Evaluation of Intermediate Culture Techniques, Growth, and Survival of the Giant Scallop, *Placopecten magellanicus*, in Passamaquoddy Bay, New Brunswick

G. J. Parsons and M. J. Dadswell

Biological Station
St. Andrews, N. B. E0G 2X0

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by

G. J. Parsons and M. J. Dadswell[1]

Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick E0G 2X0
Canada

[1]Present address: The Great Maritime Scallop Trading Co. Ltd.
P. O. Box 489
Chester, Nova Scotia B0J 1J0

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Culture of the giant or sea scallop (*Placopecten magellanicus*) requires a three step process; spat procurement, intermediate culture, and final grow-out. In Japan, square pearl nets are widely used for intermediate culture but this gear requires extensive handling. Because of the labour required to complete the culture of a cohort, reduction in equipment cost and increases in efficiency to ensure maximum growth and survival of scallops are necessary to attain profitability in Canada. The objectives of this study were to compare the cost and time required for loading and unloading commercially available gear types and compare growth and survival of scallop and fouling of nets during intermediate culture over 8 mon. We examined six gear types (square pearl net, round pearl net, superlantern, Shibetsu, lantern nets and oyster cages) and compared them for standardized cost of net, handling time, net fouling, and survival and growth of scallops. Growth rates in all gear types were similar (approximately 0.12 $mm \cdot d^{-1}$). Growth exhibited a seasonal pattern of slower growth during winter (0.08 $mm \cdot d^{-1}$) and faster growth during summer (0.18 $mm \cdot d^{-1}$). Survival of scallops in lantern and Shibetsu nets was about 95% but was lower in other gear types. Fouling was worst on pearl nets compared to the other gear types. Using a model to assess the overall cost-effectiveness associated with raising 100,000 scallops through intermediate culture for each net design, we concluded that scallop production was most effective and least expensive in small mesh lantern nets and Shibetsu nets; handling times were 119.1 hr and 123.9 hr and costs for labour were \$3015 and \$2990, respectively. Approximately 0.0012 hr/scallop and \$0.03/scallop were required to complete intermediate culture. We recommend that aquaculturists employ small-mesh lantern nets or Shibetsu nets and evaluate their own choice regarding ease of handling and personal preference.

Key words: Gear type, fouling, growth, survival, economic assessment

RÉSUMÉ

Parsons, G. J., and M. J. Dadswell. 1994. Evaluation of intermediate culture techniques, growth, and survival of the giant scallop, *Placopecten magellanicus*, in Passamaquoddy Bay, New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. 2012: vii + 29 p.

La culture du pétoncle géant (*Placopecten magellanicus*) comporte trois étapes: obtention du naissain, prégrossissement et grossissement. Au Japon, les paniers japonais carrés sont largement utilisés pour le prégrossissement, mais ceux-ci demandent beaucoup de travail. Vu la somme de travail nécessaire pour élever une cohorte, la réduction des coûts d'équipement et l'accroissement de l'efficacité de l'élevage, de façon à ce que la croissance et le taux de survie des pétoncles soient maximisés, sont nécessaires si on veut assurer la rentabilité de ce type d'exploitation au Canada. Cette étude avait pour objectifs de comparer les coûts et le temps requis pour le chargement et le déchargement des pétoncles dans différents types d'engins commerciaux, ainsi que les taux de croissance et de survie des pétoncles et l'encrassement des filets durant le prégrossissement, sur une période de 8 mois. Nous avons considéré six types d'engins (casier japonais carré, casier japonais rond, superlanterne, Shibetsu, filets lanternes et casiers à huîtres) pour les comparer à divers chapitres: coût normalisé de ces divers engins, temps de manutention, encrassement des filets, et taux de survie et de croissance des pétoncles. Aucune différence notable n'a été observée dans les taux de croissance, qui étaient d'environ 0,12 mm/j. Le taux de croissance était plus bas en hiver (0,08 mm/j) qu'en été (0,18 mm/j). Le taux de survie dans les filets lanternes et Shibetsu était d'environ 95 %, et plus faible dans les autres engins. Les paniers japonais ont montré le plus fort encrassement. À partir d'un modèle d'évaluation de la rentabilité globale pour le prégrossissement de 100 000 pétoncles, nous avons déterminé que les filets lanternes à petites mailles et les filets Shibetsu étaient les plus efficaces et les plus économiques; les temps de manutention ont été de 119,1 et 123,9 heures, et les coûts de la main d'oeuvre, de 3015$ et 2990$, respectivement. Avec ces deux types d'engins, le prégrossissement d'un pétoncle aura donc dinalement exigé 0,0012 heur et 0,03$. Nous recommandons aux aquaculteurs d'utiliser les filets lanternes à petites mailles ou les filets Shibetsu, et de faire leur choix en tenant compte de la facilité d'utilisation de ces engins et, bien sûr, de leurs préférences personneles.

Mots clés: type d'engin, encrassement, croissance, survie, évaluation économique

INTRODUCTION

Aquaculture operations farming the giant or sea scallop, *Placopecten magellanicus* (Gmelin, 1791), have been started with increasing frequency during the last 5 yr throughout Atlantic Canada (Lanteigne and Mallet 1991). Initial research which recognized the aquaculture potential of this species (Naidu and Cahill 1986, Wildish *et al.* 1988, Dadswell and Parsons 1991, 1992) is now being put to practical use. Some of the features of this species, which make it attractive for commercial development, include availability of wild spat, rapid growth to a large size, and wide market acceptability with high value. The most popular form of farming has been suspension culture either with nets or by earhanging (Imai 1977, Ventilla 1982), but an economic and technical evaluation of this method has yet to be demonstrated for the giant scallop (Naidu *et al.* 1989). Suspension culture involves high costs for labour and equipment and can only be successful if there is good scallop growth and survival.

Giant scallop culture techniques that are being adapted in Canada are based on the Japanese model (Ventilla 1982, Naidu and Cahill 1986). The steps are spat procurement (either wild spat collections or hatchery-produced seed), intermediate culture in several different net designs, and final grow-out to market size in either nets or by earhanging. Aquaculture research concerning the giant scallop has dealt with spawning period (Parsons *et al.* 1992), maximizing spat collection (Naidu and Scalpen 1979, Naidu *et al.* 1981, Dadswell *et al.* 1988, Parsons *et al.* 1990), growth (Parsons *et al.* 1993), optimum stocking densities for intermediate culture (Parsons and Dadswell 1992), grow-out strategies (Wildish *et al.* 1988, Dadswell and Parsons 1991, 1992) and the use of different populations to obtain longer periods of market availability (Dadswell and Parsons 1992).

Intermediate culture using square pearl nets is a widely practiced method for growing all species of scallops (Ventilla 1982, Wallace and Reinsnes 1984, Naidu and Cahill 1986, Aoyama 1989). Despite their universal acceptance, no previous studies have explored the feasibility of using different technology or have examined whether pearl nets are the best technology available for intermediate grow-out. Several factors should be considered when selecting gear for intermediate grow-out, such as: initial cost, ease of handling, time required to load and unload scallops, durability, susceptibility to fouling, and growth and survival of the scallops. Personal preference of a gear type is also a factor in gear selection.

The aim of this study was to compare and evaluate the performance of different gear types (nets) for intermediate culture of juvenile giant scallops. The work was carried out in two parts. In 1991-92, we assessed cost, handling time, and handling mortality over a 1 and 5 mon period of culture in the different nets. In 1992-1993, a study was conducted over an 8 mon period (July 1992 to March 1993) in order to assess growth and survival of scallops as well as the degree of fouling prevalent with each gear type. A second assessment of handling time was also carried out to compare to our 1991-92 findings.

MATERIALS AND METHODS

The performance of six different net designs (square base pearl net, round base pearl net, lantern net, Shibetsu net, superlantern net, and oyster tray) for intermediate culture of giant scallops was evaluated in two separate studies conducted during 1991-92 and 1992-93. Giant scallop juveniles (1991-92) and spat (1992-93) were stocked at commercial densities and nets were suspended on a horizontal line, 3 m off-bottom, at our scallop aquaculture site off Tongue Shoal, Passamaquoddy Bay, New Brunswick.

