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Damage caused to mussels (*Mytilus edulis* L.) by dredging and mechanized sorting

P. J. Dare

Fisheries Experiment Station, Conwy, North Wales, United Kingdom

Up to 13% of mussels which had passed through a rotary sorting machine experienced shell damage and many apparently suffered some internal damage which impaired their long-term survival out of water. These injuries were superimposed upon others when harvesting was done with large dredges. Sublittoral mussels had a significantly higher shell-damage rate than intertidal mussels of comparable age; they also survived less well out of water. Relaying sublittoral stock into the low intertidal zone, for at least 6 months, increased resistance to sorting damage and to lengthy exposure in air. At least 90% of sorted mussels survived for 8 days out of water in winter in North Wales, and survival for at least 36 days was recorded with a few unsorted individuals.

Introduction

Dredges and sorting machines are widely used by large-scale mussel cultivators in northwest Europe, particularly in Holland and Great Britain. However, no published work can be located concerning the possible harmful effects on mussels of dredging and sorting operations. Dodgson (1928) found that mussels handled roughly were often stunned for several days and did not cleanse properly in the Ministry's purification tanks at Conwy. Similarly, frequent malfunctioning of Conwy mussels was noted later (about 1951) by R. H. Baird (personal communication) when using a mechanical sorter essentially similar to those in use today.

Recent work at this laboratory indicated that the survival of machine-sorted mussels was also noticeably impaired, even when there was no visible shell damage. It was therefore decided to examine more closely the adverse effects of dredging and sorting procedures upon mussels being handled for harvesting or relaying. This paper records observations on the incidence of shell damage inflicted by dredges and sorters and the results of experiments on the survival of machine-sorted, compared with unsorted, mussels.

Material and Methods

Mussels were collected from sublittoral and intertidal beds in the Menai Straits, North Wales, by means of conventional Baird (Baird, 1955) and Dutch dredges, washed with a hose on deck, then bagged and stored overnight ready for the experiments. The sorting and washing machine used comprised a gently sloping, cylindrical iron cage (of Dutch commercial design), 1·75 m long and 0·5 m internal diameter, which rotated at approximately 18 rev/min. The annular bars of the cage were 1 cm wide and 2 cm apart, and longitudinal bars were spaced at 20 cm intervals around the walls of the cage. Mussels were fed into the sorter via a large hopper and a conveyor belt. Live mussels normally loosen their byssal attachments during handling and storage. In the machine, shell debris and undersized mussels were separated and washed out between the bars. Clean, marketable mussels passed from the sorter along a moving belt into wire baskets. Each batch of mussels took approximately 3–5 minutes to pass through the cage.

Two experiments were carried out, in January and May 1972, in each case using mussels of marketable size (mostly 50–60 mm length). The two populations used were of comparable age ($1\frac{1}{2}$ to 2 years). The intertidal population, situated just above mean low water mark of spring tides, had been relaid there from the sublittoral bed nearby in spring 1971. Thus, the intertidal mussels had spent approximately half their life at that shore level.

In both experiments, the bags of mussels from each population were divided, one half being put through the sorter, the rest remaining unsorted. Random samples of sorted and unsorted mussels were examined for shell damage.

Replicated subsamples from the treatments of each population were then taken for survival studies. Only individuals with intact shells were used. In the first experiment, three replicates of 100 uncracked mussels were taken from each treatment, placed in labelled,

Table 1. Frequency of shell damage in sorted and unsorted dredged Menai Straits mussels (May 1972)

Origin of mussels	Number examined per treament	Number of damaged mussels					
		Unsorted (dredging damage)			Sorted (dredging + sorter damage)		
		Total	Severe	Light	Total	Severe	Light
Sublittoral	500	7 (1·4%)	5	2	30 (6·0%)	15	15
Intertidal	500	9 (1·8%)	8	1	11 (2·2%)	6	5

χ^2 significance tests:

sublittoral sorted: intertidal sorted $\chi^2 = 7{\cdot}90$, $P < 0{\cdot}001$
sublittoral unsorted: intertidal unsorted $\chi^2 = 0{\cdot}06$, $P = 0{\cdot}80$
sublittoral sorted: sublittoral unsorted $\chi^2 = 13{\cdot}08$, $P \ll 0{\cdot}001$
intertidal sorted: intertidal unsorted $\chi^2 = 0{\cdot}05$, $P < 0{\cdot}80$

wire trays, and set out in the open air for observation. Only the tops of the trays were covered, for protection from frost and precipitation. In the second experiment, four replicates of 50 mussels were used. The numbers of persistently gaping (i.e. dead or moribund) animals in each tray were counted and removed at, usually, daily intervals. During the later stages, several tests were made to determine whether closed mussels were still alive.

