
Aquaculture	Major —Extensive macrofouling of gear and stock increase operational costs (handling, maintenance and control efforts), and can cause diminished returns due to poorer condition and increased discards of fouled stock. Infestations not known to be reversible.
Vessels/moorings	Insignificant —Not an aggressive primary macrofouling organism; would not necessitate frequent/extra maintenance.
Maori cultural & spiritual	Insignificant to Major — May reduce abundance and distribution of treasured and key seafood species, in turn potentially compromising ability to meet social obligations. May compromise sense of spirit by simply being present.
Morbidity	
<ul style="list-style-type: none"> • Asthma 	Moderate —This is an arbitrary assignment of a median value, given a lack of information on the severity and duration of asthmatic condition.
<ul style="list-style-type: none"> • Personal injury 	Moderate —This is an arbitrary assignment of a median value, given a lack of information on the severity, duration, and frequency of back strain/injury.

Aesthetics/diving	Insignificant to Minor —May reduce local biodiversity and change habitat structure, but tends to have a patchy distribution.
Recreational harvest	Insignificant to Moderate —A function of potential effects on biodiversity and habitat structure/composition.

2.3 Risk Estimation

Risk is determined by comparing the likelihood of an event against its consequences—these potential combinations are typically represented in a risk matrix (Table 6).

Table 6. Example risk matrix. Letters represent risk level for a given consequence–likelihood combination: N = negligible, L = low, M = moderate, H = high, E = extreme.

Likelihood	Consequence			
	Insignificant	Minor	Moderate	Major
Highly unlikely	N	L	L	M
Unlikely	N	L	M	H
Possible	N	L	M	H
Likely	N	M	H	E
Almost certain	N	M	E	E

We characterized *Styela*'s risk to subcomponents of New Zealand core values based on the combinations of consequence and likelihood defined in Sections 2.1 and 2.2, respectively (Table 7).

Table 7. The risk *Styela* poses to core value subcomponents. For subcomponents with a consequence range (e.g., Low to Moderate), the higher level of risk was used to determine cell colour. Risk is characterized as N = negligible, L = low, M = moderate, H = high, E = extreme, based on consequence–likelihood combinations (Table 6).

Subcomponent	Risk
Biodiversity	Negligible to Moderate
Habitat	Negligible to Moderate
Protected areas	
• Biotic & abiotic components	Negligible to Moderate
• Intrinsic value	Low to High
Protected species	
• Corals	Negligible to High
• Spotted black grouper	Negligible to High

<ul style="list-style-type: none"> • Seabirds • Marine reptiles • Marine mammals 	Negligible to Low
Trophic interactions	Negligible to Moderate
Aquaculture	Extreme
Vessels/moorings	Negligible
Maori cultural & spiritual	Negligible to High
Morbidity	
<ul style="list-style-type: none"> • Asthma • Personal injury 	Low
	Moderate
Aesthetics/diving	Negligible to Low
Recreational harvest	Negligible to Moderate

2.4 Uncertainty

Uncertainty evaluation is used to estimate risk and identify data gaps. The fundamental uncertainties surrounding *Styela* are epistemic—a lack of knowledge of the biology, ecology, and potential impacts of the organism. Of those data that do exist, most demonstrate some degree of variability (aleatory uncertainty).

2.4.1 Biology and Ecology

Apparently little is known of *Styela* in its native distribution, and most of this information is in Korean, Japanese, and Russian publications. *Styela* demonstrates idiosyncratic behaviour across its introduced distribution, ranging from a relatively low-density, nonprolific organism (Australia) to an aggressively-growing pest of aquaculture operations (PEI); the mechanism of this variability has yet to be identified, and may involve elements such as the biotic and abiotic characteristics of the receiving environments. The variability of *Styela*'s life-history traits makes prediction of its growth and spread very difficult. The community ecology of *Styela* has been subject to some study, however the majority of this work has occurred in the Northeast US (e.g. Berman *et al.* 1991; Osman *et al.* 1989; Osman & Whitlatch 1999) and has focused primarily on epifauna.

2.4.2 Vectors

BNZ's current research programme is focused on profiling the hull fouling risks posed by international vessels entering New Zealand, however this work is in progress, and data are not yet available. At present, there are no detailed data on vessel movement histories or the relative risk that different sectors (e.g. commercial shipping, commercial fishing, yachting) may pose. Few data exist on the patterns of vessel movements within New Zealand waters.

2.4.3 Impacts

Geographic variation in *Styela*'s biology, ecology, and observed impacts make it difficult to predict with any certainty how this ascidian may affect New Zealand's core values (Environmental, Commercial, Maori cultural and spiritual values, Human health, and Social). The ecosystem elements upon which Maori cultural and spiritual values are based can vary regionally among hapu (sub-tribes) and iwi (tribes), therefore *Styela*'s impacts can be expected to vary accordingly.

The fundamental uncertainties about *Styela*'s potential impacts are the organism's life-history and ecology within New Zealand, the variability surrounding these, and the identity of ecological endpoints that link to specific aspects of core values (e.g. What are key taonga species? Which ecosystem elements are important influences on recreational diving?).