1991-92

This experiment was conducted during December 1991 to July 1992. Six net designs were used, including three different mesh sizes of the traditional square base pearl nets (3, 6, and 9 mm). A guideline used in stocking scallops is not to exceed a 30% floor coverage of the net at the end of a grow-out cycle (Imai 1977). Stocking densities in pearl nets can range from 5 to 300 scallops per net depending on shell size. During the first stage of this project, we stocked nets with juvenile scallops (mean shell height=42.6 mm, SD=1.66 mm, range=40 to 45 mm) at approximately 20 scallops/0.1 m^2. Time needed to load the nets, and after a 1 and 5 mon period of deployment, time required to unload the nets were determined. Survival and growth of scallops were analyzed after each period. A description of the six different net designs used in this experiment follows:

<u>Pearl nets, square base</u>

<u>Gear Type</u>
Pearl net, side-loading, square base, 3, 6, and 9 mm mesh.

<u>Description</u>
Side loading, square base pearl nets are 34 cm by 34 cm for a floor area of 1156 cm^2 or 0.116 m^2 (Table 1). Nets are constructed of a vinyl coated wire (various gauges) and multifilament polyethylene mesh. The net assumes a pyramid shape when complete (Fig. 1). Mesh sizes vary from 1.5 mm to 18 mm and, for this experiment, we used mesh sizes of 3, 6, and 9 mm. Suspension ropes are built in and permanently attached to each net. The side opening is closed with stiff monofilament polyethylene line (Fig. 2).

<u>Cost</u>
Cost/net varies with mesh size and ranges from $1.86 to $2.05 for small orders (Table 1). However, for shipments of 20,000 nets (a container), quotes in February

1992 were $1.21/net.

Stocking Density

Pearl nets were stocked with 40 to 45 mm scallops at 20/floor (Fig. 2).

Stocking Procedure

Nets were untied from each other and the sides are opened. One person counts out the scallops and loads the net and a second person ties the side opening shut. Nets are then tied together by their suspension ropes in strings of three nets for deployment at sea.

Pearl net, round base

Gear Type

Pearl net, top-loading, round base.

Description

Top loading pearl nets with a round base are 35 cm in diameter for a floor area of 960 cm^2 or 0.096 m^2 (Table 1). Construction is of multifilament polyethylene mesh and vinyl coated wire of various gauges. The net assumes a conical shape when complete (Fig. 3). Nets come in mesh sizes ranging from 4 mm to 12 mm. We used 6 mm mesh for this experiment. Suspension ropes are built into the net and are permanently attached. The top opening is closed with a nylon rope which is knotted to the suspension rope.

Cost

Cost of a 6 mm mesh round pearl net was $2.53 (Table 1). Cost/net varies with mesh size. Reductions in cost can also be obtained for these nets by ordering in lots of 20,000.

Stocking Density

Round base pearl nets were each stocked with 20 scallops/net of 40 to 45 mm shell height (Fig. 4).

Stocking Procedure

Nets were untied and opened. One person counted the scallops and loaded the nets. The second person tied the nets closed then tied nets together by their suspension rope in a string of three nets.

Superlantern

Gear Type

Superlantern net, side loading, round base, multi-tiered.

Description

Superlantern nets are assembled while loading the scallops. Each level consists of a round base 40 cm in diameter for a floor area of 1260 cm^2 or 0.126 m^2 (Table 1). The cross pieces and rim of the bases are constructed of a heavy grade plastic and covered with a nylon monofilament mesh (Vexar type). The mesh size is not uniform and varies from about 2 to 4 mm. The nets are multi-tiered and can be constructed in one to ten levels. To construct the nets the bases are placed in a metal stand and are spaced 10 cm apart (Fig. 5). After the scallops are loaded onto each level, a monofilament mesh sheath (9 mm mesh size) is dropped over the stand and bases (Fig. 6). The bases have outwardly projecting teeth which extend through the nylon mesh sheath securing the bases in place. The completed net is then lifted out of the metal stand (Fig. 7).

Cost

A net base costs $2.50 each and the mesh costs $1.00/m. For a five-tiered net, the total cost is $12.65 or $2.65/level (Table 1).

Stocking Density

Stocking density was 20 scallops/level of 40 to 45 mm shell height for a total of 100 scallops/net (Table 1).

Stocking Procedure

One person set up the metal stand and plastic bases. The second person counted and loaded the scallops. Both people then placed the mesh sheath over the bases and stand. The completed net was then removed and the ends were tied shut.

Shibetsu

Gear Type

Shibetsu net, side loading, round base, multi-tiered.

Description

Shibetsu nets are five-tiered round nets with a 36 cm diameter for a floor area of 1020 cm^2 or 0.102 m^2/tier (Table 1). Construction is of a vinyl coated wire with multifilament polyethylene mesh (Fig. 8). Shibetsu nets are very compact and quite heavy compared to the other types of gear. Mesh sizes range from 3 mm to 36 mm and a mesh size of 6 mm was used in this study. Suspension ropes are built into each level of the net. The side of each level is closed by simply folding the mesh over the top of the wire frame of the previous level (Fig. 9).

Cost

Cost of nets varies with mesh size. The cost of the 6 mm Shibetsu we used were $15.45/net or $3.09/level (Table 1) and costs can be reduced with large orders.

Stocking Density

Nets were stocked with 20 scallops per level of 40 to 45 mm shell height for a total of 100 scallops/net (Table 1).

Stocking Procedure

Nets were opened from the top. Only one person was required to count, load, and close the nets.

Lantern

Gear Type

Lantern net, side loading, round base, multi-tiered.

Description

Side-loading, five-tiered lantern nets with a 50 cm diameter were used in this study. Floor area/level was 1960 cm^2 or 0.196 m^2 (Table 1). Construction was of vinyl coated wire (various gauges) and multifilament polyethylene mesh (same material as the pearl nets) (Fig. 10). Mesh sizes vary from 6 mm to 60 mm and a 6 mm mesh was used in this study (Table 1). Suspension ropes are built into each level of the net. The side opening is closed with a stiff monofilament line (Fig. 11).

Cost

Five level lantern nets used in this study cost $20.50/net (Table 1). Net costs vary with mesh size and number of levels (5 or 10).

Stocking Density

As the floor area was greater in these nets the stocking density used was 30 scallops/level of 40 to 45 mm shell height for a total of 150 scallops/net.

Stocking Procedure

The sides of the nets were opened. The net was laid out on its side partially submerged in seawater. One person counted and loaded each level of the nets. The second person tied the side openings closed.

Oyster tray

Gear Type

Oyster tray, end loading, rectangular base, multi-tiered.

Description

Oyster trays are rectangular and measure 1 m by 0.4 m for a floor area of 400 cm^2 or 0.4 m^2 (Table 1). They are made of polyvinyl mesh (9 mm vexar) folded over and formed into flattened tubes (Fig. 12). Generally 4 levels are fastened together into one unit with separation lugs. Each tray opens at both ends and when loaded they are tied shut. This equipment is generally handmade (we know of no commercial source) and the price quoted is for material only.

Cost

Oyster trays with four levels cost $12.00 or $3.00/level (Table 1).

Stocking Density

Trays were stocked with 60 scallops each (40 to 45 mm shell height) for a total of 240 scallops/unit.

Stocking Procedure

Scallops were counted by one person and placed in containers. The second person loaded the oyster tray from the container, through the end, and fastened the tray end shut with an elastic cord and hook or snap ties.

1992-93

The second part of our study was conducted between July 8, 1992 and March 26, 1993. Five intermediate grow-out gear types were used: square pearl nets, round pearl nets, five-level Shibetsu nets, five-level superlantern nets, and five-level standard lantern nets. All nets were 6 mm mesh and were stocked at a density of approximately 300 scallops/m^2 of floor area (Table 2). Giant scallops were sorted from spat collection bags, size selected (mean=10.8 mm, SD=1.7 mm, range=7.4 to 14.0 mm), and loaded immediately into grow-out nets. Stocked nets were deployed at our aquaculture site off Tongue Shoal in Passamaquoddy Bay where they were dispersed randomly along a horizontal line and suspended 3 m off-bottom. One third of the number nets were retrieved every 3 mon (October, December 1992, and March 1993). Deployment and retrieval of nets was by SCUBA diving.

Loading and unloading times were recorded during initial stocking and during each sampling period, respectively. At each sampling period, nets were assessed qualitatively for fouling, live and dead scallops were counted to determine mortality rates, and scallops were taken for growth analysis. At the start of the experiment, 30 juveniles from spat collectors were analyzed for shell height (S_h), total wet weight of the entire scallop in the shell (W_t), and wet meat weight (W_m). During each sampling period all scallops from each net type were measured for shell height. In October and December, a random sub-sample of 30 scallops was obtained from scallops pooled from all the nets and mean W_t and W_m determined. However, for the final sample (March 1993), 10 scallops were randomly taken from each of the 5 net types. Mean W_t and W_m were determined for each net type and then pooled (n=50 scallops).

