<u>Potential for rapid recovery of eelgrass *Zostera marina* from short-term damage: a review</u>

<u>Summary</u>

Concerns have been raised about possible damage to Eelgrass (*Zostera marina)* from anchoring by leisure vessels. Eelgrass is on the IUCN Redlist, in the category of Least Concern, and not in a threatened category. It is widely distributed in the northern hemisphere. There appear to be few or no reports of significant anchor damage to eelgrass in the scientific literature. A brief review of published reports of mortality and recovery of eelgrass from various causes showed a distinction between damage from long-acting (over a year) threats, which can cause serious and long-lasting declines, and short-acting threats which can be followed by rapid recolonisation. Four studies of short-acting damage found substantial or complete regrowth from seedlings in a year or less. A study in which all shoots and rhizomes were raked out from 2m square plots (4 sq m) found rapid growth initiation and full recovery in two years by rhizome growth from the adjacent undisturbed eelgrass bed. It is argued that damage from anchoring , which is a short-acting event, might be repaired by regrowth from seed or by rhizome spread, and these mechanisms can account for the lack of reports of eelgrass damage from anchoring.

An appendix to the review considers published evidence relating to eelgrass re-colonisation in Studland Bay, contained in a report by Collins et al.

<u>Introduction</u>

The seagrass *Zostera marina*, common name eelgrass, is under consideration for conservation measures as the process to establish British Marine Conservation Zones continues.

The typical eelgrass habitat is on a sandy or muddy seabed in shallow and sheltered waters, conditions which also provide favourable anchorages for boats. Concern has been expressed that anchoring might be harmful to eelgrass, although the author is not aware of any paper in the extensive scientific literature on *Zostera marina* which describes significant damage to eelgrass due to anchoring. Many causes of serious eelgrass mortality are reported, but these do not include anchoring. Anchor damage to the seagrass *Posidonia oceanica* has been described **(1**), but this was to a particularly slow-growing species in a non-tidal habitat. Damage due to the scouring effect of the ground chains of fixed moorings is described in the literature, but this is caused by repeated dragging of a chain across a fixed location with every turn of the tide, for months on end, and is not to be confused with short-term anchoring events. In a number of papers and articles, anchoring is included amongst lists of possible causes of mechanical damage to eelgrass, but on examination is not backed up by actual reports or data.

A study by Collins et al **(2)** describes investigations at one mooring and four anchor scar sites in Studland Bay, Dorset, but as previously discussed by the author **(3)**, it gives no indication of any significant extent of damage to the eelgrass beds as a whole. In fact, local knowledge suggests that those eelgrass beds have been increasing in extent over the past 40 years, despite the bay's continuing use as an important anchorage for leisure vessels over that period **(3)**. Further discussion of Collins et al is given in the Appendix.

The lack of evidence to the contrary could suggest that *Zostera marina* is reasonably robust to anchoring pressures, and the object of this short review is to see if this hypothesis finds support in the published literature.

<u>Conservation Status:</u>

The seagrass *Zostera marina* is listed in the IUCN Red List under the lowest category, that of Least Concern **(4)**. To quote from the listing:

"This species is widespread, circumglobal in the Northern hemisphere. There have been documented localized declines in parts of the range, but not sufficient to warrant placement in a threatened category. *Zostera marina* is listed as Least Concern."

It is widely distributed*:*

"*Zostera marina* is widespread and circumglobal in northern latitudes, found throughout the north Atlantic and north Pacific and in the Mediterranean and Black Seas. *Zostera marina* extends into the Arctic in Alaska, Canada, Greenland, and northern Europe and to the tropics in Baja California, Mexico."

The MarLIN (Marine Life Information Network) entry **(5)** shows wide but patchy distribution around the shores of the British Isles, from the South Coast to the Shetlands, and around Ireland, while the OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic) entry **(6)** shows widespread distribution throughout its area.

In short, although threats to the species clearly exist (below), it is common, widespread and flourishing in many areas. It is not a rare endangered species.

<u>Reproduction and Life Cycle</u>

Eelgrass is a perennial plant but in stressful situations, such as very high summer temperatures, it may act as an annual, re-growing from seed each year. In Britain it is perennial, and reproduces both vegetatively by rhizome growth, and by seed. See, for example, the MarLIN article **(7)**.