For the January experiment the weather was generally typical of winter at Conwy, being predominantly cool and sometimes wet, with occasional light frosts. Air temperatures ranged usually between 7°C and 2°C, but during days 23–26 they remained between 2°C and −6°C. In the early May experiment the weather was cool and often wet, with temperatures between 13°C and 4°C, i.e. comparable to the milder spells of a normal winter.

Results

Shell damage

The frequency and nature of damage to shells during the May and January experiments is shown in Tables 1 and 2 respectively. Structural damage was divided into 2 categories: (i) severe – shell crushed or punctured, mussels already dead or moribund; (ii) light – ranging from obvious fractures to fine, hairline cracks. Cracks normally radiated from the rounded (posterior) margin of the shell, and usually only one crack per animal was found. Most mussels with light damage were still alive 72 h after sorting, and it seemed likely that many could have survived much longer.

Table 1 shows that approximately 1·6% of the catch was damaged by the dredging and handling operations before mussels reached the sorter, most of the damage being severe and presumably caused by the dredge itself. There was no statistically significant difference between the amount of damage caused on intertidal and sublittoral stocks. Sorting produced no significant increase in overall damage among intertidal mussels, but did cause a very significant rise in the damage rate for sublittoral mussels (presumably because the latter are relatively thin-shelled).

Variations in damage rate are to be expected, due to operational factors, and the January observations show that losses could be quite high (Table 2). Pre-sorting damage was not determined on this occasion.

Overall, the population which had been relaid from the sublittoral on to the low intertidal zone withstood the sorting and handling procedures significantly better than did the original sublittoral stock, suggesting that the intertidal mussels had developed stronger shells.

Survival in air

The survival curves of mussels with intact shells during long-term exposure out of water are shown in Figures 1 and 2. Each curve in Figure 1 is the average of three replicates of 100 mussels, and each

Table 2. Frequency of shell damage in dredged and sorted Menai Straits mussels (January 1972)

Origin of mussels	Number examined	Number damaged	Type of damage	
			Severe	Light
Sublittoral................	478	63 (13·2%)	42 (8·8%)	21 (4·4%)
Intertidal.................	400	20 (5·0%)	9 (2·3%)	11 (2·7%)

χ^2 significance tests: intertidal: sublittoral, $\chi^2 = 15{\cdot}42$, $P \ll 0{\cdot}001$

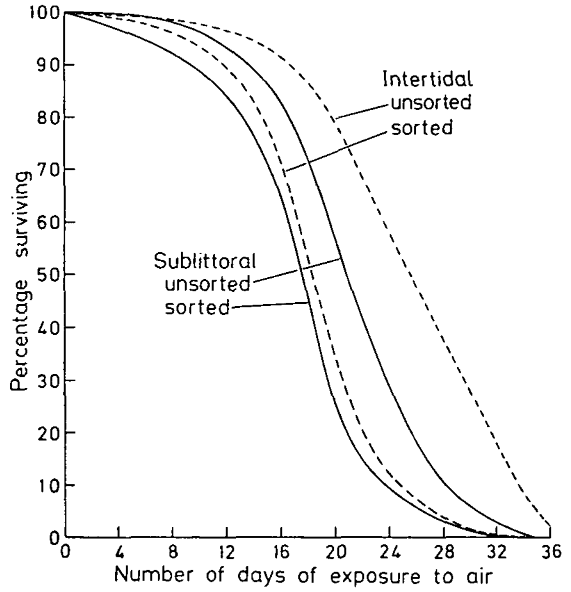

Figure 1. Survival curves for sorted and unsorted mussels from two populations (January–February 1972); each curve was fitted by eye through not less than 24 points (at 1 or 2 days intervals) with a maximum displacement of points from the curves of 3 %.

of those in Figure 2 relates to four replicates of 50 animals. Many mussels were gaping on each inspection, particularly the sublittorals during the first few days, but an individual was counted as dead or moribund only if its valves gaped persistently after repeated tapping. Possibly some mussels which were closed at each examination were also dead (see below; also Dodgson, 1928). Because of this element of doubt, each curve probably slightly overestimates survival.