RESULTS

1991-92

Mortality and Growth

There were no handling mortalities or growth after a 1 mon period in suspended culture. High survival was probably a result of handling scallops during the winter at cold water temperatures. Survival of scallops after a 5 mon period was still very high and ranged from 94.4% for oyster trays to 98.7% for Shibetsu and superlantern nets and 100% for the different pearl nets and lantern nets. There was no significant difference in survival among the nets (ANOVA, $p>0.05$). There was a significant difference in growth rate among the different net types over the 5 mon period (ANOVA, $p<0.001$). Average daily growth ranged from 0.011 $mm \cdot d^{-1}$ for oyster trays to 0.097 $mm \cdot d^{-1}$ for superlanterns (Table 3).

Stocking and Unloading Time

Pearl net, square base

Counting out scallops, loading into the net, and tying up the opening averaged 37.5 to 47.5 s/net at 20 scallops/floor for mesh sizes of 3 to 9 mm, respectively (Table 4). Unit effort of two people to load and finish was 12.6, 16.0, and 16.0 scallops/min/person for 3, 6, and 9 mm mesh size, respectively (Table 4). Unloading the pearl nets involved having one person separate the nets, untie the opening, and unload the scallops into a container. Unloading time for three types of nets was 73, 92, and 140 s for 9, 6, and 3 mm mesh, respectively (Table 3). Unit effort for unloading was 49.3, 39.1, and 25.7 scallops/min/person for the three mesh sizes, respectively (Table 3).

Pearl net, round base

Time required to count and load scallops and tie the nets was 270 s for two people for the 6 nets (Table 4). Average time per net was 45 s and unit effort was 13.3 scallops/min/person (Table 4). Unloading time for 3 round pearl nets was 80 s and unit effort was 45.0 scallops/min/person (Table 3).

Superlantern

It required 48.0 s to load each level of net and sheath the levels for a total unit effort of 12.5 scallops/min/person (Table 4). This was the slowest of all nets to load and our times do not include the addition of suspension ropes to each net. Superlantern nets required two people to unload. Unloading time for 3 nets was 135 s for a unit effort of 66.7 scallops/min/person (Table 3).

Shibetsu

Total loading time for one person was 34.5 s/level/net and unit effort was 34.8 scallops/min/person, the highest value for all the nets tested (Table 4). It took one person 189 s to unload 3 Shibetsu nets (each with five levels) for a unit effort of 95.2 scallops/min/person (Table 3).

Lantern

Loading and tying time was 50 s/level/net and unit effort was 18.0 scallops/min/person (Table 4). Three lanterns nets were unloaded in 124 s by one person. Unloading unit effort of 217.7 scallops/min/person was the greatest speed for this experiment (Table 3).

Oyster tray

It required 360 s for two people to load the four levels of the oyster tray (Table 4). Unit effort was 20.0 scallops/min/level. Two levels of the oyster tray were unloaded by two people in 31 s for a unit effort of 116.1 scallops/min/person (Table 3).

The unloading rates were lower for the July 1992 sampling period but showed a similar pattern as that of March 1992 (Table 3).

1992-1993

The five different net designs used in this experiment were square pearl nets, round pearl nets, superlantern nets, Shibetsu nets, and lantern nets and were selected after our 1991-92 study because these nets are commercially available for growers. Shibetsu nets were the most expensive when the price of nets was based on a standardized floor area (Fig. 13) and square pearl nets were least expensive.

Scallops were initially loaded into nets in July 1992. Rate of loading was variable between nets, with Shibetsu nets the fastest to load and superlantern nets the slowest (Fig. 14 and Table 5). Considering only net price and similar stocking densities, cost per scallop was lowest for square pearl nets and highest for Shibetsu nets (Table 2).

Scallops were sampled on three occasions; in October and December 1992 and March 1993. Rate of unloading varied both between nets and between different sampling periods (Tables 6, 7, and 8) Lantern nets were consistently the fastest to unload, with rates ranging from 35 to 84 scallops/min/person (Fig. 15). Round pearl nets were consistently the slowest to unload with rates of only 9 to 12 scallops/min/person but this was caused largely by fouling (Fig. 15).

Fouling organisms encountered on the nets resulted from the larval settlement of blue mussels, sea stars, tunicates, red filamentous algae, and bryozoans. Fouling of square pearl nets was predominantly by sea stars and mussels; round pearl nets mainly mussels, some sea stars, and red algae; Shibetsu nets a few mussels and sea stars; superlantern nets mainly mussels and tunicates and a few sea stars; and lantern nets mainly sea stars, a few mussels and tunicates. By the end of the experiment, square pearl nets were heavily infested with large sea stars, and round pearl nets with large mussels. Levels of fouling were lower in the other net types.

Survival of scallops in the lantern nets and Shibetsu nets was very high (>95%) throughout the experiment (Fig. 16). Survival in the other three nets was lower after 3 mon of growth; the number of scallops remaining in these nets was between 60 and 75% (Table 6). After 8 mon of grow-out, 72% of the initial scallops remained in the superlantern nets and <50% for both types of pearl nets (Fig. 16). These survival levels were lower than in other studies for pearl nets where survival rates were >90% after 1 yr (Parsons and Dadswell 1992). Survival is strongly influenced by fouling which depends on the time of net deployment.

The initial samples of scallops had a mean size of 10.8 mm (SD = 1.7 mm, range = 7.4 to 14.0 mm). Scallops grew rapidly in the first 3 mon of grow-out in all nets and mean shell heights ranged from 29.7 to 32.8 mm for Shibetsu nets and round pearl nets, respectively (Fig. 17). Average rate of growth was 0.20 to 0.24 $mm \cdot d^{-1}$ over this period. Range in mean shell height of scallops after 5 mon was 38.1 mm for lantern nets to 43.0 mm for superlantern nets (Fig. 17) which corresponded to an average daily growth of 0.17 to 0.20 $mm \cdot d^{-1}$. Little growth occurred between December 1992 and March 1993, and the final mean shell heights ranged from 38.1 to 45.3 mm for square pearl nets and superlantern nets, respectively (Fig. 17). The overall average growth rate for the period of July 1992 to March 1993 was 0.09 to 0.13 $mm \cdot d^{-1}$. For each sampling occasion mean shell height was significantly different among net type (ANOVA, $p<0.001$).

At the end of the experiment, there was no significant difference among wet meat weight of scallops and net type when controlling for shell height (ANCOVA, $p<0.01$) but total wet weights were marginally significant among net types (ANCOVA, $p<0.05$, $p>0.01$). Total wet weights ranged from 2.5 to 16 g for 31 to 58 mm scallops, respectively (Fig. 18). Individual wet meat weights varied from 0.25 to 1.9 g for 31 to 58 mm scallops, respectively (Fig. 19). Overall total weight-shell height relationship for the complete grow-out period was

$$W_t = 8.507 \times 10^{-5} S_h^{3.034} \quad \text{(Fig. 20)}$$

and overall wet meat weight-shell height relationship was

$$W_m = 5.310 \times 10^{-6} S_h^{3.233} \quad \text{(Fig. 21).}$$

A simple model to assess the overall cost effectiveness (survival, labour, and gear) associated with bringing 100,000 scallops to market for each different design of net was developed for 1991-92 and 1992-93 (Table 9 and 10). Loading times were based on the initial number of scallops required, after accounting for mortality, whereas time required for unloading was based on obtaining 100,000 scallops for market. Total cost of labour was calculated using an hourly rate of $7.00. Cost of gear was based on the number of nets required assuming a similar stocking density and amortizing the cost of the gear over a 5 yr period. Overall total cost of handling the different nets ranged from $2990 to $6355 for 1992-93 (Fig. 22). Producing scallops in Shibetsu and lantern nets was the least expensive, whereas production costs were highest for round and square pearl nets.

