



Shellfish  
Association of Great Britain

Provisional Review and Advice of Cockle Management in the Burry  
Inlet

Report to the Environment Agency from the Shellfish Association of Great Britain

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## Aim of this report

This report was commissioned by Environment Agency fishery managers to inform their short-term decision making in the management of the Burry Inlet cockle fishery. The report aims to review traditional and current management actions and to provide the rationale behind them and to provide an indication of risk and benefits of their application.

## Background and history

Evidence of cockle gathering in the Burry Inlet traces the fishery back to the Mesolithic period with records of shell middens from archaeological excavations on the surrounding shores. An organised commercial fishery has existed on both shores of the Burry Inlet from Roman times continuing through the middle ages.

The fishery was traditionally carried out by women using a rake and riddles much like those employed today gathering between 100-150 kg per day. The traditional method of transporting cockles from the beds using donkeys was superseded in the 1920s with the introduction of horse-drawn carts allowing the ~250 gatherers to transport up to 500 kg per day. This increase in gathering capacity resulted in the introduction of a minimum landing size in 1921 in order to safeguard the reproductive capacity of the stock. Landing controls in the form of daily quotas were introduced in the 1950's in response to increases in landings.

The Burry Inlet Cockle Fishery Order was established in 1965 to enable the licensing through limited permits of the cockle fishery therefore control fishing effort and landings of cockle. Numbers of licenses issued have ranged from 43-67 and currently there are 50 issued. The Order was granted to the South Wales Sea Fisheries Committee (SWSFC) who managed the fishery until 2010 when the Environment Agency became the grantee following the reorganisation of sea fisheries management by Welsh Assembly Government.

The Burry Inlet is an internationally important overwintering site for wildfowl and wading birds and as such the Burry Inlet is Special Protection Area (SPA) under the EC Birds Directive, a Special Area of Conservation (SAC) under the EC Habitats Directive and a Ramsar Site under the International Convention on Wetlands. The cockle stocks are key supporting prey species for a number of the bird species for which the site is designated raising further management challenges. The site also contains a number of Site Special Scientific Interest (SSSI) under the Wildlife and Countryside Act 1981; the Loughor Estuary SSSI, Pembrey Coast SSSI, Llandimore Marsh SSSI and Whiteford Burrows National Nature Reserve (NNR).

The Burry Inlet cockle stocks have suffered from unexplained annual mortality events since 2002. This has resulted in a population size structure dominated by a single year class of 1 year olds cockles. An investigation is currently being coordinated by the Environment Agency which aims to identify the underlying cause of the mortality. The unusual population structure and recruitment dynamics of the Burry Inlet stock present unique fishery management challenges for managers particularly given the sensitive conservation designation of the site.

## Glossary of commonly used cockle fishing terms and their application to the Burry Inlet

**Cockle Minimum Size:** 'Any cockle (*Cerastoderma edule*) that will pass through the gauge of a riddle or like instrument used for the purpose of riddling, sorting or sifting cockles which has an aperture 19 mm square.' Extract of the SWSFC Bylaw 13.

A rule of thumb for converting square mesh cockle MLS sizes to shell length as measured during surveys:

- 19 mm square mesh (5/8") = 23 mm shell length;
- 17.5 mm square mesh (1/2") = 21 mm shell length

Cockle gatherers commonly use the imperial measurements (5/8" or 1/2") with reference to the MLS.

**Hand gathering:** Cockles are raked from the sediment by gatherers using short handled rakes and are subsequently 'riddled' or sieved through 5/8" square meshed screens (riddle).

**Gutter:** small channels or depressions channelling water off sand flats and cockle beds in to Pills (below).

**Mussel Crumble:** areas where *Mytilus edulis* has colonised traditional cockle beds forming thin and patchy veneer of mussel clumps. The formation of crumble is exacerbated high levels of shell material on the sediment surface.

**Pant:** depressions or low lying areas on cockle beds often containing high cockle densities

**Pill:** stream channels through cockle beds the source of which is usually in or above the saltmarsh. Often used interchangeably or conjunction with Gutter.

**Rushed Cockle:** cockles sitting on the surface of the sediment or washed into the gutters and pills by the wind, wave and tide action. Considered to be a result of density dependant processes in high density cockle beds.

Figure 1. Orientation map showing the vernacular names of cockle beds and locations on the Burry Inlet.



