Queensland Journal of Agricultural and Animal Sciences Vol. 42 (1), 1-9 (1985)
Published by the Queensland Department of Primary Industries

An evaluation of ship-board scallop grading equipment

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Summary

The efficiency of two types of scallop graders has been evaluated. One type, based on a rotating perforated metal drum, remained efficient under all test conditions whereas efficiency of the second type, a perforated metal chute, varied greatly with its length and angle of fall. Mean size of scallops selected by each type of grader has been estimated and variation in mean selection size induced by different perforation sizes has been meansured. The rotary grader induced more chipping of scallop shells than did the chute, but scallops graded by a rotary grader did not suffer significantly greater mortality than a hand sorted control.

INTRODUCTION

In Queensland the saucer scallop *Amusium japonicum balloti* (Bernardi) is fished commercially by otter trawlers in the area bounded by latitudes 18°30′S and 26°S and longitudes 146°30′E and 153°E. Mesh size of trawl nets used in this fishery is normally 75 mm stretched mesh which selects for scallops with a shell height (SH, auricles to opposite margin) of approximately 75 mm.

There is no legal size limit on scallops landed in Queensland but processors currently pay a lower price for scallops with a meat weight (adductor muscle) less than 7.5 g. From data given by Williams and Dredge (1981), this is commensurate with scallops which lie within the range 84 to 92 mm SH, depending on a seasonally varying condition factor. Participants in the fishery have attempted to observe a voluntary lower size limit of 83 to 88 mm SH but as catch rates in the period 1977 to 1980 frequently exceeded 3 000 scallops per boat per hour (Dredge, unpub. data) hand culling is obviously impracticable. A number of grading devices which sort scallops into large and small categories and return small scallops to the sea have been developed to overcome this problem. Two such graders in common use are the rotary grader and the chute grader.

Rotary grader (Figure 1a)

This is a perforated drum, 1 to 1.5 m long and approximately 0.7 m in diameter, which has the top and bottom removed and which is mounted longitudinally around a central axle. The axle is mounted onto a frame which angles the drum downwards at 10° to 15°. Perforations (normally circular holes) are cut to a size that allows scallops of a given SH to fall through. When operating, the drum is rotated at a speed of 25 to 35 r.p.m. by an electric motor. Scallops are fed into the upper end of the drum and tumble down the slope of the rotating drum. Small scallops fall through the perforations and are swept overboard.

Chute grader (Figure 1b)

Perforated metal chutes are used to grade scallops on some trawlers. After scallops are sorted from other trawl trash they are passed from the sorting tray to storage space across the chute, which is normally angled downwards. Small scallops fall through the perforations and are washed overboard.

There is no information available on the effectiveness of these devices in terms of the proportion of small scallops which they retain, or on operating conditions which give maximum escapement of small scallops. Both graders are known to chip the margins of

scallop shells but the extent of this chipping is unknown. If a size limit was imposed on scallops, data on expected reduction in SH induced by ship-board handling would be an obvious pre-requisite.

The relationship between perforation size and the mean size of scallops retained by the grader is necessary if the use of grading equipment becomes mandatory in this fishery.

Scallops passed through rotary graders undergo severe tumbling while being graded. Some fishermen have expressed concern that scallops returned to the sea after grading may be subject to higher than normal mortality.

A series of trials, carried out between November 1980 and January 1981 were designed to give information on the foregoing aspects of grader performance.