DISCUSSION

Gear cost, time and effort to load and unload, and handling performance were evaluated for eight different gear designs for use in intermediate grow-out of giant scallops. The lowest gear cost, when adjusted for stocking density, was the oyster tray and most expensive was Shibetsu nets. Fastest loading time and highest unit effort was for the Shibetsu nets which have a very simple opening and closing feature enabling them to be loaded quite quickly. The 3 mm mesh square pearl nets were the slowest to load in terms of unit effort. It was particularly difficult to weave the opening shut with this fine a mesh. It was comparatively much quicker to close the 6 and 9 mm mesh pearl nets. It should be added, however, that the 3 mm pearl nets are usually used first in the grow-out period when scallops are small (Imai 1977). At this time, approximately 200 scallops can be loaded into each net and grown for 2 to 4 mon before the stocking density has to be reduced. The 3 mm pearl nets, if used in this manner, makes economic sense because unit effort for loading and unloading would be increased by a factor of 10 at these densities. Lantern nets were quickest to unload, for after the sides were opened, all five levels could be simultaneously emptied through their relatively large side openings. The 3 mm mesh square pearl nets were the slowest to unload, again mainly due to the fine mesh and difficulty in opening the side. Generally, comments on gear performance were limited; oyster trays were very awkward to handle because of their size, superlantern nets were buoyant and required extra weight and also the bases of the superlantern nets did not preserve their original position as the teeth seldom securely lock into the mesh sheath.

Handling times, for both loading and unloading of nets, were slower during the 1992-93 experiment than in 1991-92 study. Slower loading times can be accounted for by the smaller initial size of scallops used in 1992-93 (7.4 to 14.0 mm) compared to the previous work (40 to 45 mm for 1991-92). Slower unloading times in the 1992-93 study were due mainly to fouling. Fouling organisms on the surface of the nets slowed the process of opening the nets as well as the unloading of scallops. The presence of mussels, which byssed the scallops down, made it necessary to pry them off the mesh.

Differences in handling times associated with net type were comparable to our 1991-92 study and were a function of the different net designs. The opening and closing of Shibetsu nets, by simply folding the mesh over the rim of the previous level, was quite rapid compared to other nets. Lantern nets were quite fast to unload, as the monofilament string can be quickly untied for all five levels at once and these nets have wide openings which facilitates the removal of scallops.

Overall handling mortality of scallops was 0% for each gear type for 1991-92. This excellent rate of survival was due in part to careful handling, size of the scallops (40 to 45 mm shell height) and the fact that they were handled under cool air (winter) temperature conditions. Heat stress can cause an initial handling mortality of about 9% during summer operations (Parsons and Dadswell 1992). There was a limited amount of growth mainly due to the short experimental period and, especially since it took place during the winter months when water temperatures (0.5°C) and food are at a minimum (Parsons and Dadswell 1992).

In 1992-93, survival of scallops in lantern and Shibetsu nets was >90% but was about half that of the pearl nets. Square and round pearl nets and superlantern nets from the October 1992 sample contained a reduced number of scallops, the majority of which were alive, than would be expected if a mortality event had occurred. It is therefore surmised that a number of the initially stocked scallops escaped from these nets but not from the lantern nets or Shibetsu nets. The reason for this is unclear since all nets had the same reported mesh size of 6 mm and a similar size range was used for all nets (i.e. 7.4 to 14 mm). However, scallops may have escaped through the stretched mesh of these nets suggesting that net construction, style, material, etc. may be a factor. No more scallops were lost through the mesh after the October sampling period and survival rate of scallops in these nets from October 1992 to March 1993 was higher.

Growth rate of scallops in each of the net types was similar. Scallops exhibited a typical seasonal growth pattern, with fast growth in the summer and autumn and reduced rates of growth in the winter. Growth rates were similar to those reported elsewhere for giant scallops (Dadswell and Parsons 1991, 1992, Parsons and Dadswell 1992).

Degree of fouling and type of fouling organisms present varied among the different nets. This may be explained, in part, by the different materials of which nets were constructed. Fouling affects both handling time of the nets and survival of scallops within the nets. It is also possible that growth can be hindered, if the fouling community either blocks off water flow through the nets or competes with the scallops for food or space resources. Degree of fouling or at least composition of the fouling organisms can be controlled by changing the time of net deployment.

A simple model summarizing the costs associated with raising 100,000 scallops in intermediate culture was prepared for the 1991-92 study. Several initial conditions were set, including: (1) number of nets required was based on the stocking density and size of scallops used in this experiment, (2) cost of the gear was based on the price quoted for small orders, (3) cost of nets was amortized over an average life expectancy of 5 yr for all gear types, (4) the only labour considered was loading and unloading times (i.e., time required to deploy and retrieve the nets was not included), and (5) labour was set on an hourly rate of $7.00. Considering these premises, total costs of producing 100,000 scallops in intermediate culture ranged from $1684 to $3666 for the different gear types (Table 9). The greatest proportion of the total cost was attributable to the initial cost of the gear. Any savings which may be incurred by price comparisons between suppliers or by ordering bulk quantities would have a significant impact on reducing overall costs associated with this grow-out stage. For instance, in 1991-92 cost of 6 mm pearl nets could be reduced to $1.21 each if 20,000 (a container full) was ordered at one time, reducing the overall cost to grow 100,000 scallops to $2238 from $2838.

A similar model was constructed to summarize costs of handling the nets, survival of scallops in the nets, and cost of the gear for 1992-93. Pearl nets are frequently used because they are inexpensive and identified with scallop culture throughout the world. Our evaluation, however, suggests that despite their high initial cost, lantern nets and Shibetsu nets out-performed pearl nets when labour was factored into the cost equation. We have assumed that each of the different nets would have a 5 yr life expectancy but durability of the different gear types has yet to be determined. Design of superlantern nets, for example, is such that the external mesh must be replaced each time the scallops are removed. The increased cost of additional mesh was not accounted for in this model.

There are several important factors which need to be considered when deciding on the best type of gear to use for intermediate growth and some can only be effectively evaluated by observing the nets underwater. For example, if the net or tray is large, the current will cause the net to be continually slanted, which results in all the scallops being piled up on one side. Likewise, if nets are too light, extra weight may be required. Lastly, durability of the nets should be assessed with a long-term study in order to determine what is a reasonable life expectancy for all the gear types.

When scallop aquaculturists have to decide which nets to choose for intermediate culture a number of factors will influence their decision. From experience, we believe personal preference will play a large role; some growers just like one type of gear better than another. Gear performance is not necessarily a factor that will be considered, especially if the person has no prior experience with a new type of net, e.g. a Shibetsu net. Further, in any business climate growers may be able to deal for better prices for a certain type of gear. The personal situation of individual growers should also be taken into account. Someone who has time but limited funds may choose the oyster tray strategy (i.e. low cost and time to construct), whereas growers with funds may wish to buy manufactured gear. We recommend that scallop aquaculturists try using Shibetsu and lantern nets and evaluate the performance of these nets for themselves.

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Table 1. Net type and dimensions, mesh size, costs, stocking density and unit prices during 1991-92.

Net type	Size (m)	Area (m^2)	Mesh (mm)	Price $/level	Price $/net	# Scallops/ net	Price ¢/scallop
Pearl-sq	0.34x0.34	0.116	9	1.86	1.86	20	9.30
Pearl-sq	0.34x0.34	0.116	6	1.81	1.81	20	9.05
Pearl-sq	0.34x0.34	0.116	3	2.05	2.05	20	10.25
Pearl-rd	0.35 diam	0.096	6	2.53	2.53	20	12.65
Superlantern	0.40 diam	0.126	9	2.65	12.65	100	12.65
Shibetsu	0.36 diam	0.102	6	3.09	15.45	100	15.45
Lantern	0.50 diam	0.196	6	4.10	20.50	150	13.67
Oyster tray	1.0x0.04	0.400	9	3.00	12.00	240	5.00

Table 2. Net type and dimensions, mesh size, costs, stocking density and unit prices during 1992-93 for giant scallop spat.

Net type	Size (m)	Total area (m^2)	Mesh (mm)	Price $/net	Price $/m^2	# Scallops/ net	Price ¢/scallop
Pearl-sq	0.34x0.34	0.116	6	1.81	15.60	30	6.03
Pearl-rd	0.35 diam	0.096	6	2.53	26.35	30	8.43
Superlantern	0.40 diam	0.630	9	12.65	20.08	175	7.23
Shibetsu	0.36 diam	0.510	6	15.45	30.29	150	10.30
Lantern	0.50 diam	0.980	6	20.50	20.92	200	10.25

Table 3. Net type, growth, unloading time, and unit effort during 1991-92 for juvenile giant scallops.