Figure 1 shows that mussels can survive for a surprisingly long time out of water in winter, and a few individuals lived for at least 36 days. Sorted mussels clearly fared much less well than unsorted mussels, indicating that mechanical shaking had caused internal injuries. There was little difference between the two sorted groups, the intertidal mussels proving just a little hardier. At least 90% of sorted, and 97% of unsorted, mussels were still alive after 8 days, and 50% of sorted (75% unsorted) after 17 days of exposure. In the May experiment (Figure 2) survival was much poorer for all groups – a maximum of about 12 days. Otherwise, the May results were in general agreement with those of January, the poorest survival being shown by sorted, sublittoral animals and the best by unsorted, intertidal mussels.

After day 21 of the January experiment several tests were made to check the viability of closed mussels (Table 3). Small samples were re-immersed in sea water and observed for opening and siphoning activities. All mussels floated initially, having lost their mantle cavity (shell) water by gaping during exposure. Samples tested for only one hour were put back in the survival trays, but those tested for 4 hours or more were not used for further observations. The great majority of closed mussels proved to be alive, although by day 32 some were so weak that they died during re-immersion. A few individuals did not open and remained floating; if not dead they must have been close to death.

Discussion

The experiments described, and more recent experience with suction-dredging smaller mussels for relaying, indicate that up to 5% of crops may be destroyed due to severe shell fractures caused by dredges. Further, the survival of mussels with undamaged shells may be impaired markedly by mechanical agitation, as during sorting and suction-dredging operations. The deaths of some suction-dredged mussels may be attributed to excessive silt taken into the mantle cavity, or to byssus injuries, but many individuals clearly suffered less obvious tissue or physiological damage.

Variations in shell breakage and mortality rates are to be expected, depending on various operational factors as well as population and seasonal differences in the mussels themselves. Thus, shell damage was significantly less among mussels relaid intertidally from the sublittoral zone than in the original sub-

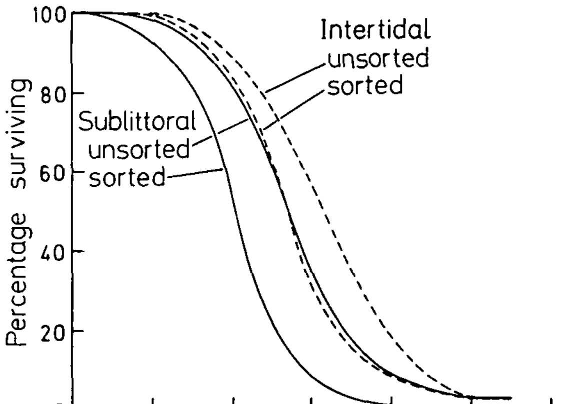

Figure 2. Survival curves for sorted and unsorted mussels from two populations (May 1972); each curve was fitted by eye through 8 points (at daily intervals except between days 3 and 6 for which there were no data) with a maximum displacement of points from the curves of 1·5%.

Table 3. Revival tests on mussels exposed to air for 3–5 weeks, January–February 1972

Number of days exposure	Origin of mussels tested	Re-immersion time (hours)	Number tested	Minimum number still alive	Comments
21	Intertidal unsorted	24	58	55	49 siphoning after 2 h; other 3 stayed closed.
25	Intertidal unsorted	1	10	5	
25	Sublittoral sorted	1	5	2	
32	Intertidal unsorted	20	20	17	One active after ½ h, 11 after 1 h, and 17 within 2 h; but 7 had died after 20 h.
34	Intertidal unsorted	20	2	2	1 revived within ½ h, other within 1½ h.
34	Sublittoral unsorted	20	2	0	1 opened but proved to be dead; other stayed closed.
36	Intertidal unsorted	4	5	4	2 active after 1½ h, 3 at 2½ h, 4 at 4 h.

littoral stock, suggesting that the intertidal mussels had developed stronger shells. This would be in agreement with the findings of Baird and Drinnan (1957), who reported that shell weight in *Mytilus edulis* increases with increased exposure to air. Conversely, Dare (1971) found that young mussels transplanted from the low shore on to sublittoral ropes developed relatively lightweight shells.

Survival for both populations was much poorer in May than in January, perhaps because the May experiments were made shortly after the spring spawning (normally between late March and mid-May in north Wales), when mussels possess low food reserves. In summer at Conway, Dodgson (1928) recorded that healthy mussels could withstand 24 days out of water, including exposure to sunshine. At that season, however, carbohydrate reserves are at their annual peak (Daniel, 1922; Williams 1969).

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