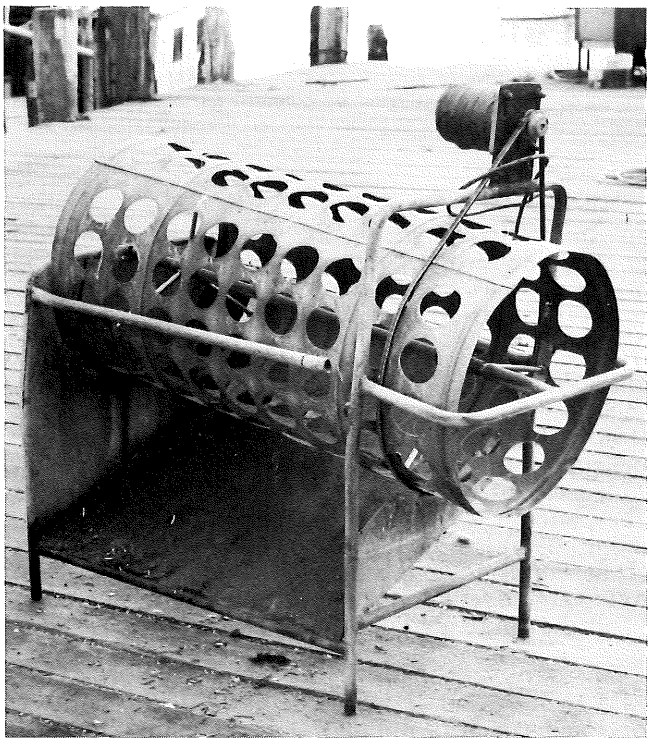

Figure 1a. Rotary grader.

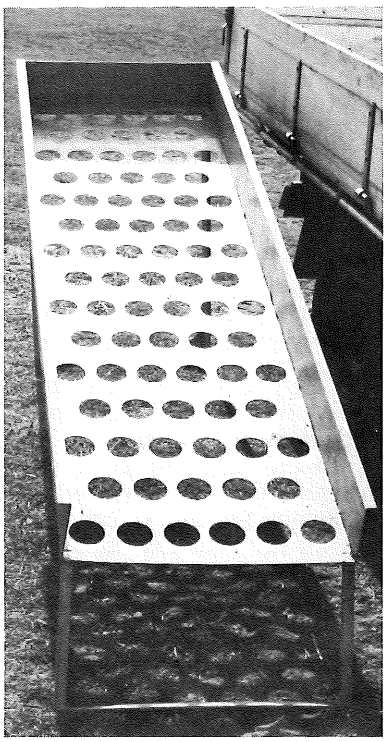

Figure 1b. Chute grader.

MATERIALS AND METHODS

A rotary grader 1.2 m long and 0.7 m in diameter was used to evaluate efficiency of this type of grader at various speeds of rotation. The drum was perforated with 187 evenly spaced 82 mm diameter holes, and was angled downwards at 12° from the horizontal. The drum was rotated by hand with the varying speed of rotation being measured against a stopwatch.

An aluminium grading chute 2.5 m long, 0.625 m wide, with sides 0.15 m high was used to test the effect of length and angle of fall upon the effectiveness of this type of chute. The base of the chute was perforated with 83 evenly spaced 82 mm diameter holes. The effective length of the chute could be varied by inserting a stop at an appropriate position on the tray, and the angle of fall could be varied between 15° and 35° using a base frame with adjustable legs.

An additional three chutes, similar to the one described above, but with hole diameters of 72, 77 and 87 mm were used to determine the relationship between perforation size and the mean SH of scallops retained (i.e. 50% retention size) by graders.

Shell proportions

Data on the relationship between shell height and shell length (Taylor and Venn 1978) were obtained by measuring across the axes of 133 scallops obtained from Hervey Bay in April 1984. Corresponding data for the relationship, between shell height and an oblique measurement across the shell's diameter (Figure 2) were obtained from scallops taken off Townsville in September 1985.

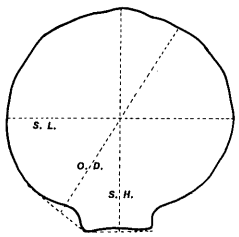

Figure 2. Measurements across the scallop shell, SH=Shell Height, SL = Shell Length, OD = Oblique Diameter.

Extent of shell chipping

A total of 303 scallops in the range 44 to 119 mm SH were measured to the nearest millimetre and individually marked on the right hand valve. The scallops were passed through the rotary grader while it revolved at a speed of 30 r.p.m., after which each scallop was remeasured. The procedure was repeated with 228 scallops in the range 48 to 119 mm SH being passed over a two metre length of the grading chute drilled with 82 mm holes. In this trial the chute was angled down at 15°.

50% retention sizes and grader effectiveness

In a series of 13 trials carried out at seas, scallops taken in half to one hour trawl shots were separated from trawl trash and graded using either the rotary or chute grader according to the schedule given in Table 1. Scallops which passed through the grader were held separate from those retained during grading and the SH of scallops from each group was recorded to the nearest mm.

