HERRING IMPOUNDMENT AND PUMPING OPERATIONS
Factors Affecting the Quality of Roe Herring Products

by

D.J. Gillis, C.A. Whiting, R.A. Radley,
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PREFACE

This report has been compiled from several longer reports which are held in the Fisheries Development Division of the Department of Fisheries and Oceans.

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ABSTRACT

Gillis, D.J. et al. 1982. Herring Impoundment and Pumping Operations.
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This report describes three roe herring projects. The first one described, the Sliammon Roe Herring Project, involved seining for herring in Areas 15 and 17, towing them to ponds constructed nearby, capturing the fish inside the ponds once they had reached optimum maturity and processing them as roe herring for the Japanese market. The techniques used succeeded in producing a high-quality roe herring product.

The second one described, the Nimpkish Fishing Company Project, involved seining for herring in Area 12 and towing them to nearby ponds. But because the roe yield proved to be unsatisfactory, the herring could not be processed as roe herring (as planned), so were sold as bait.

The third project described, the Seining and Pumping Operation of Pacific Rim Mariculture Limited, involved seining for herring in Areas 23 and 24 and pumping them into a barge, which transported the fish to the processing plant. The pumping caused gross damage to the fish and thus yielded a poor-quality product.

The quality of fish produced by the seine-to-pond manual operation (Sliammon Project) and the seine-to-pump mechanical operation (Pacific Rim Mariculture project) are then described and compared. The fish produced by the former were found to be vastly superior to those produced by the latter.

Finally, the problems with marketing the roe herring are discussed.

Key words: herring, roe herring, impoundment, pound, ponding, ponds, seining, pumping

RÉSUMÉ

Le présent rapport décrit trois projets portant sur le hareng prêt à frayer. Le premier, le Projet Sliammon, consistait à pêcher le hareng à la seine dans les zones 15 et 17, à le traîner ensuite jusqu'à des viviers aménagés tout près de là, à le capturer dans ces viviers une fois sa pleine maturité atteinte et à le traiter pour le marché japonais du hareng plein. Les techniques utilisées ont permis de produire du hareng plein de grande qualité.

Pour le deuxième, le Projet de la société de pêche des Nimpkish, il s'agissait de pêcher le hareng à la seine dans la zone 12, puis de le traîner jusqu'à des viviers situés tout près. Cependant, comme la production d'oeufs s'est révélée insuffisante, on n'a pu, tel que prévu, traiter les harengs comme des harengs prêt à frayer; aussi les a-t-on vendus comme appâts.

Dans le troisième projet, l'Opération de seinage et de pompage de la société Pacific Rim Mariculture Limited, il s'agissait de pêcher le hareng à la seine dans les zones 23 et 24 puis de transférer le poisson dans une barge à l'aide d'une pompe afin de le transporter à l'usine de traitement. Le pompage a causé de grands dommages aux poissons et il en est résulté un produit de mauvaise qualité.

On décrit et on compare ensuite la qualité du poisson obtenue par le procédé manuel de transport de la seine au vivier (projet Sliammon) et celle obtenue par le procédé mécanique de pompage (projet de Pacific Rim Mariculture). On a trouvé que la qualité du poisson était de beaucoup supérieure avec la première méthode.

Finalement, on étudie les problèmes de commercialisation du hareng prêt à frayer.

Les mots clés: hareng, hareng prêt à frayer, vivier, seinage, pompage

INTRODUCTION

The principal objective of this project and its 1979 forerunner was to pursue the development of improved techniques for the seining, towing and ponding of herring. If such techniques could be shown to be practical, several advantages would result. For example, if ponding could furnish the processor with a high quality raw material avenues would open up for the development of products that would use the whole fish. (At present female roe is extracted and the flesh converted to meal and oil.) And with the ability to hold herring for several weeks, the processor would be able to adhere to orderly production schedules. Furthermore the fishing would be a less competitive and economically secure activity for the fishermen, particularly if products could be developed that would use herring throughout the year rather than mainly during the winter. This would also make the fishery more manageable, and would lessen what, in many quarters, are thought to be the negative effects of concentrating fishing activity on stocks that are preparing to spawn.

A secondary objective of the project was to give processors the opportunity to process and market whole mature frozen herring in Japan in order to test the demand for such a product.

For the foregoing reasons four permits were issued.