It has long (20 to 50 cm, occasionally up to 2m) narrow leaves in summer, which are shed annually and replaced by shorter winter leaves **(8)**. The dense growth (500 – 1300 shoots per sq m) is replaced annually **(9)**. It is noted as a species of high growth productivity.

<u>Threats:</u>

A wasting disease caused massive dieback in the 1930's and it took up to 40 years for substantial recovery. Turbidity of the water reduces light availability and can kill eelgrass. Eutrophication, a process in which excessive nutrient supply, eg nitrates and phosphates, causes excessive growth of algae followed by oxygen depletion, which kills eelgrass both directly, and indirectly through increased turbidity. Pollution can cause direct poisoning as well as oxygen depletion. Dredging and construction works can destroy habitat and increase turbidity. **(6)**

The table below gives some measure of the relative significance of these threats as reflected in published papers. A Google Scholar search was conducted on article titles containing the terms "Zostera marina" and/or eelgrass together with the listed threat, and the number of hits in each category recorded. (The search was restricted to titles as a term in the title indicates that it is central to the paper. The only alternative available to the author was a full text search, which would include citations of other papers, and in which the search term might only be mentioned in passing. For example the full text search for "Zostera marina" and/or eelgrass together with pollution produced over 5000 hits).

Search terms with Zostera marina or eelgrass	**Hits**
Disease	44
Pollution , Anoxia	15
Eutrophication	12
Shading , Turbidity	13
Dredging	4
Anchor, Anchoring	1

(Note: three “hits” for anchor related to the establishment of a single voluntary no-anchor zone, and did not report damage, so were ignored).

Recolonisation Studies:

Most of the above causes of damage or mortality occur over a period of time, often years, resulting in the extensive death of shoots, leaves, roots, rhizomes and the seed bank, and recolonisation can then take a long time. However, a few cases of short term damage and the ensuing recovery have been reported, and these may be relevant to the case of possible anchoring-related disturbance or damage.

Plus, Deslous-Paoli and Dagault **(10)** describe a rapid recolonisation of eelgrass in the Thau lagoon, southern France, following complete destruction in an anoxic crisis, from 1998 to 1999. Biomasses similar to those in unaffected areas were restored within nine months through germination of seeds from the seedbank and rapid vegetative recruitment.

Recolonisation after a red tide algal bloom in 2002, which killed the eelgrass above and below the seabed, is described by Ks Lee et al **(11)**. The site was Jindong Bay in South Korea, and the bed was completely re-established by germination from the existing seed bank in less than a year. In the second year after the event, asexual reproduction occurred through lateral shoot production by rhizome elongation and branching.

Greve, Rasmussen and Christensen **(12)** studied a rapid recolonisation of eelgrass in the summer of 2001 following an anoxia event the previous summer in a Danish estuary. While the two studies mentioned previously were in waters which become warmer in summer than British waters, Danish sea temperatures are similar to those in Britain, albeit colder in the winter. Although healthy-looking roots and rhizomes remained below the seabed surface, 96% of the recolonisation was by seedlings from the seedbank. The study did not cover a second season.

A study in Chesapeake Bay by Jarvis and Moore **(13)** following a large scale decline attributed to unusually high water temperatures (up to 33C) in late summer 2005, found that the beds recovered in 2006 with seedlings providing the major part of the recovery. In the following season, vegetative shoots provided the major part of the crop. However a second decline occurred in some areas in summer 2006 due to low light levels, and recovery in 2007 was minimal in those areas. This was attributed to absence of viable seeds as seeds are not produced until the second year of growth in that area, so the 2006 seedlings did not have the opportunity to produce new seeds before die-back.

Of particular interest in the context of anchoring effects is a study of eelgrass recovery following its mechanical removal carried out by Boese et al **(14)** in a river estuary on the Pacific coast near Newport, Oregon. Sea temperatures there average about 2C cooler than the UK south coast, but the estuary location would probably have warmer water, perhaps similar to the UK south coast. Presumably for reasons of accessibility, the study was carried out in the intertidal zone, near or above the low water line.

The experiment was conducted on 2m x 2m plots, and similar control plots were identified. Each experimental plot was treated by removing all eelgrass shoots and rhizomes by raking with a four-tined garden hoe. (It should be noted that this is a far wider area than any single anchor scar from a small vessel, and involved complete removal of all the eelgrass, not merely dislodgement). The experiment was started in February 2004, and recovery followed by measuring plant shoots at two-monthly intervals until December 2006.