Fifty per cent retention size for chutes perforated with 72, 77, 82 and 87 mm diameter holes were estimated in separate trials using sample sizes of between 360 and 568 scallops. In each trial scallops were passed over the chute under test using 2.0 m of chute length at a 15° angle of fall. Scallops were separated and measured following the procedure used in earlier trials.

An estimate of mortality induced by rotary grading was obtained from tag release data. Scallops from port and starboard nets were held separately after a 45 minute trawl shot and scallops judged by eye to have a SH of less than 80 mm were taken from the starboard net's catch and held in circulating seawater. All scallops taken in the port net were subjected to rotary grading at a speed of 30 r.p.m. and scallops graded out as small were placed in a second bin of circulating water. Using the tagging technique described in Williams and Dredge (1981), 150 hand sorted and 200 machine sorted scalloped were tagged with individually identifiable tags, and all tagged scallops were mixed in a third bin of seawater. Tagged scallops were released within three hours of capture on 1 November 1980 at 24°00′S, 151°55′E, over an extensive bed of small scallops where future commercial trawling was considered likely to occur.

Table 1. Sequence and details of trials conducted to evaluate efficiency of graders

Trial number	No. of animals graded	Grader type	Angle of fall (degrees)	Length of fall (m)	Speed of rotation (r.p.m.)	Through put time (minutes)
1	590	Rotary	12	1.2	20	1.75
2	523		12	1.2	25	1.67
3	732		12	1.2	30	2.5
4	508		12	1.2	35	1.17
5	885		12	1.2	40	2.5
6	595	Chute	15	.5	n.a.	2.25
7	670		15	1.0	n.a.	2.0
8	736		15	1.5	n.a.	2.75
9	568		15	2.0	n.a.	2.0
10	526		20	1.0	n.a.	2.33
11	443		25	1.0	n.a.	2.5
12	893		30	1.0	n.a.	1.75
13	470		35	1.0	n.a.	2.17

n.a.=not applicable.

RESULTS

Shell proportions

The relationship between shell height and shell length (SL) is linear:

$$\text{SL (mm)} = -2.637 + 1.019 \text{ SH (mm)}$$

$$(n=133,\ r=0.96).$$

Likewise, the relationship between shell height and the oblique diameter (OD, Figure 2) fits the linear form:

$$\text{OD (mm)} = -0.037 + 0.963 \text{ SH (mm)}$$

$$(n=107,\ r=0.99).$$

Chipping of shell edges by graders

Linear least square regressions were used to determine the extent of shell chipping induced by grading. For the rotary grader the regression took the form:

$$\text{SH after grading (mm)} = -1.81 + 1.01 \text{ SH before grading (mm)}$$

$$(n=303,\ r=0.998).$$

For the grading chute:

$$\text{SH after grading} = -0.02 + 1.00 \text{ SH before grading (mm)}$$

$$(n=228,\ r=0.999).$$

Size of scallops selected out by graders

Plots of the proportion of each size class of scallops retained by graders were characteristically sigmoid, with some irregularity on the lower left hand limb (Figures 3a, 3b). This curve is commonly encountered in net selection studies, which are analogous to the present work. Pope (1966) suggested that this curve can be approximated by a cumulative normal or logistic distribution, and the mean size of selection (50% retention size) and its variance estimated using either probit or logit analysis. In the present study logit analysis was used to determine the 50% retention size for both rotary and chute graders.

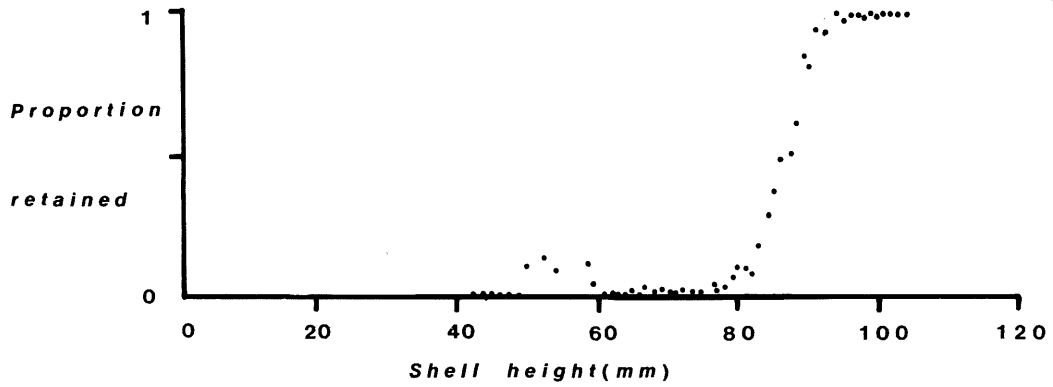

Figure 3a. Proportion of scallops retained versus size for all scallops graded by rotary sorter.