Sliammon Indian Seafoods Limited contracted to conduct ponding operations with their attendant construction and maintenance costs, and was issued a permit to take 200 tons from Areas 14, 15 and 17, using the seiner Sea Luck. As a condition of the permit, the captain of the Sea Luck was required to forfeit his vessel's licence to participate in the sac roe fishery.

Nimpkish Fishing Company Limited proposed to conduct another ponding operation and was issued a permit to take 200 tons in Area 12 under the same condition as imposed on Sliammon Indian Seafoods Limited. Fish taken by the seiner Nimpkish Producer were to be processed by the Central Native Fishermen's Cooperative plant at Ucluelet.

S.S.I. Sea Products Limited, which for 20 years has conducted a bait herring operation, was issued a permit to take 50 tons from Area 18 under the condition that it forfeit its licence to participate with a gillnetter in the sac roe fishery.

Pacific Rim Mariculture Limited did not propose to impound herring. Instead, the company proposed to seine and then deliver directly after either brailing or pumping the herring from the seine. Because costs of pond construction and maintenance were not incurred, the company was permitted to take only 300 tons in Areas 13, 23 and 24. Again, it was agreed that the three seiners—Cape Perry, Cape Russel and Salli J Rogers from Canadian Fishing Company Limited—would not participate in the sac roe fishery.

Unfortunately, neither the S.S.I. Sea Products nor Nimpkish Fishing Company operations materialized; the first failed because herring did not enter the trap in sufficient quantities to justify processing them, the second because of a series of misfortunes that delayed fishing and subsequent problems with variable and inadequate roe yield.

The project was supervised and coordinated by Mr. Lloyd Webb of Fisheries and Oceans Canada. Messrs. Dan Gillis, Reed Radley, Chris Whiting and John Wilcox of Schultz International Limited were employed as boat observers to record activities and collect and report data obtained in the course of fishing operations. Mr. Ken Jackson, a private consultant, was retained to monitor and report on product quality with the assistance of Mr. Murray Ross of Schultz International Limited. Mr. Jackson was also responsible for the overall compilation of this report.

1. THE 1981 SLIAMMON ROE HERRING PROJECT - IMPOUNDMENTS

1.1 BACKGROUND

In the seining, towing and ponding project, Mark and Bud Recalma, the captains of two seiners, the Sea Luck and the Qualicum Producer, respectively, agreed to an arrangement whereby the proceeds from both the conventional sac roe fishery activities of the Qualicum Producer and the ponding activities of the Sea Luck would be combined in a pond. Only the Sea Luck was permitted to seine for impounded herring, but the crews of both vessels participated in pond construction and any other non-fishing activities. The combined complement of both vessels totalled 13, a significant work force of fully competent and dedicated fishermen.

Herring was taken off Lund and impounded at the Copeland Islands near Lund in Area 15. They were also taken in Nanoose Bay and impounded there in Area 17. All fish that were processed came from the Copeland Island Impoundments.

This project has generated some important information regarding pond construction and location, pond loading densities, and fish transfer and towing techniques.

1.2 METHODS

1.2.1 Pond Construction

In the course of this project, three ponds were constructed: Pond No. 1, a beach pond; Pond No. 2, a floating pond; and Pond No. 3, another floating pond. Ponds No. 1 and 2 were located in a small bay in the Copeland Islands, 2.6 miles northwest of Lund, B.C.; Pond No. 3 was located in Nanoose Bay. Table 1-1 gives the ponds' dimensions; Figure 1, the locations; and Figure 2, the configuration of Ponds No. 1 and 2.

Pond No. 1. Prior to construction of Pond No. 1, the bottom of the proposed site was examined by a scuba diver. The beaches of the pond were rocky with some *Laminaria* and *Fucus*, but the floor was mud. A few logs, abandoned logging machinery and other debris were also evident.

The floating frame for this pond was constructed of logs, bound together with wire (see Plate 1-1). Twelve logs of varying lengths were used, three on the short side and eight on the long. One short log was used to triangulate the junction between the short and long dimensions (see Plate 1-2). To provide a safe working platform, the working front of this and the other ponds was constructed of double logs lashed with wire.

The total log span was 197 feet by 87 feet. The ends of the span were just aground at low tide. The usable volume of the pond was estimated at 432,000 cubic feet with an estimated maximum capacity of 216 tons of fish when fully loaded. This capacity was based on a theoretical maximum density of one pound of herring per cubic foot.