Review of management actions and bylaws

Table 1. Current WAG Statutory Instruments (previously SWSFC Bylaws) with explanations and descriptions and the basis for their development

Management Action	SWSFC Bylaw/WAG SI	Explanation	Evidence/Basis
<b>Effort Controls</b>			
<b>Sunday Gathering</b>	<p>Bylaw 16. No Sunday Gathering</p> <p>No person shall fish, take or otherwise remove cockles (<i>Cerastoderma edule</i>) from within any part of the area regulated by the Burry Inlet Cockle Fishery Order 1965 on a Sunday except with the prior written authority of the Director of the Committee.</p>	<p>Historic root relating to supply of markets and rail transport in addition to religious observance.</p> <p>Gives officers and gatherers rest day as there is social and economic pressure to work seven days when permitted.</p>	
<b>Permit/Licence Numbers</b>	<p>17. The Licensing of Cockle Gathering in the Burry Inlet</p> <p>a) No person shall fish for, take or otherwise remove cockles (<i>Cerastoderma edule</i>) from within any part of the area regulated by the Burry Inlet Cockle Fishery Order 1965, except as permitted by the provisions of a licence in that behalf, or by the prior written authority of the Director to the Committee and in accordance with the conditions set out in that authority or by the authority of the appointee of the Director present at the time of removal except that:-</p> <p>b) In that part of the area regulated by the Burry Inlet Cockle Fishery Order 1965, which lies to the east of a line drawn from the eastern bank of the Llanrhidian Pill in the south, true north until it meets the western extremity of the Llanelli Dock 51°39.95'N, 04°09.80'W, in the north, a person who is not the holder of a licence under that Order may fish for, take or otherwise remove not more than 8 kg of cockles in any one day and those cockles shall not be offered for sale or processed for sale, and that these shall be removed from the fishery on his own behalf and on the day on which they were gathered.</p>	<p>Enabled under the Burry Inlet Fishery Order this bylaw removes the 'public right to fish' for cockles in the Burry Inlet.</p> <p>This bylaw provides a means to limit effort by issuing licences to gatherers. This bylaw enables managers to increase or decrease effort via licence numbers in relation to stock levels and socio-economic demand.</p> <p>There remains a right to collect cockles for personal consumption in the east of the Order area.</p>	<p>The application of a fixed level of effort, through licences, results in a fixed level of fishing mortality.</p> <p>A widely recognised weakness of an open access public fishery is the difficulty in establishing effort control. The ability to licence limited numbers of gatherers enables managers to establish strict limits on numbers of gatherers. When used in conjunction with daily quotas managers can achieve a fine control of total fishing mortality and assists with achieving the TAC target.</p> <p>The bylaw enables a degree of flexibility in adjusting effort via licence numbers in relation to stock levels and socio-economic demand.</p>

Management Action	SWSFC Bylaw/WAG SI	Explanation	Evidence/Basis
Individual Quotas	<p>Bylaw 18. Daily Cockle Quota (Burry Inlet)</p> <p>No person who is the holder of a licence issued under the provisions of the Burry Inlet Cockle Fishery Order 1965 shall fish for, take or otherwise remove more than 100 kg of cockles in any one day from the area regulated by the said Order except in accordance with the prior written authority of the Director to the Committee or by the authority of his appointee present at the time.</p>	<p>Provides a means of controlling the daily landing per gatherer. Although established as 100 kg (~2 cwt imperial measure) this can be changed in relation to fishery conditions.</p> <p>Provides a means of controlling effort and rate of fishing mortality.</p>	See discussion Bylaw 17.
Technical Measures to protect stock/habitat			
Minimum Landing Size	<p>Bylaw 13. Shellfish – Minimum Sizes</p> <p>No person shall take or otherwise remove from any part of a fishery within the South Wales Sea Fisheries Committee District:-</p> <p>c) Any cockle (<i>Cerastoderma edule</i>) that will pass through the gauge of a riddle or like instrument used for the purpose of riddling, sorting or sifting cockles which has an aperture 19 mm square, provided that it shall not be an offence under this Bylaw to remove cockles from a fishery in accordance with the prior written authority of the Director to the Committee or as permitted by his appointee at the time of removal.</p> <p>Shellfish, the taking or removal of which is prohibited by this byelaw, shall be returned immediately to the sea at a position as nearby as is possible from where they were taken.</p>	<p>Establishes a MLS of 19 mm on a square mesh.</p> <p>Provides a means of altering MLS with written permission e.g. reduction to 17.5 mm MLS has been employed to enable early gathering where a threat of mortality existed.</p> <p>Ensures that cockles (or other shellfish) are not removed from gathering site and can rebury in suitable habitat. Also aids compliance of MLS.</p>	<p>A basic principle of good management for commercial species including cockles is to set a minimum landing size (MLS) in order to prevent animals being captured before they reach maturity.</p> <p>Literature suggests that <i>Cerastoderma edule</i> first mature and spawn in their second summer, at about 18 months old and 15-20 mm in length, however, large cockles (&gt;15 mm) may mature in their first year suggesting that size and maturity are linked (Orton, 1926; Hancock &amp; Franklin, 1972; Seed &amp; Brown, 1977)</p> <p>The current situation in the Burry Inlet suggests that cockles are growing quickly and spawning in their 1<sup>st</sup> year before the MLS is reached.</p>