Net type	# Nets retrieved	# Levels /net	Total # spat	Growth (mm/d)	Unloading time (s)	# People unloading	March scallops /min/ person	July scallops /min/ person
Pearl-sq-9	3	1	60	0.084	73	1	49.3	30.0
Pearl-sq-6	3	1	60	0.074	92	1	39.1	22.8
Pearl-sq-3	3	1	60	0.072	140	1	25.7	21.7
Pearl-rd	3	1	60	0.085	80	1	45.0	40.0
Superlantern	3	5	300	0.097	135	2	66.7	38.0
Shibetsu	3	5	300	0.076	189	1	95.2	49.4
Lantern	3	5	450	0.059	124	1	217.7	73.0
Oyster tray	3	2	120	0.011	31	2	116.1	100.0

Table 4. Net type, stocking density, loading time and effort, and unit effort during 1991-92 for juvenile giant scallops.

Net type	# Scallops/ level	# Levels /net	# Nets deployed	Total # scallops	Loading time (s)	Time/ level (s)	# People loading	Scallops/ min/ person
Pearl-sq-9	20	1	6	120	225	37.5	2	16.0
Pearl-sq-6	20	1	6	120	225	37.5	2	16.0
Pearl-sq-3	20	1	6	120	285	47.5	2	12.6
Pearl-rd	20	1	6	120	270	45.0	2	13.3
Superlantern	20	5	6	600	1440	48.0	2	12.5
Shibetsu	20	5	6	600	1035	34.5	1	34.8
Lantern	30	5	6	900	1500	50.0	2	18.0
Oyster tray	60	4	1	240	360	90.0	2	20.0

Table 5. Net type, stocking density, loading time and effort, and unit effort during (July 8, 1992) for giant scallop spat.

Net type	# Scallops/ level	# Levels /net	# Nets deployed	Total # scallops	Loading time (s)	Time/ level (s)	# People loading	Scallops/ min/ person
Pearl-sq-6	30	1	9	270	585	65.0	2	13.8
Pearl-rd	30	1	9	270	530	58.9	2	15.3
Superlantern	35	5	3	525	540	36.0	2	11.3
Shibetsu	30	5	3	450	900	60.0	2	25.0
Lantern	40	5	3	600	1395	93.0	2	20.0

Table 6. Net type, survival, unloading time, and unit effort (October 1992) for giant scallop spat.

Net type	# Nets retrieved	# Levels/ net	# Scallops	% Survival	Unloading time (s)	# People unloading	Scallops/ min/ person
Pearl-sq	3	1	59	65.6	225	1	15.7
Pearl-rd	3	1	55	61.1	270	1	12.2
Superlantern	3	5	132	75.4	360	1	22.0
Shibetsu	3	5	150	100.0	300	1	30.0
Lantern	3	5	190	95.0	330	1	34.5

Table 7. Net type, survival, unloading time, and unit effort (December 1992) for giant scallop spat.

Net type	# Nets retrieved	# Levels/ net	# Scallops	% Survival	Unloading time (s)	# People unloading	Scallops/ min/ person
Pearl-sq	3	1	47	52.2	205	1	13.8
Pearl-rd	3	1	54	60.0	340	1	9.5
Superlantern	1	5	102	58.3	270	1	22.7
Shibetsu	1	5	143	95.3	332	1	25.8
Lantern	1	5	194	97.0	254	1	45.8

Table 8. Net type, survival, unloading time, and unit effort (March 1993) for giant scallop spat.

Net type	# Nets retrieved	# Levels/ net	# Scallops	% Survival	Unloading time (s)	# People unloading	Scallops/ min/ person
Pearl-sq	3	1	37	41.1	137	1	16.2
Pearl-rd	3	1	42	46.7	281	1	9.0
Superlantern	1	5	126	72.0	307	1	24.6
Shibetsu	1	5	145	96.7	254	1	34.3
Lantern	1	5	187	93.5	133	1	84.4

Table 9. Handling times and costs associated with growing 100,000 juvenile giant scallops in intermediate culture for the different net designs for 1991-92 data.

Net type	Loading time (hr)	Unloading time (hr)	Total time (hr)	Labour cost ($)[1]	Cost of gear ($)[2]	Total cost ($)[3]
Pearl-sq (9)	104.2	33.8	138.0	966	1860	2826
Pearl-sq (6)	104.2	42.6	146.8	1028	1810	2838
Pearl-sq (3)	132.3	64.8	197.1	1380	2050	3430
Pearl-rd	125.3	37.0	162.3	1136	2530	3666
Superlantern	133.3	25.0	158.3	1108	2530	3638
Shibetsu	47.9	17.5	65.4	458	3090	3548
Lantern	92.6	7.7	100.3	702	2734	3436
Oyster tray	83.3	14.4	97.7	684	1000	1684

[1] Based on an hourly rate of $7.00.
[2] Based on a stocking density from Table 1 and amortized over 5 years.
[3] Total cost = labor cost + amortized cost of gear.

Table 10. Handling times and costs associated with growing 100,000 giant scallop spat in intermediate culture for the different net designs for 1992-93 data.

Net type	Loading time (hr)[1]	Unloading time (hr)[2]	Total time (hr)	Labour cost ($)[3]	Cost of gear ($)[4]	Total cost ($)[5]
Pearl-sq	294.6	109.6	404.2	2829	2943	5772
Pearl-rd	231.8	163.4	395.2	2766	3589	6355
Superlantern	204.9	72.2	277.1	1940	2009	3949
Shibetsu	68.7	55.2	123.9	867	2123	2990
Lantern	88.7	30.4	119.1	834	2181	3015

[1] Based on the initial number of scallops (i.e., after accounting for mortality and lost scallops).
[2] Based on a final survival of 100,000 scallops
[3] Based on an hourly rate of $7.00.
[4] Based on a stocking density from Table 1 and amortized over 5 years.
[5] Total cost = labor cost + amortized cost of gear.

Figure 1: A side loading, square based pearl net.

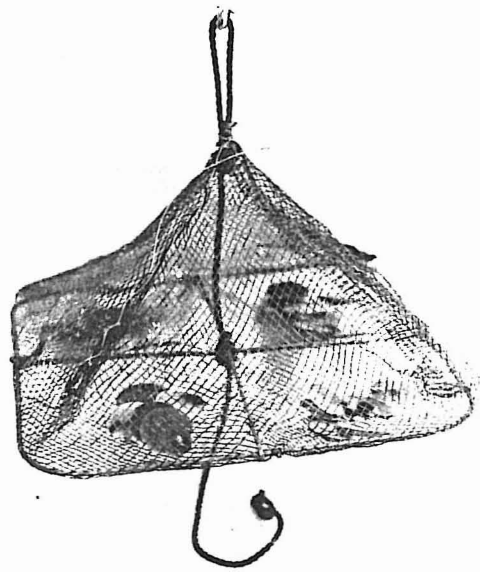

Figure 2: A square pearl net stocked with 20 scallops.

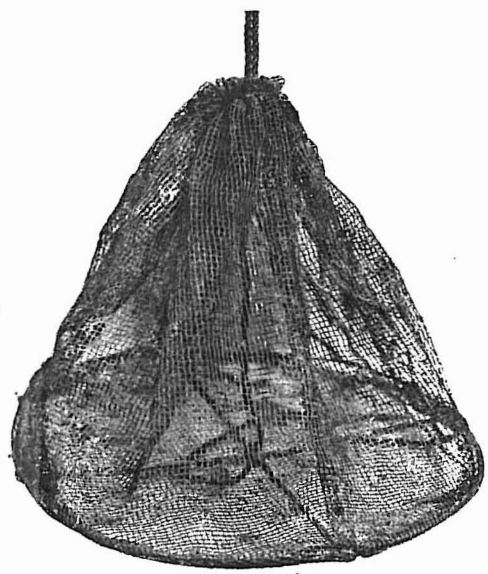

Figure 3: A top loading, round based pearl net.

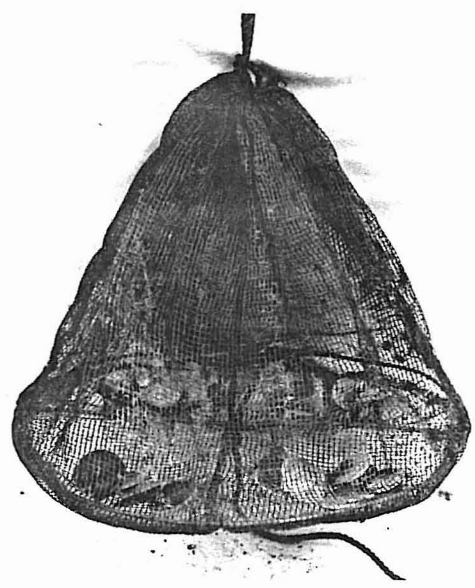

Figure 4: A round pearl net stocked with 20 scallops.