Webbing was hung inside the frame. It was held against the bottom by heavy lead line and by chain where the net traversed rocky bottom near the beach ends. After the pond was loaded with fish, spawn and algal fouling increased the web's resistance to current. So a diver later placed heavy rocks along the lead line to prevent its being lifted off the bottom by currents. Webs were, for the most part, three strips deep and made of new knotted, tarred-nylon, herring-body web. (A strip is equivalent to 100 meshes each measuring one inch when extended.)

A gate was constructed by passing a section of the pond net to the outside of the log structure, making two vertical cuts in the web on either side of the gate, and lacing in one tapered web panel in each cut. This provided a gate, about 30 feet in width which hung down nearly 28 feet during fish transfer. A piece of lead line was laced to the gate to aid its sinking. This same construction was used in the other ponds as well.

Approximately 120 man-hours were required to construct the pond, including the hanging of the pond web within the frame but not including the construction of the pond web nor its removal and cleaning after the project. In addition, two 65-foot seine boats, two power skiffs and two dead skiffs were used.

Pond No. 2. Pond No. 2 was a floating pond and measured 60 feet by 58 feet by an average depth of 24 feet. The volume was approximately 83,000 cubic feet with an estimated capacity of 41 tons of herring based on a density of one pound of herring per cubic foot of water. The pond web was held in shape by hanging onion sacks filled with 50 to 75 pounds of rocks inside the pond. The sacks were hung on half-inch diameter blue poly pennants, which were suspended at such a depth that the sacks were near the bottom, but not aground, at low tide.

In this pond (and Pond No. 3), the nets were sufficiently deep so that their bottom panels were resting on the sea floor. This made it difficult to induce the side panels to hang straight in currents, which seriously reduced Pond No. 2's effective volume.

Pond No. 3. Pond No. 3, shown in Plate 1-3, was constructed in Nanoose Bay with logs that were transported from Lund. The pond frame measured 138 feet by 53 feet by an average depth of approximately 30 feet at low tide. The pond volume was approximately 220,000 cubic feet with an estimated maximum capacity of 109 tons of fish. The pond web was held in shape using the same method used for Pond No. 1.

1.2.2 Fishing

All ponds were filled with fish immediately

Table 1-1. Pond Dimensions.

Pond No.	Length (feet)	Width (feet)	Depth (fathoms)	Pond Volume (cu. feet)	Capacity (short tons)	Load (short tons)	Density
1 Beach Pond	197	87	2.5	432,000*	216	125	0.6
2 Floating Pond	60	58	4	83,000	41	75	1.8
3 Floating Pond	138	53	5	220,000	109	45 to 70	0.5

*Note: Length and width given are the dimensions of the log frame. The volume is an estimate taking into account the irregular shape of the embayment.

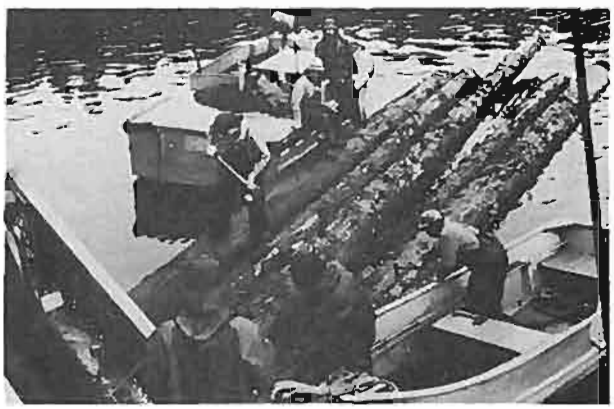


Plate 1-1. Log bundle. A bundle of cedar logs is being unbundled preparatory to pond construction.

Plate 1-2. Pond No. 1 construction. The seawall corner of the pond is being triangularized to strengthen the pond frame.

Plate 1-3. Pond No. 3 at Nanoose Bay. This rectangular pond measured 138 feet by 53 feet.

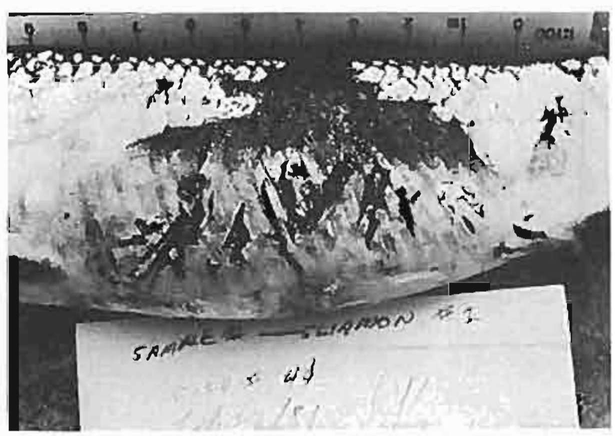


Plate 1-4. Predator marks on a captured herring.