Management Action	SWSFC Bylaw/WAG SI	Explanation	Evidence/Basis
Vehicle Controls	<p>Bylaw 15. Vehicle Usage in the Burry Inlet Cockle Fishery</p> <p>No person shall cause or permit any mechanically propelled vehicle to stand on or pass over any part of the area regulated by the Burry Inlet Cockle Fishery Order 1965, without the prior written authority of the Committee and in accordance with the conditions set out in that authority, provided that the provision of the above mentioned Byelaw shall not apply to the carrying out of any operation by any Organisation in the exercise of any of its statutory functions.</p>	<p>Implemented to reduce the vehicular disturbance to cockle beds and mechanical damage to cockles and other invertebrates.</p> <p>Reduces bird related disturbance in the SPA</p> <p>Reduces likelihood of damage to SSSI close to access points</p> <p>Also aids enforcement by reducing unregulated access to beds and removing the means of transport for illegally gathered cockles.</p>	<p>Low levels of mechanical damage to cockles have been observed although no experimental evidence has found despite a search.</p> <p>The passage of a vehicles wheel exhibits a hydraulic action bringing cockles to the surface. These mostly rebury but this action does expose them to predators and exposure stresses for a period.</p> <p>Studies on mechanical harvesting of cockles have highlighted the impacts of vehicular traffic on cockles and other invertebrates in the sediment community(Rees, 1996; Cotter et al. 1997; Ferns et al, 2000)</p>
Protection of Cockle Beds from Disturbance	<p>20. Protection of Shellfish Beds - Burry Inlet</p> <p>No person shall engage in any activity which disturbs or damages the surface of the sea bed within the areas specified below, except by prior written authority of the Director to the Committee and in accordance with the conditions set out in that authority:-</p> <p>a) An area contained within an imaginary line drawn as follows:- from Burry Port Harbour West Breakwater Lighthouse in a 1710 (T) direction to the Northern extremity of Whiteford Point, thence in a 1260 (T) direction to the disused Spotting Tower at 51° 37' .91N 4° 12' .44W and thence in a 166° (T) direction from the tower along the Weobley track causeway road and thence in an easterly direction following the High Water Mark Ordinary Tides to meet and then follow a line</p>	<p>This bylaw protects the main cockle beds and the associated benthic community from disturbance or damage from non-gathering activities such as bait digging.</p>	<p>Bait digging results the formation of pits and trenches which can exacerbate erosion by wave and tide.</p> <p>There is extensive literature on the negative effects of bait digging on soft sediment communities (e.g. Cadman, 1989; Cryr et al., 1987; Dyrnda, 1995). Smothering and physical damage effects are likely to also affect both adult and juvenile cockles.</p>

Management Action	SWSFC Bylaw/WAG SI	Explanation	Evidence/Basis
	<p>drawn 000° (T) from the eastern bank of Llanrhidian Pill along Longitude 04° 09.9'W towards the western extremity of the Great Western Dock, Llanelli, to meet and then follow a line drawn 297.5° (T) to a point 51°40.6'N 04°11.86'W where a line drawn 180° (T) from the church at Pwll intersects a line drawn 090° (T) from Burry Port Harbour West Breakwater Lighthouse, thence in a 270° (T) direction to Burry Port Harbour West Breakwater Lighthouse.</p> <p>b) An area contained within an imaginary line drawn from the Northern extremity of Whiteford Point, thence in a 1260 (T) direction to the Spotting Tower (as defined), and thence in a 1660 (T) direction from the tower along the Weobley Track causeway road and thence in a Westerly and Northerly direction following the High Water Mark or Ordinary Tides to Whiteford Point, provided that such activity shall only be permitted in the period 1 st May to 30th September (inclusive).</p> <p>Provided that nothing in this byelaw shall prevent any person from lawfully gathering cockles.</p>		
Discard handling	<p>23. Shellfish - Re-Deposit Of</p> <p>Any person who takes any shellfish, the fishing for or taking, gathering or removal of which from any part of a fishery within the South Wales Sea Fisheries Committee District is prohibited by any of the Committee's Byelaws, or the possession or sale of which is prohibited by or in pursuance of any Act of Parliament, or any Order or Regulations made there under, shall forthwith re-deposit the same as nearly as possible in the place from which they were taken or under the prior written authority of the Director on other suitable ground, and in re-depositing cockles (<i>Cerastoderma edule</i>), in accordance with this Byelaw shall spread them thinly and evenly over the beds.</p>	<p>This bylaw promote best practice of returning cockle discards (undersize) to suitable habitat in such a manner to promote reburying and survival.</p> <p>This bylaw also promotes compliance with MLS by removing the defence of moving cockles to another site to grade. This enables enforcement officers to monitor compliance on the beds.</p>	<p>Cockles have behavioural adaptations to disturbance in response to the dynamic nature of their environment. They are active burrowers and have the ability to rapidly rebury after exposure.</p> <p>Hand raking of cockles has been demonstrated to have no effect on the ability of cockles to rebury (McLaughlin et al., 2007) and even after mechanical harvesting are able to rebury survive (Cook, 1988; Coffen-Smout &amp; Rees, 1999)</p>