2.5 Risk Description

Risk description is the process of evaluating the lines of evidence supporting or refuting the risk estimates. For each of the core value subcomponents, we consider data quality and availability, degree and type of uncertainty, and the potential significance of adverse effects:

- Biodiversity (Negligible to Moderate)

Styela has demonstrated the potential to reduce local biodiversity, but data are lacking on the scale (spatial and temporal), magnitude, and mechanism of impacts. Although *Styela* may outcompete native taxa for food and space, the physical structure of the organism may provide habitat for epibionts (some of which may be invasive species), therefore increasing local biodiversity. The community- and ecosystem-level effects of *Styela* are largely unknown. Overall, available information suggests *Styela* could impact upon biodiversity; given the geographic variation in its growth patterns (e.g. forming dense monospecific stands on natural substrates in New England vs. a low-density, scattered distribution in Port Philip Bay) and patchy local distributions, consequence may range from insignificant to moderate (limited distribution and/or severity).

- Habitat (Negligible to Moderate)

Styela can attain high densities on biotic and abiotic structures, but aggregations tend to be patchy and the degree to which this occurs varies geographically. Mats of *Styela* may alter habitat quality and/or availability for other organisms, but these potential impacts remain poorly known. The physical structure of the *Styela* may provide habitat for epibionts, some of which may be invasive species. It is possible that *Styela* will impact upon habitats in New Zealand, and given the geographic variation in its growth patterns and patchy local distributions, consequence may range from insignificant to minor (limited distribution and/or severity).

- Protected areas

- Biotic & abiotic components (Negligible to Moderate)

Although introduced populations of *Styela* demonstrate an affinity for anthropogenic structures, it is possible the ascidian will become established in New Zealand protected areas. *Styela* may alter habitat quality and availability, and its impacts on biodiversity are essentially unknown; given the degree of uncertainty around these potential effects and the potential extent of its spatial distribution, consequences to protected areas may range from insignificant to moderate.

- Intrinsic value (Low to High)

Styela may affect the integrity of marine reserves by simply being present, in which case consequence could range from minor to major (depending upon geographic extent and reversibility).

- Protected species

- Corals, spotted black grouper (Negligible to High)

It is possible that *Styela* may compete with black and red corals for food and space. *Styela* may also impact on spotted black grouper as a function of potential effects on habitat structure/composition/availability, biodiversity, and trophic interactions. There's no information on the degree to which *Styela* may affect corals or predatory reef fish, hence consequences may range from insignificant to major.

- Seabirds, marine reptiles and mammals (Negligible to Low)

Styela's effects are not expected to propagate at an ecosystem level; if this were to occur, trophic linkages would likely be weak and/or limited in spatial scale (with respect to the taxa of interest), and consequences insignificant or minor.

- Trophic interactions (Negligible to Moderate)

Styela predation on plankton may alter resource availability and use for other organisms, and thus alter energy flow. It is possible such trophic impacts could occur, but the potential magnitude and extent of the consequences remain unknown; given *Styela*'s local distributions tend to be patchy, major consequences (extensive spatial distribution and disruption to a core value subcomponent) seem unlikely to occur, hence consequence could range from insignificant to moderate.

- Aquaculture (Extreme)

Given that *Styela* is fouling some aquaculture operations on and around Waiheke Is. in a similar manner as to the PEI invasion, it is likely that the ascidian will impact upon New Zealand aquaculture industry. *Styela* poses potentially major consequences— biofouling could become widespread and persistent, with significant impacts on the shellfish industry through increased costs (maintenance, handling) and decreased yields (e.g., via competition for space).

- Vessels/moorings (Negligible)

Although it is possible *Styela* may impact upon vessels and moorings, consequences will probably be negligible. *Styela* is not expected to cause any impacts beyond those typically associated with biofouling organisms (e.g., increased drag); it is not an aggressive primary macrofouling organism, will not likely necessitate frequent or extra maintenance.

- Maori cultural & spiritual (Negligible to High)

Styela has demonstrated the potential to reduce local biodiversity and alter habitat quality and/or availability for other organisms. It is possible *Styela* may directly or indirectly impact upon *taonga* (treasured species) and/or *kaimoana* (seafood), in turn potentially affecting the *manaaki tangata* obligations of a hapu or iwi. Presence or impacts of *Styela* may also influence *mana*, as well as *kaitiakitanga* obligations. Because of the potential variability in the ecological endpoints upon which Maori cultural and spiritual values are based, and variability in the magnitude and extent of *Styela*'s biodiversity and habitat effects, consequences may range from insignificant to major.

- Morbidity

- Asthma (Low)

Potential human health impact on shellfish processors is known to occur under only under very specific conditions, and is highly unlikely to manifest in New Zealand. Information is lacking on the severity and duration of the condition; as such, our arbitrary assignment of a median consequence level indicates low risk.

- Personal injury (Moderate)

Davidson (pers. comm.) reports an increased incidence of back-related injuries among labourers handling *Styela*-fouled gear, and similar trends are possible in New Zealand. Information is lacking on the severity and duration of the condition; as such, our arbitrary assignment of a median consequence level indicates moderate risk.

- Aesthetics/diving (Negligible to Moderate)

Styela can possibly affect aesthetics as a function of influences on biodiversity and habitat structure/composition. Consequences to aesthetics will be governed by the magnitude of effect (e.g. reduced biodiversity, area covered by monospecific aggregations); given the generally patchy local distributions of *Styela* elsewhere, consequence may range from insignificant to moderate.

- Recreational harvest (Negligible to Moderate)

Styela can possibly affect recreational harvest as a function of influences on biodiversity (e.g. predation, competition) and habitat structure/composition. Consequences will be governed by the magnitude of effect (e.g. reduced biodiversity, area covered by monospecific aggregations); given the generally patchy local distributions of *Styela* elsewhere, consequence may range from insignificant to moderate.

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