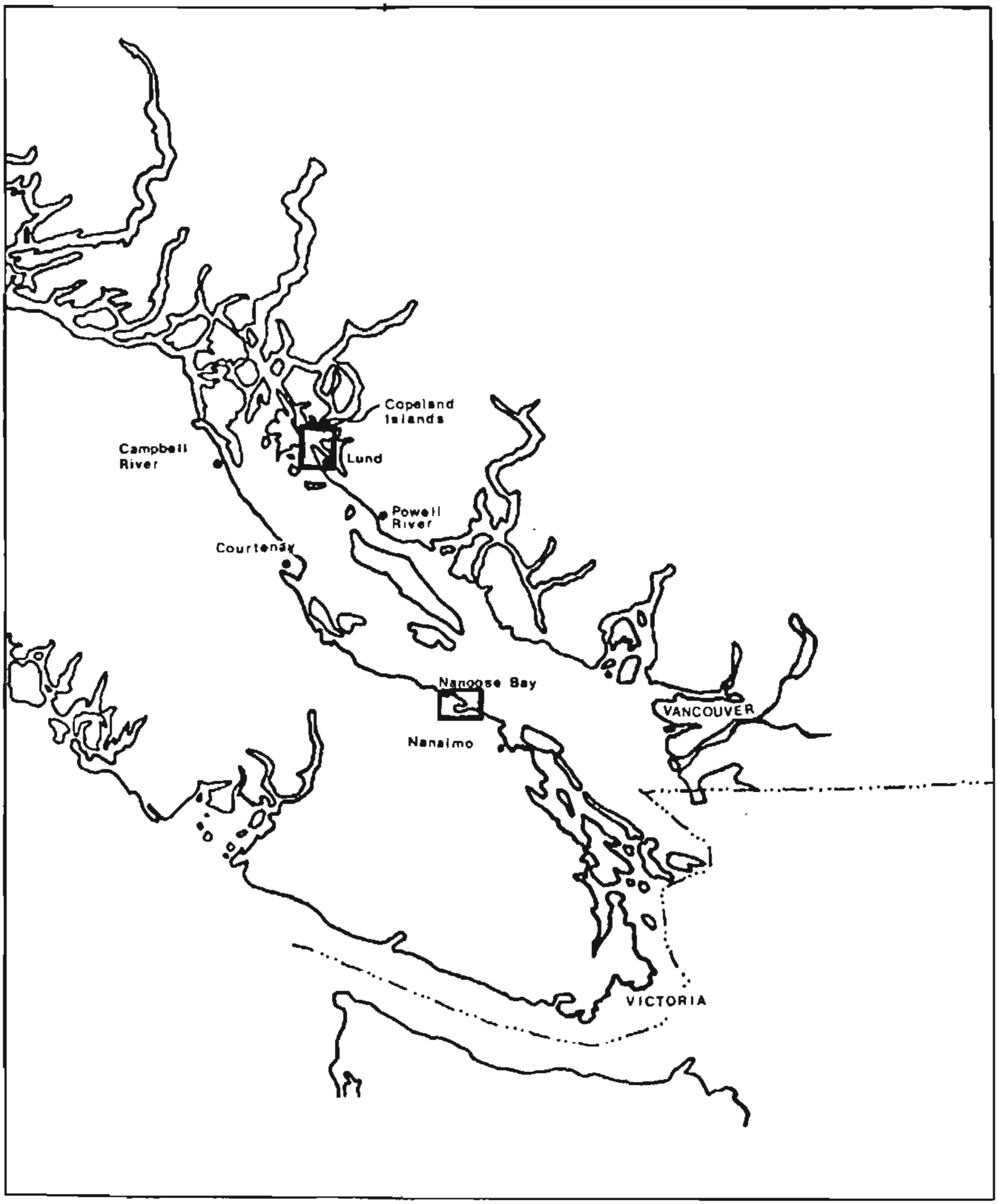


Figure 1-1. Pond Locations
(Scale: 1:2,000,000)