Management Action	SWSFC Bylaw/WAG SI	Explanation	Evidence/Basis
Method Controls	<p>40. Bivalve Molluscan Shellfish - Methods of Fishing</p> <p>No person shall fish for or take or remove from any part of a fishery within the South Wales Sea Fisheries Committee District any species of bivalve mollusc except:-</p> <p>a) by hand or with a hand held instrument; or</p> <p>b) with a hand riddle or like instrument having a rigid aperture or grid (not netting of any description); or</p> <p>c) with the prior written authority of the Director of the Committee, and in accordance with any conditions such as may be imposed by that authority, a fishing instrument of an approved pattern.</p> <p>A fishing instrument shall not be of an approved pattern if its use results in unacceptable damage to any molluscan fishery and/or other biota (marine or otherwise), and/or more than 10% by weight of the target species are damaged.</p> <p>Conditions which may be imposed are:-</p> <p>Definitions of the fishing instrument and ancillary equipment including design, size and number.</p> <p>The requirement to provide daily returns on molluscan shellfish so taken, or discarded, the quantity and duration of use of any instrument. Prohibition in the use of any instrument in any particular area or times.</p> <p>In deriving such conditions and approval of pattern, the Committee will be advised by scientists who appear to them to be suitably qualified.</p>	<p>A broad bylaw designed to limit the methods employed in all shellfish fisheries.</p> <p>Provides protection against methods with high breakage rates.</p> <p>In the context of the Burry Inlet this bylaw places constraints on the type of equipment employed to prosecute the fishery.</p> <p>Traditionally hand rakes and ridged 'riddles' are employed in the Burry Inlet. In other areas net bags are used in place of riddles and devices such as 'tamps' are employed to bring the cockles to the surface through a hydraulic process generated by the rocking of the device on the sediment surface.</p>	<p>Hand raking of cockles has been demonstrated to have no effect on the ability of cockles to rebury (McLaughlin et al., 2007). Nevertheless a degree of breakages are observed when raking has been employed in high density beds. This is accepted as 'collateral damage' and added to the fishing associated mortality.</p> <p>The negative effects of other hand gathering methods is unclear although discussions with Bill Cook NWNWSFC reveal that Tamps or Jumbos may allow the exploitation of low density beds by their action of bringing cockle to the surface.</p> <p>More information is required on alternative methods to assess their relative merits.</p>

Management Action	SWSFC Bylaw/WAG SI	Explanation	Evidence/Basis
<b>Spatial Controls</b>			
Closed Areas/Fishery	<p>24. Temporary Closure of Shellfish Fisheries</p> <p>(i) The Committee may for the purposes of:</p> <p>(a) ensuring recovery of depleted stocks, and/or</p> <p>(b) ensuring the protection and development of mainly immature or undersized or transplanted shellfish, and/or</p> <p>(c) protection of the fishery, fishery management and control of exploitation</p> <p>(d) temporarily close any shellfish fishery, any bed or part of a bed of shellfish which in the Committees' opinion ought not to be fished.</p> <p>(ii) No person shall, without the prior written authority of the Director of the Committee, fish for, remove, take or disturb any shellfish from any fishery or part thereof, which has been closed under this bylaw.</p> <p>(iii) Where the Committee is of such opinion, and it is practicable to do so, notices shall be displayed in the vicinity of the closed fishery, and/or published in a newspaper circulating in the district in which the shell fishery is situated, and/or written notice shall be given by one of the Committees' Officers, clearly defining the closure area.</p>	<p>This bylaw enables Burry Inlet cockle managers to close the fishery or certain parts (individual beds) to gathering for a variety of reasons.</p> <p>This bylaw enables managers to adopt a flexible approach to spatial management especially when growth rates of cockles are different on different beds.</p> <p>Enables a variety of adaptive management approaches and experimental work.</p>	
<b>Compliance Related</b>			
Night Gathering	<p>21. Prohibition of Night Gathering of Cockles</p> <p>No person shall fish for or take cockles (Cerastoderma edule) from any part of a fishery within the South Wales Sea Fisheries Committee District between half an hour</p>	<p>This bylaw is predominantly enabling legislation for compliance reasons:</p> <ul style="list-style-type: none"> <li>• Enables compliance with daily quota and prevents gatherers working 2 x</li> </ul>	