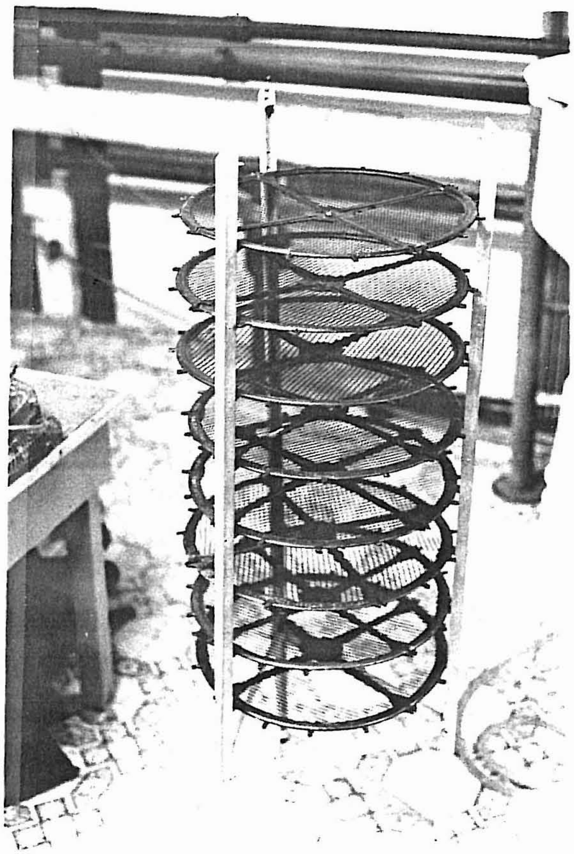

Figure 5: Metal stand and bases for constructing a superlantern net.

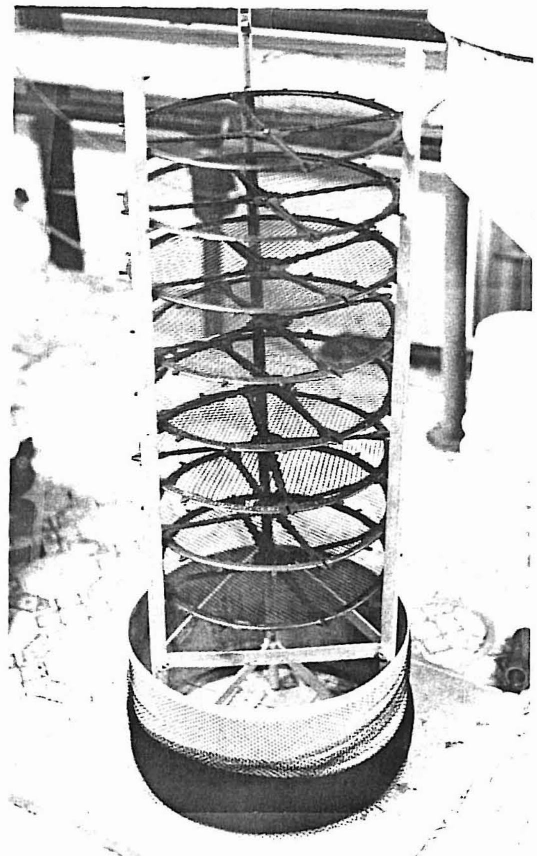

Figure 6: Superlantern net with round bases.

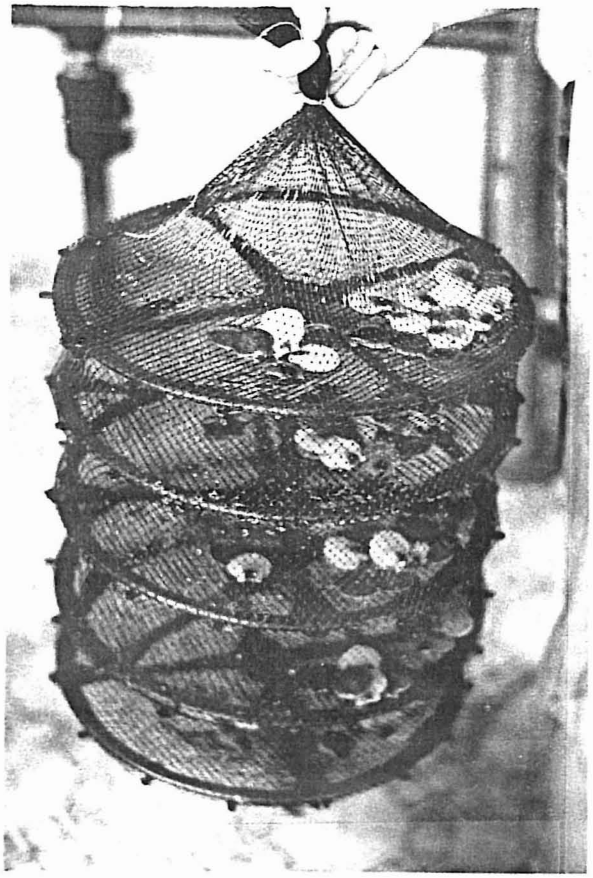

Figure 7: A fully constructed 5 level superlantern net stocked with 20 scallops/level.

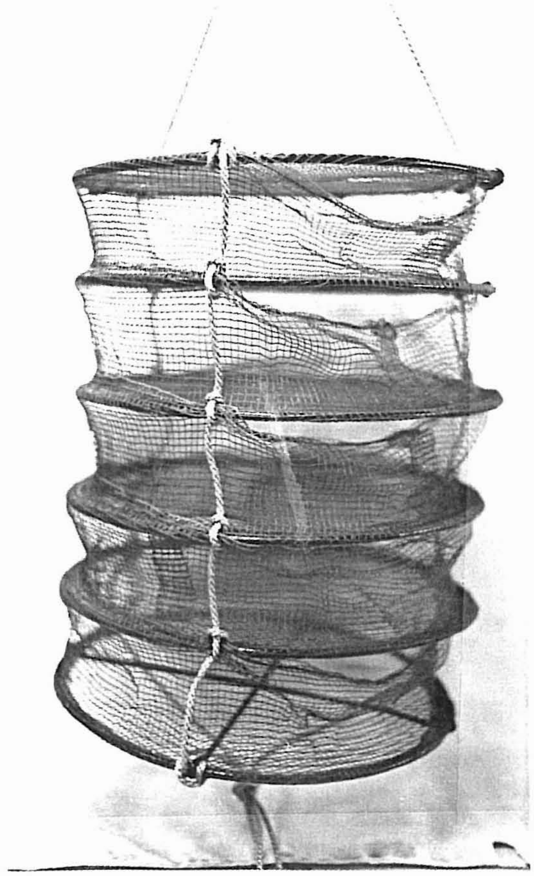

Figure 8: A side loading, round based Shibetsu net. Note mesh opening for loading scallops into net.

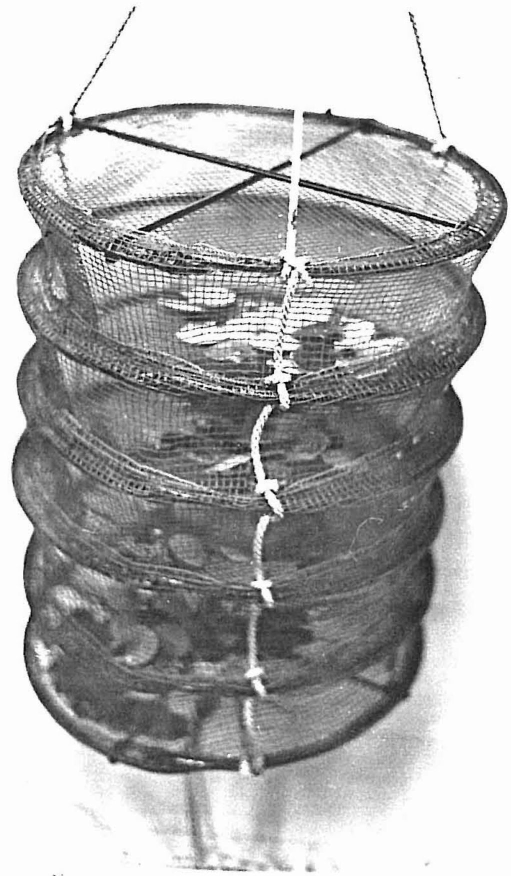

Figure 9: Shibetsu net with 20 scallops/ level.

Figure 10: A side loading, round based lantern net.