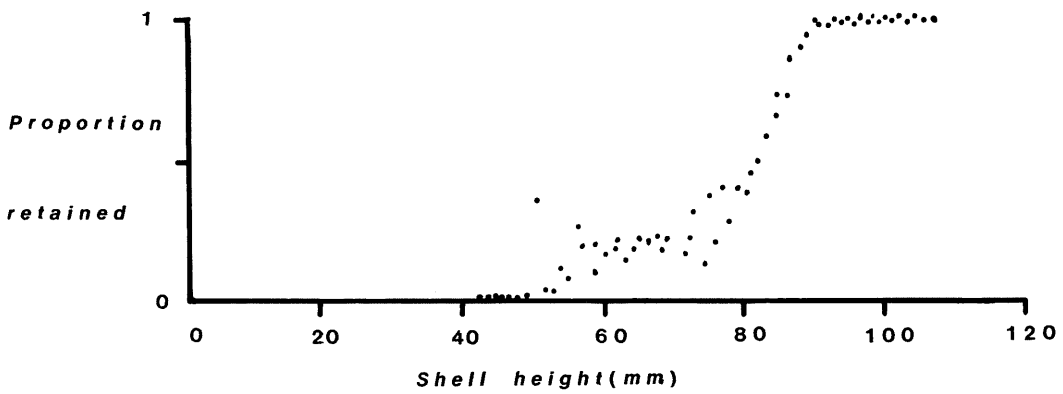

Figure 3b. Proportion of scallops retained versus size for all scallops graded by chute sorter with 82 mm holes.

Data for all trials which involved the use of the rotary grader were pooled to give an estimate of the 50% retention size for that grader. Proportions of scallops retained versus size are given in Figure 3a. For the purpose of this analysis the irregular retention of scallops smaller than 76 mm SH was ignored and the data smoothed to give a zero retention below 76 mm. Fifty per cent retention size for the rotary grader, corrected to size before grading, was estimated at 86.5 mm with 95% confidence limits of±0.4 mm.

Comparison of the number of scallops predicted by the fitted logistic curve to occur in each 1 mm size class against observed numbers retained by the grader was used to estimate a χ^2 value of 12.7 (n.s., $P>0.05$) suggesting that the fitted curve gave a reasonable approximation to the actual data.

Pooling data from all trials involving the use of the chute grader with 82 mm holes gave the retention curve shown in Figure 3b. There is a noticeable irregularity in the left hand limb, indicating that the grader may have been less effective than the rotary grader at least under some conditions of use. In that form they are not suitable for logit analysis. To estimate a mean retention size, data from trials in which there was a high retention of scallops with SH less than 75 mm were removed. These removed sets included those from trials 9, 10, 11 and 12 (Table 1), and the modified data (i.e. that pertaining to trials 6, 7, 8 and 13) are given in Figure 3c. Logit analysis, carried out on scallops between 74 mm and 92 mm SH gave an estimated 50% selection size for the grading chute of 83.4 mm, with 95% confidence limits of ± 0.5 mm.