Management Action	SWSFC Bylaw/WAG SI	Explanation	Evidence/Basis
	after sunset on any day and half an hour before sunrise on the following day.	<p>tides</p> <ul style="list-style-type: none"> <li>• Makes poaching activity more readily detectable</li> </ul> <p>Also promotes better health and safety for gatherers after the Morecombe Bay incident.</p>	
Quota monitoring	<p>22. Allowances for Weighing</p> <p>For the purposes of enforcing Byelaws the weight of shellfish gathered from any fishery shall be determined by weighing the same in sacks and no allowance shall be made in respect of the weight of the sacks (whether wet or dry) nor of any sand or other materials present.</p>	This bylaw removes ambiguity for enforcement of daily quota. Key when pursuing prosecutions.	

Table 2. Key fishery management actions for the Burry Inlet cockle fishery.

Management Actions	Drivers	Explanation/Discussion
<p><b>Total Allowable Catch in Relation to Bird Prey Provision</b></p>	<p>Statutory responsibility to consider the nature conservation implications of the management of the fishery. These responsibilities are conferred by the Countryside and Rights of Way Act (CRoW), section 74, requires WAG to have a regard for conservation of biodiversity (an amendment of the Wildlife and Countryside Act, 1981) and the Natural Environment and Rural Communities (NERC) Act, part 3, section 40, which states a duty on public and local authorities to conserve biodiversity.</p> <p>The Burry Inlet in an internationally important overwintering site for wildfowl and wading birds and as such the Burry Inlet is Special Protection Area (SPA) under the EC Birds Directive, a Special Area of Conservation (SAC) under the EC Habitats Directive and a Ramsar Site under the International Convention on Wetlands.</p> <p>The site is used regularly by ca. 1.6 % of the biogeographic population of migratory and overwintering oystercatcher. The 5 year peak mean for 1991/92-1995/96 was 13,590 individuals.</p> <p>The Burry Inlet SPA is used regularly by ca. 0.6 % of the biogeographic population of migratory and overwintering knot. The 5 year peak mean for 1991/92-1995/96 was 2,153 individuals.</p> <p>The cockle stocks are key supporting prey species for a number of the bird species for which the site is designated and the Regulation 33 conservation objectives for the SPA state:                      '(ii) The abundance and distribution of suitable prey are sufficient and appropriate to support the numbers of all SPA bird species.'</p>	<p>Traditionally the TAC in the Burry Inlet has been established based on a rule of thumb where the commercial fishery took 33% of estimated adult (&gt;19 mm) cockle biomass.</p> <p>This rule of thirds assumes that the remaining cockle represented sufficient biomass for bird prey and breeding stock reserves. This approach has been demonstrated to minimised fishery impacts on cockle stock impacts in the Burry Inlet (Bell et al., 2001). It is likely that under normal circumstances, in the absence of atypical mortality and adequate stock levels, that this level of exploitation is sufficiently precautionary to provide sufficient prey and stock reproductive output to fulfil both the conservation objectives for bird prey and fishery management objectives for stock reserves.</p> <p>More recently computer simulations using individual (bird) based models have been tested as an alternative method of inform TAC setting (Goss-Custard et al., 2004; Stillman et al. 2001; Stillman 2009). The latest CCW report recommends that bird prey provision, including mussel stocks, should equate to at least two times the birds' physiological requirements, in addition to stock reserves.</p> <p>It is recommended that TAC setting is carried out in collaboration with WAG Fisheries who regulate mussel stocks and CCW but with reference to the socio-economic needs of the local industry.</p> <p>It should be noted that setting of TAC using either method relies on the precision of survey estimates of fishable biomass derived from accurate survey data. These surveys will need to be planned and implemented well in advance.</p>