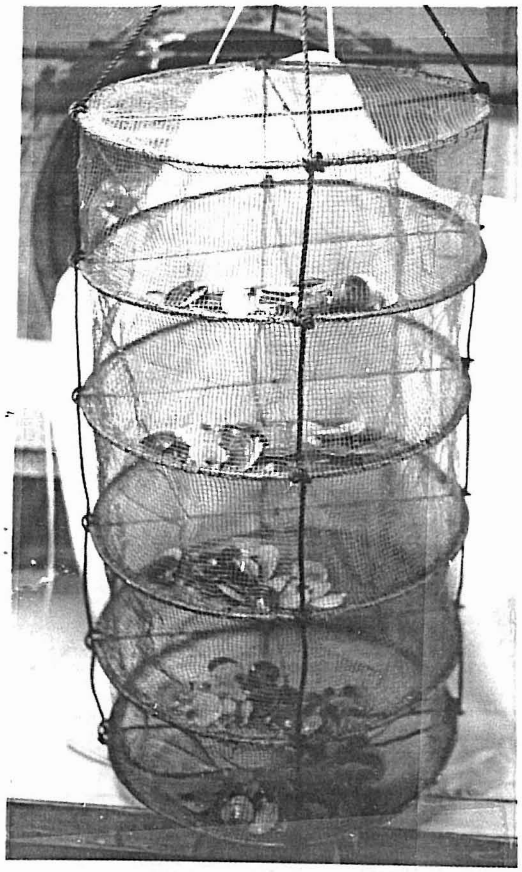

Figure 11: A five level lantern net stocked with 30 scallops/level.

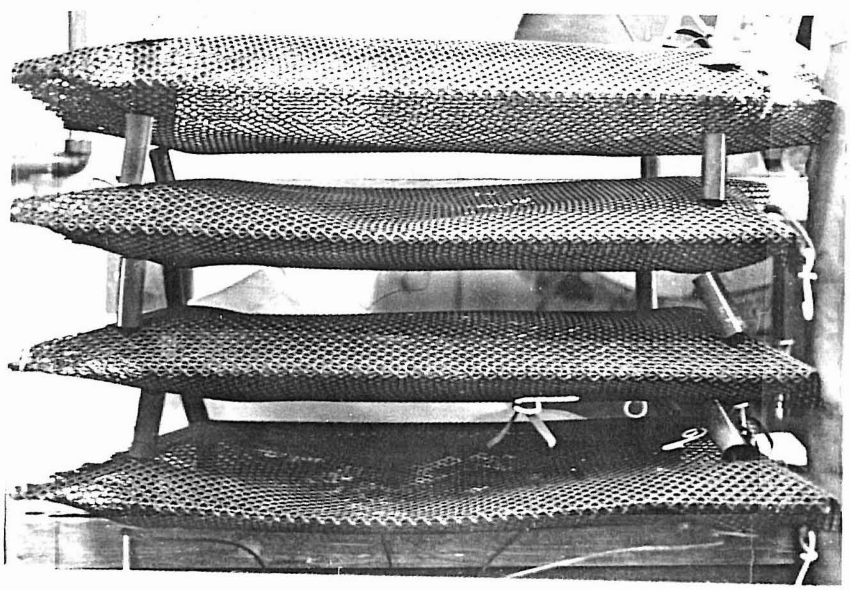

Figure 12: A multi-tiered rectangular Oyster tray. The scallops are stocked at 60/level and are loaded through the ends of each level.

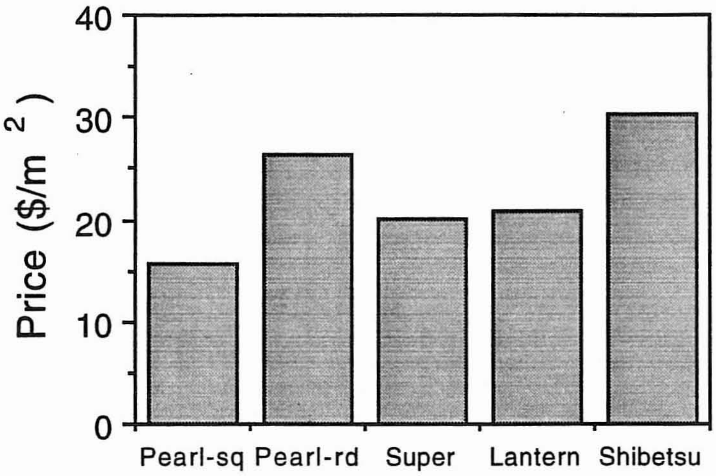

Figure 13. Standardized price of nets based on a common floor area.

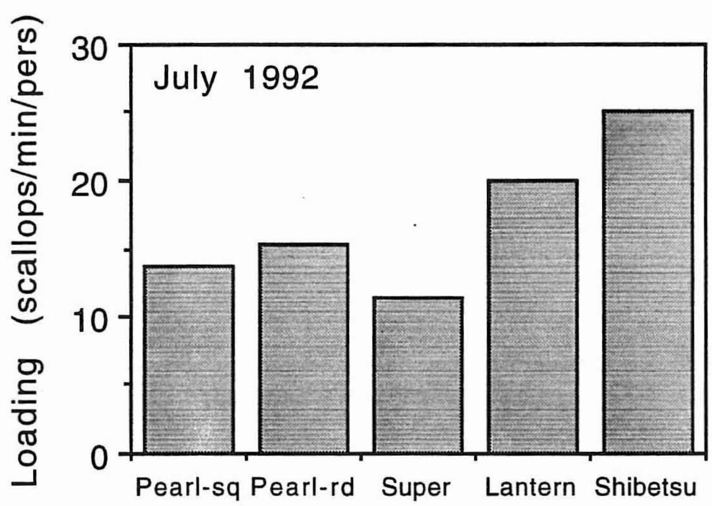

Figure 14. Loading rate of scallops by each net type for July 8, 1992.

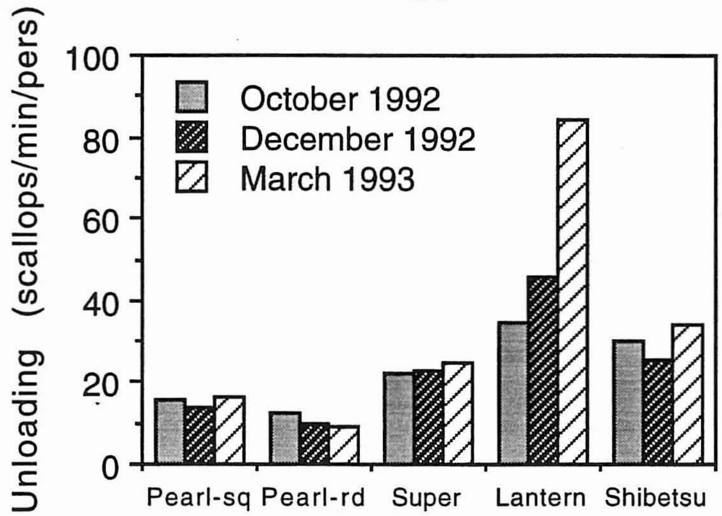

Figure 15. Unloading rate of scallops by each net type for October and December 1992 and March 1993.

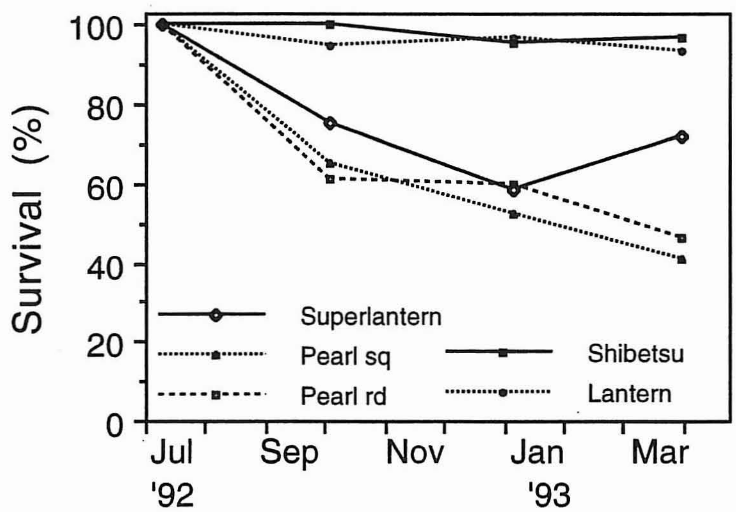

Figure 16. Percent survival of scallops by net type for July 1992 to March 1993.