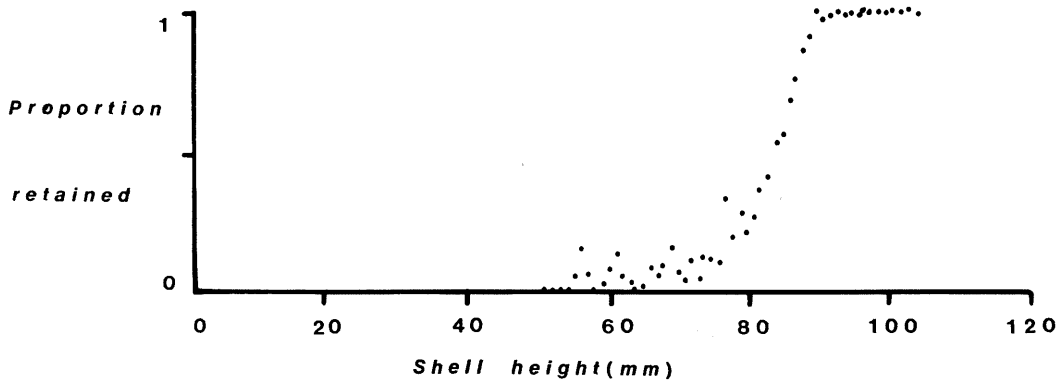

Figure 3c. Proportion of scallops retained versus size for selected trials using sorter with 82 mm holes.

Efficiency

For the purpose of this study, grader efficiency in any trial was defined as the percentage of scallops smaller than the 50% retention size which were rejected by the grader in that trial.

Data on the percentage of scallops with SH less than 87 mm retained by the rotary grader at varying speeds of rotation are given in Table 2. All data have been corrected to size before grading. Comparable data giving retention of scallops smaller than 83 mm SH in trials using the chute grader under varing conditions of chute length and angle of fall are given in Tables 3 and 4.

Table 2. Retention of scallops smaller than 50% retention size (87 mm) by rotary grader

Speed of rotation	Number<87 mm (SH) graded	Number retained	Proportion retained	Efficiency (%)
20	310	13	0.042	95.8
25	293	34	0.116	88.4
30	428	19	0.044	95.6
35	187	37	0.198	80.2
40	372	66	0.177	82.3

Table 3. Retention of scallops smaller than 50% retention size (83 mm) by chute grader with fixed angle of fall (15°) and variable length

Grader tray length (m)	Number<83 mm (SH) sorted	Number retained	Proportion retained	Efficiency (%)
0.5	297	106	0.357	64.3
1.0	328	28	0.085	91.5
1.5	331	48	0.145	85.5
2.0	208	25	0.120	88.0

Table 4. Retention of scallops smaller than 50% retention size (83 mm) by chute grader with fixed length (1.0 m) and variable angle of fall

Angle of fall	Number<83 mm (SH) graded	Number retained	Proportion retained	Efficiency (%)
15°	328	28	0.085	91.5
20°	234	31	0.132	86.8
25°	153	56	0.366	63.4
30°	587	237	0.404	59.6
35°	180	102	0.567	43.3

Variation of 50% retention size with grader perforation size

Fifty per cent retention sizes were estimated for the four chute graders with perforation sizes of 72, 77, 82 and 87 mm using a 15° angle of fall and a tray length of 2.0 m. The selection curves derived from these trials are given in Figure 4 and 50% retention sizes with 95% confidence limits are given in Table 5. The data show irregularity around the retention curve which appears to be a feature of grading trays. This irregularity is reflected in the variation in the relationship between shell perforation size and SH selected out.

Table 5. Variation in 50% retention size with perforation size for chute graders (tray length 2.0 m, angle of fall 15°)

Perforation hole diameter (mm)	Number of scallops	50% selection size* (mm)	95% CI (mm)
72	549	73.1	±0.9
77	360	76.3	±1.0
82	568	84.6	±1.0
87	509	89.5	±1.3

* SH corrected for chipping.

Comparative mortality for machine and hand graded scallops

Eight months after their release 13 tagged scallops from each treatment (7.4% overall) had been recaptured and returned (Table 6). A χ^2 test on expected tag returns from machine and hand graded treatments against observed numbers from each treatment indicated no significant difference in returns between treatments $\chi^2=0.541$, (n.s., $P>0.05$).