Management Actions	Drivers	Explanation/Discussion
<p><b>Extended Opening/Effort During Mortality Event</b></p>	<p>The Burry Inlet cockle stocks have suffered from unexplained annual mortality events since 2002. This has resulted in a population size structure dominated by a single year class of 1 year olds cockles which have regularly began to die in late spring/early summer with a mortality rate of over 85%..</p>	<p>SWSFC managers have previously adopted an approach of reducing the MLS and increasing quotas during these events in order for the local industry to derive some income before the majority of cockle stocks are lost.</p> <p>It is clear that the partitioning of the TAC becomes redundant in the face of these mortality events</p> <p>The information shortfalls in assessing the implications of these actions on the cockle population include:</p> <ul style="list-style-type: none"> <li>• The effect of added disturbance stress to already compromised cockles; it has been suggested that gathering activity exacerbates mortality rates in areas around gathering.</li> <li>• The potential of positive effects of gathering on mortality rates; the concept of ‘Thinning’ is often mooted as a means of reducing density moderated stressors on dense cockle beds (see below).</li> <li>• The compound effect of fishing and disturbance related mortality on total mortality; it is unclear whether total mortality is significantly reduced in unfished areas resulting in recovery of older year classes (see ‘Recovery’ areas below)</li> </ul>
<p><b>Allowing Gathering of Rushed Cockle</b></p>	<p>Requests to managers are often received from gatherers for permissions to gather ‘rushed’ cockle.</p> <p>Rushed cockle is the colloquial term for cockles found sitting on the surface of the sediment or washed into the gutters and pills. Often observed in large mounds or piles which contain 1 tonne +.</p> <p>SWSFC managers have previously issued written and verbal permissions to requests to take rushed cockle.</p>	<p>Rushed cockle in the Burry Inlet is commonly considered to be the result of wind and wave action washing individual cockles out of high density beds were they are unable to burrow due to the density of cockles below. Discussions with other cockle fishery managers suggests that, with the exception of the occurrence of ‘ridged’ cockle in some areas of the Wash, rushed cockle in the quantities commonly observed in the Burry Inlet has not been observed. This is possibly due to a combination of physical and biological factors such as bed size, orientation and morphology acting in combination with density dependant processes in the cockle bed or behavioural adaptations of the cockle.</p>

Management Actions	Drivers	Explanation/Discussion
<p>Allowing Gathering of Rushed Cockle cont.</p>		<p>It is possible that rushed cockles are the result of a density moderated behaviour promoting a secondary adult distribution of cockles. These behaviours are known to occur in post larval cockles and have been suggested as a means of secondary dispersal (Hall 1994; Coffen-Smout &amp; Rees, 1999). Cockles are known to colonise experimentally cleared areas and have the capacity to rebury after disturbance (Hall 1997; Coffen-Smout &amp; Rees, 1999). Cockles are reported to exhibit emergence and crawling behaviour in response to diurnal cycles and inundation by sediment (Richardson et al., 1993; Rygg, 1970).</p> <p>Cockles unable to redistribute to suitable habitats and rebury are washed into the gutters and pills forming various aggregations and occasionally extensive banks. These banks of live cockle have been observed by the author to remain stable in the same position for at least two weeks. This stability suggests that these cockles have reached a terminal position and are unlikely to be redistributed to surrounding cockle beds. Observations suggest that rushed cockle will persist for some time before ultimately dying and/or being washed into the main river channel.</p>
<p>Thinning</p>	<p>Requests to managers are often received from gatherers for permissions to thin high density cockle beds in order to promote growth and possibly promote survival.</p> <p>Thinning as permitted by SWSFC is described 'Thinning (mainly of cockle in their second year) is achieved on an occasional basis by a reduction of cockle size and / or increase in daily quota applied to a defined area for a determined time.' (Hough, 2008)</p>	<p>Density-dependant effects on growth in <i>Cerastoderma edule</i> is a well established phenomena (Hancock, 1969, 1973, Ivell, 1981.; Jensen, 1993, Orton, 1926, Ramon 2003).</p> <p>Thinning of a cockle bed that is subject to density-dependent growth influences has been demonstrated to increase the potential growth rate of the survivors (Hancock, 1969, 1973). If the thinning activity is carried out when the small cockles are at a marketable size this can develop into a two-stage harvesting strategy with clear economic benefits to the fishery.</p> <p>It is unclear if there is a density-dependant factor in the incidence of the atypical mortality but observations by the author suggest that it is not the primary factor involved; cockles are seen to suffer similar fates in low density beds. Nevertheless density-dependant factors such as competition for food and space may increase stress on already</p>

Management Actions	Drivers	Explanation/Discussion
		<p>compromised animals leading to mortality. The use of thinning as a preventative action against atypical mortality remains unproven as in previous years mortality across all beds has occurred before field experiments could address the issue.</p> <p>The approach in which thinning is carried out warrants some attention in the current single year class situation as dense beds are of a uniform size. Gathering over that bed for an unlimited period is likely to continue until it becomes commercially unviable to do due to low densities. Obviously from a fishery management perspective gathering should be curtailed before that time.</p> <p>Optimum growth densities need to be identified but these may be derived from literature sources.</p>
Closed 'Recovery' Areas	The use of closed areas has been mooted as a means of 'letting nature take its course' by reducing fishing mortality and associated disturbance stress on cockle population.	<p>Evidence of enhanced survival in closed areas has not been reported although logically the removal of fishing disturbance and fishing mortality may promote survival in the absence of density-dependant effects.</p> <p>Although formal field experiments have not been carried out to test the viability of this approach evidence may be derived from the CEFAS May and November surveys and the CCW bird prey surveys recording the result of the maintenance of the 19 mm MLS on the south side of the Burry Inlet during 2007. This essentially prevented all gathering during that period.</p>

Risks associated with management actions

Environment Agency managers have requested that risks associated with changes to current management controls and the implementation of key management actions in relation to atypical mortality. Knowledge gaps in the scientific understanding or where evidence is lacking are indicated.