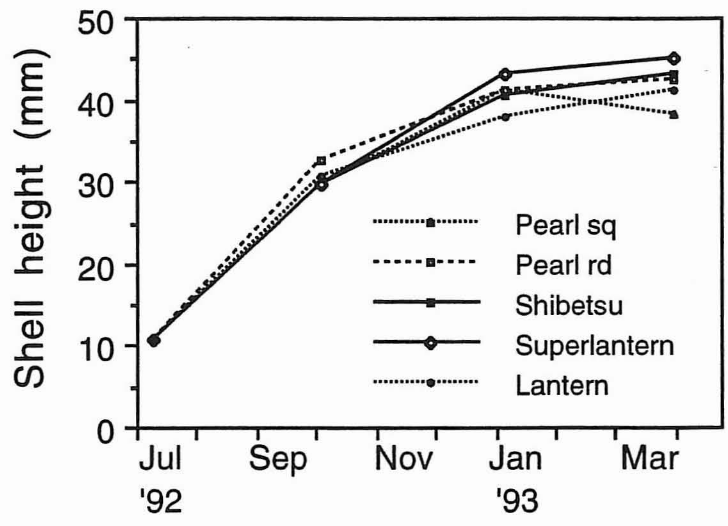

Figure 17. Growth, in shell height, of scallops by net type for July 1992 to March 1993.

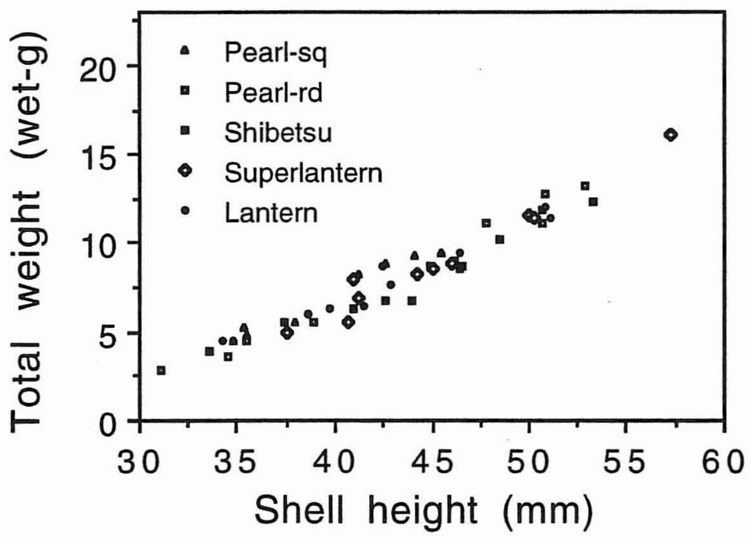

Figure 18. Total wet weight-shell height relationship by net type for scallops sampled during March 1993 (n=10 per net).

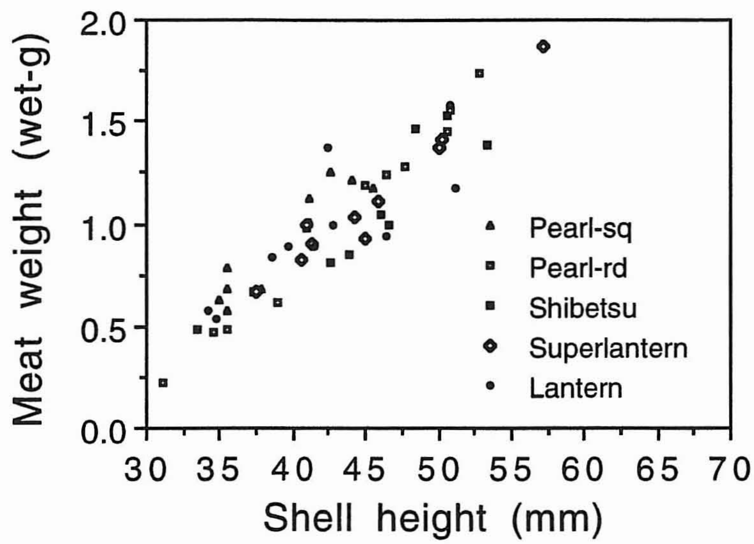

Figure 19. Wet meat weight-shell height relationship by net type for scallops sampled during March 1993 (n=10 per net).

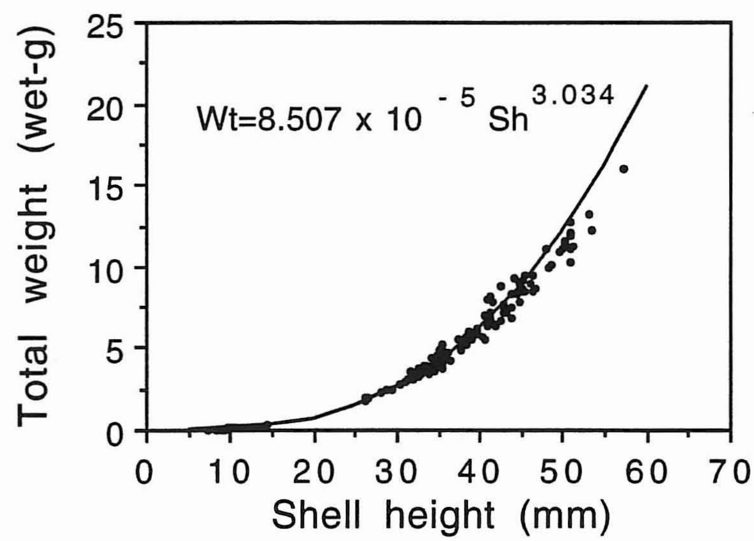

Figure 20. Overall total wet weight-shell height relationship by net type for scallops sampled from July, October, and December 1992 and March 1993 (n=140).

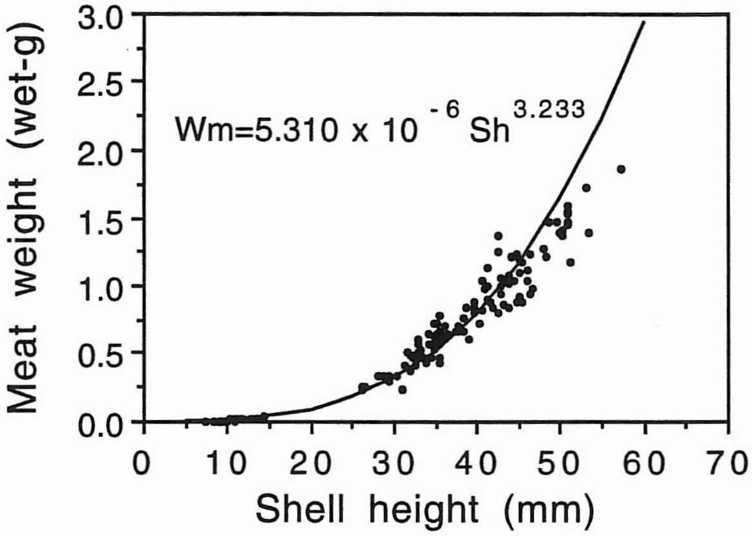

Figure 21. Overall wet meat weight-shell height relationship by net type for scallops sampled from July, October, and December 1992 and March 1993 (n=140).

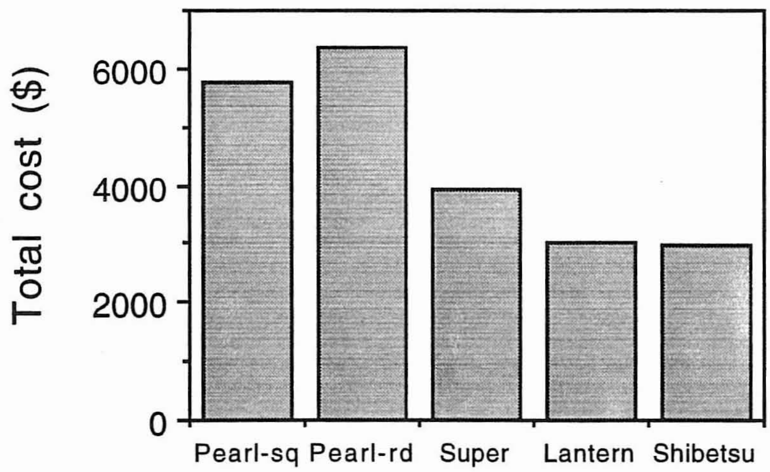

Figure 22. Total cost of labour and gear by net type for handling 100,000 scallops in intermediate suspension culture in Passamaquoddy Bay, 1992-1993.