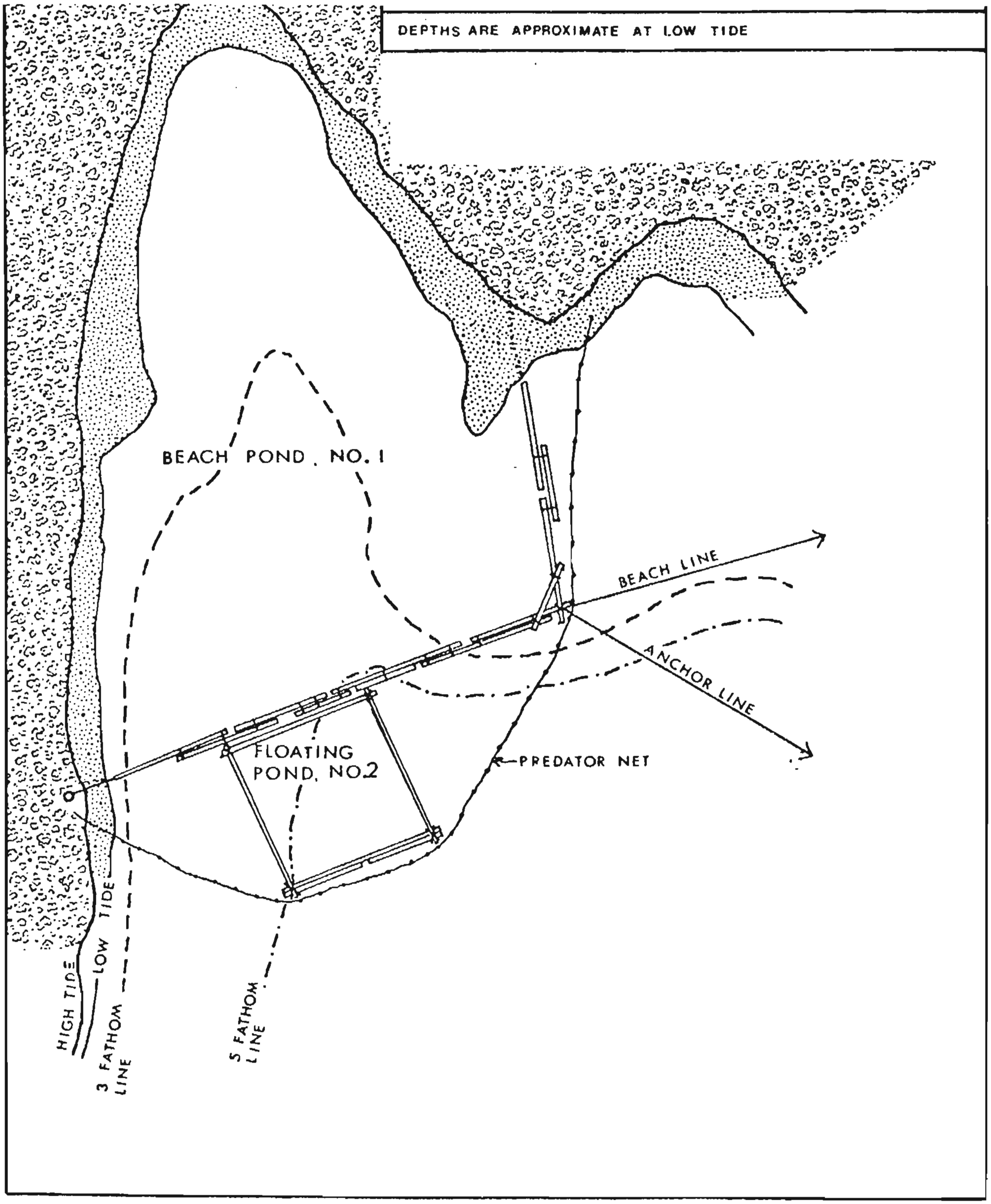


Figure 1-2. Copeland Island Pond site. Ponds No. 1 and No. 2
(Scale: 1" = 60'0")

after construction. In the course of capturing fish, the seine net was set five times. All aspects of the fishing activity were conducted slowly and methodically in order to minimize damage to the fish. Special care was taken while drumming in order to reduce the number of fish caught in folds of the body web. Approximately two-thirds of the net was drummed, leaving one-third in the water for towing.

Several fish in various sets were found to be damaged. Close examination of fish with open wounds (see Plate 1-4) revealed that at least one-half to two-thirds of these wounds showed signs of infection or signs of healing. So the damage must have been done some time prior to capture and was probably due to predation. (Damage from conscientious seine fishing should be limited to relatively minor scale loss.)