Table 3. Potential Risks associated with key management actions of the Burry Inlet cockle fishery

Management Action	Potential Risk	Information Gaps
Total Allowable Catch in Relation to Bird Prey Provision	Risk of not meeting the SPA conservation objectives if sufficient bird food is not accounted for. Risk of not establishing stock reserve. Risk of underutilisation of commercial resource.	Traditional rule of thumb (33% birds, stock, gathering) although apparently sufficiently precautionary to support all three demands on the population during normal circumstances of high cockle stocks may not do so in the current situation.  The CCW/CEH/Bournemouth University bird food model may offer a solution but this needs to be demonstrated as a site and fishery management tool.  It is recommended that EA managers liaise with CCW experts, WAG Fisheries managers (mussels) and the model authors to establish agreed process for TAC setting.
Minimum Landing Size	None if maintained in normal circumstances Risk of impacting reproductive success of stock if reduced below size at first maturity Risk of impacting reproductive success of stock if reduced at a time that enables gathering before first spawning	Current relaxations of the MLS to allow gathering to thin beds and to gather cockles before the onset of atypical mortality is unlikely to affect the reproductive output of the population due to the high numbers in the Burry Inlet. However there are many information gaps associated with these practices and so there remains some residual risk especially in years of low stock levels especially when dominated by year 1 cockles.
Extended Opening/Effort During Atypical Mortality Including: Sunday Gathering Permit/Licence Numbers Individual Quotas	Risk of increased total mortality and reduction in recovery capacity from atypical mortality	There is insufficient information available at present to determine whether additional fishing mortality significantly increases total mortality during an atypical mortality period. Although the rate of mortality is increased with additional fishing and fishing related mortality it is unclear whether cockles removed during this period are ultimately destined to die during the period.

Management Action	Potential Risk	Information Gaps
		<p>The information shortfalls in assessing the implications of these actions on the cockle population include:</p> <ul style="list-style-type: none"> <li>• The effect of added disturbance stress to already compromised cockles; it has been suggested that gathering activity exacerbates mortality rates in areas around gathering. If this is the case is it significant?</li> <li>• The potential of positive effects of gathering on mortality rates; the concept of ‘Thinning’ is often mooted as a means of reducing density moderated stressors on dense cockle beds (see below).</li> <li>• The compound effect of fishing and disturbance related mortality on total mortality; it is unclear whether total mortality is significantly reduced in unfished areas resulting in recovery of older year classes</li> </ul>
Allowing Gathering of Rushed Cockle	None	
Thinning	<p>None under normal circumstances. Risk of increased mortality rates under atypical mortality</p>	<p>It is unclear if there is a density-dependant factor in the incidence of the atypical mortality. Density-dependant factors such as competition for food and space may increase stress on already compromised animals leading to mortality. The use of thinning as a preventative action against atypical mortality remains unproven but recent observations suggest that growth in the recently worked bed is very good.</p>
Closed ‘Recovery’ Areas	Risk of loss of commercial resource	It is unclear whether removal of fishing and associated mortality reduces total mortality during an atypical mortality period.
Method Controls	None if maintained.	Effects of alternative hand gathering and mechanical methods not fully understood although there is a body of literature describing mechanical and vessels methods.
Night Gathering	None if maintained. Enforcement issues (effort and unlicensed gathering), safety issues.	
Quota monitoring	None if maintained	

## Recommended scope for comprehensive review of cockle fishery management approaches and the development of a management plan

- Review cockle management actions in UK cockle fisheries and evaluate applicability to current actions employed in Burry Inlet, these may include:
  - TAC setting approaches (use of bird food models etc)
  - Effort control (licensing, permits etc)
  - Harvest methods employed
  
- Fishery management aspects of the MSC accreditation should be addressed
  - MSC risk based approach should be considered as it enables managers to establish precautionary harvest rules enabling them to achieve a sustainable fishery in data deficient situations such as the current atypical mortality events.
  - MSC surveillance report has identified key actions including the evidencing and establishing harvest rules for 'Thinning' and suspension of the MLS
  - Possibly develop novel harvest rules responding risks associated with atypical mortality to be incorporated into a management plan
  
- Identify information gaps that require addressing to inform the above:
  - Undertake data analysis of existent data (CEFAS, CCW, SWSFC)
  - Establish field experiments
  - Review of current stock assessment surveys and identify options to rationalise CCW and CEFAS surveys
  
- Development of a management plan drawing on the above in partnership with CCW, WAG Fisheries and shellfish industry:
  - TAC setting process should be bottomed out
  - Balance between mussel and cockle fisheries established
  - Ensure Conservation Objectives considered at all stages
  - Establishment of Stakeholder Management Group