In plots within the permanent eelgrass meadow, recovery started immediately, was substantial within ten months and complete within 24 months. The recovery was from rhizome growth from adjacent perennial eelgrass, and seedlings appeared to play no part. The spread of new growth inward from the edges of one particular plot is shown graphically, and had extended about 25 cm into the plot in 10 months, 50 cm in 16 months, and the full metre into the centre of the plot within 24 months.

(The lack of seedling growth is a significant point of difference from the other four studies mentioned above. It could be speculated that the intertidal zone is not favourable to seedling growth because of disturbance of seedlings by breaking wave and wavelet action in shallow water as the tide rises and falls, and the possibility of fragile seedlings drying out at low water.)

Discussion and Conclusions

Leisure boats have been anchoring in significant numbers in Studland Bay, Dorset, for forty years and more, yet substantial eelgrass beds are still present in the bay, including in the anchored areas. It follows that any damage done by the anchoring process must be reversible, otherwise a steady incremental depletion of the beds would have occurred year on year. That has not happened.

Unlike the known and serious causes of eelgrass mortality listed above, which are often in place for years causing long term lasting damage, a typical anchoring event is short term, from perhaps an hour or two to a day or two, which is why the five studies cited are relevant to anchoring effects, as in each case the cause of the damage (anoxia, red tide, excessive temperature, digging up with a hoe) was in place for a comparatively short period.

Although the damage in each case was extensive in area, much greater than the area of an anchoring event, recolonisation was rapid, substantial within a year or less and largely complete in two. In the four studies of subtidal (permanently submerged) beds, in Southern France, South Korea, Denmark and Chesapeake Bay on the Atlantic seaboard of the USA, seedling growth from the seedbank within the sea bed played a substantial or dominant role in the recovery, which was largely achieved in a year or less. Two of those studies which covered a second year of recovery found that vegetative reproduction (via rhizomes) played a dominant role in the second year.

Those findings suggest that one route to rapid recovery from eelgrass disruption from an anchoring event is the germination of seeds from the existing seedbank. Also, in the case of anchoring, the surrounding eelgrass bed which remains in place will also be able to provide new seeds in due course.

The study in Newport, Oregon, carried out near the low water mark and in which all shoots and rhizomes were removed from 2m x 2m squares using a four-tined hoe, did not find any recolonisation by seedlings, perhaps for the reasons suggested above. Instead, regeneration was from rhizome growth from adjacent undisturbed perennial eelgrass, and the paper includes graphical plots of the growth from the edges to the middle, measured at two-monthly intervals. The growth advanced about 30 cm in the first year and a metre in two years. This rate of rhizome growth is compatible with other reports in the literature.

The anchor blades of leisure vessels are usually between 30 and 40 cm wide, so it is difficult to envisage the setting or retrieval of an anchor causing damage over a width of more than 50 or 60 cm. The Newport, Oregon study suggests that such a width could be completely bridged by rhizome growth from the surrounding area within a year, giving a second available route for rapid recovery.

There seem to be, then two routes, by seed germination or by rhizome growth, which are available to eelgrass to recover across the likely width of possible anchor damage within a year. Seed germination could of course cover a much greater width, depending on the extent of the seed bank, or spread of seed from adjoining plants. These recovery routes could explain the lack of published reports of damage to beds of eelgrass *Zostera marina* caused by leisure boat anchoring. It is noted that re-growth is part of the normal eelgrass life cycle, most or all of the above-seabed biomass being shed and re-grown annually.

It is worth drawing attention to the difference between short-acting and long-acting threats to eelgrass. Long-acting threats such as disease, or sustained (2 seasons or more) pollution or eutrification, can cause grave damage to eelgrass with very long recovery times. Short-acting threats leaving a viable seedbank, and limited-area threats leaving viable adjacent rhizomes, allow recovery over one or two seasons. Disturbance due to anchoring is both short-acting and of limited area, and does not carry the risk of catastrophic collapse of the population. In the event that excessive anchoring pressure is found to be significantly reducing the eelgrass population in a particular area (and it is emphasised again that we are aware of no such reports), then corrective action could be taken to allow rapid re-colonisation through the natural reproductive mechanisms discussed. In this context, talk of the "precautionary principle", which is usually applied when a downside risk of uncertain probability has potentially very serious effects, is not appropriate, since any effects would be area-limited and reversible. Rather, any precaution should be applied against misapplication of conservation focus and resources against what appears at present to be a minor issue having insignificant or minor effects which in any event are readily reversible.