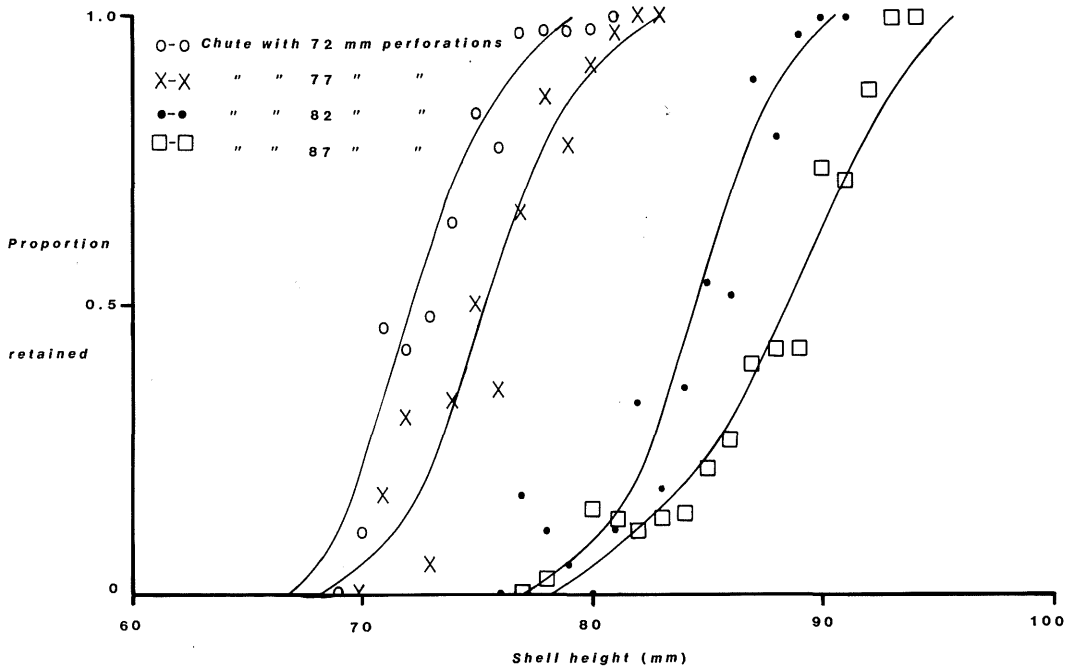

Figure 4. Selection curves for sorting chutes with different perforation sizes.

Table 6. Tag returns from machine and hand graded scallops released on 1 November 1980

Period at liberty (months)	Returns of machine graded scallops	Returns of hand graded scallops
0–1	8	3
1–2	3	2
2–3	1	7
3–4	0	1
4–5	1	0
5–6	0	0
Total after 8 months	13	13
Expected returns*	14.9	11.1

* Expected returns are based on equal ratios from machine and hand graded treatments.

DISCUSSION

Grading equipment is commonly used by Queensland scallop fishermen, which suggests that they have realised there is no economic advantage in retaining small scallops. Results obtained in the present study show that grading efficiency varies both with the type of grader and the conditions under which they are used.

The rotary grader was very effective at slow rotational speed but lost efficiency at higher speeds. Under optimum conditions, the chute grader's efficiency was similar to that of the rotary grader. If the length of the chute was reduced to 1.0 m or less, or the angle of fall exceeded 20°, efficiency decreased noticeably. Field observations indicated that the chute became saturated if more than approximately 250 scallops per minute were graded and grading efficiency declined markedly as a consequence. Such saturation has not been observed during rotary grading operations.

There was an appreciable difference in the 50% retention sizes obtained by the two types of grader with identical sized perforations. There is a greater probability for scallops to be passed across the escapement holes of a rotary grader on the oblique diameter than is the case for grading chutes. As scallops are not truly circular, and the oblique diameter is the smallest identified, the variation in mean selection sizes may be explained by the active method of sorting used in a rotary grader. If scallop boats are compelled to carry grading equipment in future, some allowance will have to be made for this difference in retention size.

The tumbling action of the rotary grader induced more chipping on scallop shell edges than did the more passive action of the chute grader. In a pilot study, scallops graded either by hand or with a rotary grader were tagged and released. There was no significant difference in the ratio of returns to releases from the two treatments, suggesting that there was no differential mortality between them.

Graders, if used properly, will remove a large proportion of scallops below a given size from a catch. Scallops are known to occur in beds which have peak density near the centre falling to near zero on the periphery. Fishing effort is directed towards maximum scallop density. The concept basic to the release of small scallops is that they should be available for recapture after a period of time during which further growth occurs. Therefore there is little point in releasing small scallops in areas of low density where the probability of their recapture is negligible.

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(Accepted for publication 4 February 1986)

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