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## Appendix I

### Options for cost-effective field studies to monitor effects of current, and inform future, cockle management actions in the Burry Inlet

#### Introduction

The Environment Agency has recently assumed responsibility for the management of the Burry Inlet cockle fishery. Cockle gathering has been permitted for licensed gatherers from Saturday 8<sup>th</sup> May 2010 for a period of 14 days. A daily quota has been set at 250 kg and there is no minimum landing size. The local industry has agreed that certain cockle beds (Ochre Draw/School Beds, Cheriton and Middle Bank) will essentially remain closed with the continuation of the 17.5 MLS.

The short-term opening of the fishery presents managers with an opportunity to determine the effects of gathering activity on cockle survival in relation to the ongoing atypical mortality events in the Burry Inlet. Discussions with other fishery managers, biologists and industry have highlighted a number of potential management actions which have uncertain outcomes in relation to cockle survival during a mortality event.

Management Action	Objective	Uncertainty
Normal gathering permitted	Normal gathering operations	Does the increased stress caused by fishing related disturbance trigger or exacerbate mortality?
'Thinning' of high density cockle beds	Reduction of density dependant competition can increase growth and production (Jensen 1993; Dijkema 1987) and has been suggested as a mechanism for moderating mortality	Does this action increase survival in post-fishing cockle bed?
Closed areas	To allow cockle year classes to recover from current single year class state.	Does year class depth increase in closed areas?

The aim of this document is to present a suggested field study strategy designed provide data and information to address these uncertainties and to provide feedback to Environment Agency fishery managers on the current management actions.

### Suggested short-term field study strategy address management uncertainties

A number of alternative experimental designs and survey strategies were considered including Before-After Control Impact (BACI) sampling designs, Gradient Observations and Control Impact approaches. Due to practical considerations a full replicated BACI approach is not viable as fishing has already taken place. The Gradient Observation approach of sampling along extended transects away from the point of impact (gathering) was considered but discounted as it is likely that biological and physical environmental factors such as height of shore/inundation time and cockle density heterogeneity would confound results. A modified Control-Impact approach is suggested:

#### Control-Impact approach

1. 'Does the increased stress caused by fishing related disturbance trigger or exacerbate mortality?'  
'Does this action increase survival in post-fishing cockle bed?'

Before-After Control Impact (BACI) sampling designs are commonly used in environmental impact assessment and are effective for detecting changes due to anthropogenic disturbances (Underwood (1991, 1992, 1994). As gathering has already begun we are unable to collect data from before any related disturbance occurred. Nevertheless a modified Control-Impact strategy may be adopted. The CI design compares adjacent un-fished (control) and fished (impact) areas. The control areas are assumed to be unaffected by fishing activity and are representative of the assumed state of the pre-fished impact area i.g. exposure times and cockle size/densities; selection of these can be informed by the CEFAS survey results.

#### Control-Impact sampling design

- 3 x Control and Impact sites
- Control sites dictated by location of fishing activity
- Impact sites informed by absence of fishing activity and CEFAS survey
- 10 random observations to be made at each site
- Factors to be recorded:
  - Cockle density per 0.1 m<sup>2</sup> quadrat
  - Dead or moribund cockle per 0.1 m<sup>1</sup> quadrat
  - Dead or moribund cockle on surface observed during 1 minute timed search<sup>1</sup>

The number of replicate sites and observations within sites is a compromise between achieving statistical power and logistical considerations of sampling over a single tidal period.

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<sup>1</sup> Time Search approach is commonly employed in the detection of rare or low density species such as non-native invasive species (e.g. Metcalfe-Smith, 2000)

In addition to quantitative observations/samples as series of digital photographs will be produced and geo-referenced using GPS positions and incorporated into Google Earth in order to assist interpretation managers and stakeholders.

2. 'Does year class depth increase in closed areas?'

The areas at Ochre Draw/School Beds, Cheriton and Middle Bank where the MLS remains in place offers an opportunity to study the effect of the absence of fishing disturbance and mortality on the population age structure, total mortality and survival.

The biannual CEFAS surveys extensively sample these and currently open cockle beds producing a comprehensive dataset and therefore additional sampling may be unnecessary.

Selection of which beds should remain closed in the event of a wider fishery opening should be informed by their representativeness of the wider estuary; results from very muddy or very high shore sites may not reflect the situation from the majority of the estuary. It is suggested that the local industry is consulted in order that their local knowledge is utilised.

And alternative to this, although possibly not as definitive may be to examine survey data from years where fishing effort was absent or very much reduced in areas covered by the CCW and CEFAS surveys.

NOTE: These options have been further developed by Environment Agency staff and the author under a separate study.