Appendix

The author is aware of only two published studies which address specifically the effects of anchoring on the eelgrass *Zostera marina*. One, a master's thesis by Leatherbarrow (University of Victoria, British Columbia) **(15)**, used towed underwater video mapping to observe the effects on eelgrass beds at two sites over a single season. No visible loss of eelgrass was observed. However, anchoring numbers were considerably lower than in Studland Bay.

The other is the paper by Collins, Suonpaa and Mallinson **(2)** which does refer to re-colonisation at anchor sites in Studland Bay, and so is of direct relevance to this review, and should therefore bear some analysis.

The main thrust of the study was an investigation of the mechanical properties, and the biological content, in bare patches of seabed described as anchoring and mooring scars, and a comparison of these with adjacent areas having eelgrass cover. The study demonstrates clear differences between the bare patches and areas with eelgrass cover. Where it is less clear is in the characterisation of what are described as anchoring scars, and in the reported lack of evidence of re-colonisation.

There is an almost complete lack of information about the number, location and age of the anchor scars, other than the statement that measurements were made at five anchor scar sites (although results for only four are reported). The sites were located by towed video sled and sidescan sonar in 2008 and 2009, suggesting they were pre-existing features, of indeterminate age.

It is not stated how they were identified as anchor scars. Eelgrass meadows are frequently patchy by nature, and bare patches exist, for whatever reason, even in areas where boats do not anchor. The possibility exists that boats could anchor on naturally bare patches and leave anchor marks, particularly as many boat skippers prefer to anchor on a clear bottom if available. In such a case, the bare patch would not have been caused by anchoring. Further, a naturally occurring bare patch is presumably unfavourable for eelgrass growth, so re-colonisation would be less likely.

There are several reports in the literature of damage to eelgrass beds by boats grounding. In the case of motor boats, the use of the propellers to drive the boat off into deeper water could cause considerable damage. In the case of yachts, it would be the keel that affects the seabed, which could happen at any depth less than 2.0 m, or more for large yachts. This could be another cause of bare patches, although the depth of water in which the studies took place is not reported.

The nature and history of the scars thus seem unclear from the information within the report.

The paper reports that sidescan sonar images of the scars before and after winter 2008 to 2009 indicated expansion of the scars but no evidence of re-colonisation during summer 2009 (actual dates not given). This statement seems to be based on sidescan sonar imaging alone, and it should be noted that Montefalcone et al in their 2011 paper **(16)** expressed reservations about the use of sidescan sonar for detailed comparison work, stating that *"Extensive sea-truthing based on a rigorous design is mandatory for efficient acoustic mapping of seagrass meadows".* In other words, sidescan sonar alone is not a reliable tool.

Collins et al **(2)** give no information on their sidescan images, whether the ones shown are depicting echo returns from eelgrass, the seabed, or both. There is no information on detection thresholds for varying densities of eelgrass. Because sidescan sonar measures echo returns, and in shallow water the return beam is at a shallow, oblique angle, higher objects nearer the sonar transducer will prevent returns from lower objects in their acoustic shadow, so shorter growth behind higher growth might not be seen.

So while it is possible that complete recolonisation to full height and shoot density (unlikely in the less than 12 month period of the study) would be detected by sidescan sonar, new growth of lower density might not be detected in the absence of careful calibration of the equipment, while new growth of lower height would be at least partly obscured by surrounding higher growth.

In regard to the statement that the scars appeared to have expanded over winter 2008 – 2009, the issue of the annual leaf shedding is not addressed. If some of the higher summer growth was present during the earlier scan, the "holes" in the growth would seem smaller as the higher growth would spread outwards to partially cover them. At the end of the winter, only short winter growth would be left, so the holes would appear larger to the sonar scan.

Update and correction, December 2012: After an exchange of correspondence, Dr Collins assures the author that ground truthing was carried out in this phase of the work:

"I can assure you that my sidescan observations on the scars were all ground truthed by diving in 2008, 2009 and 2010 using metal pegs around the perimeter to detect change in the margin. The 2010 observations are after publication of my paper and have not been published. The expansion trend reported continued."

The reservations expressed in in the four paragraphs above this update were written on the basis of material disclosed in the original paper, but should now be read in the light of Dr Collins' assurance.

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