Set No. 1 - February 27, 1981, 5:55 a.m. Because the fish were so highly concentrated near Lund, setting the whole net would have produced more fish than could have been effectively handled. So partial sets were needed. These are only possible when the net is on the drum. So Set No. 1 was made well away from Lund in order to transfer the net from the deck to the seine drum.

Set No. 2 - February 27, 1981, 6:55 a.m. This set was made to fill Pond No. 1. It was made just outside Lund on a small corner of a large body of fish. Based on ponding and delivery data, the best estimate of catch size was 250 tons.

Set No. 3 - March 1, 1981, 1:25 a.m. This set was made to fill Pond No. 2, and was made in the same location as Set No. 2. The catch estimate, based on ponding delivery data, was 85 tons. Care was taken to set on fewer fish than in Set No. 2.

Set No. 4 - March 4, 1981, 8:09 p.m. This set was made to fill Pond No. 3, but the fish were released from the pond due to premature spawning.

Fish in this school were being harassed by sea lions, and the incidence of marked and damaged fish was high. One large bull sea lion was captured in the net, but rolled out over the cork line about 20 minutes after the rings were up.

Set No. 5 - March 5, 1981, 9:36 p.m. This set was made to replace the fish released from Set No. 4 and thus to refill Pond No. 3. It was made in the same location as Set No. 4, and the estimated catch size was 40 to 60 tons.

1.2.3 Fish Towing

Table 1-2 provides data on towing distances, time and speed, and on quantities of fish.

A two-boat configuration was used for towing (see Plate 1-5 and Figure 1-3). The advantage of this configuration with large sets of fish, and hence with a considerable length of net in the water, is that the net is held open. The volume

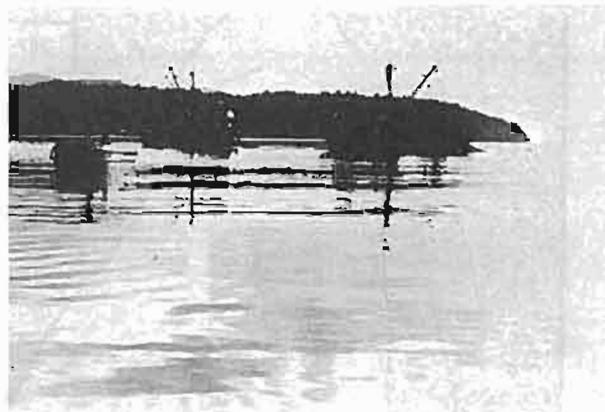


Plate 1-5. Towing configuration for Set No. 2. This two-boat configuration kept the net very full and open, minimizing fish damage.

within the net is increased, and web folds and bags are, for the most part, eliminated. Physical damage to the fish during towing was minimal. This was due more to the careful measures taken by the Captains and crew of the Sea Luck and Qualicum Producer than to the nature of the capture and towing.

To adopt the two-boat towing configuration, the second boat positions itself beside the cork line about one boat length away from the fishing vessel. The crew then attaches several lines to the cork line as shown in Plate 1-6, and passes a bow line to the bow of the fishing vessel. The second vessel is then towed into position by its power skiff, and the towing configuration is complete.

Plate 1-6. The Qualicum Producer attached to the cork line by four lines.

When an attempt was made to tow Set No. 2 to the ponds, it was found to be impossible to move. In fact, for some time, the vessels were towed backwards by the captured fish. To overcome this, some fish were released using two different means. In the first, the gable was lowered into the water

Table 1-2. Towing Data

Set No.	Towing Distance (Kn.miles)	Towing Time (hours)	Average Speed (knots)	Estimated Short Tons of Fish in Net	Tidal Influence
2	2.6	15.3	0.17	125 to 140	None
3	2.6	10.5	0.25	85 to 100	None
4	3.5	8.0	0.44	40 to 50	Flood, Positive Influence
5	3.5	9.2	0.38	40 to 60	Flood, Positive Influence

in order to permit fish to escape beneath the fishing vessel. In the other, a ten-fathom piece of lacing was cut in the trailing portion of the net (see Plate 1-7).

Plate 1-7. Releasing fish. About one-third of the catch is being released by cutting a ten-fathom section of lacing in the net.

An estimated one-third to one-half of the fish were released, reducing the initial catch of up to 250 tons to about 125 tons. Once towing headway was established, the gable was pursed and the lacing repaired. The trailing portion of cork line was heavily buoyed to reduce the fish loss over submerged cork lines (see Plate 1-8), and the fish were plunged to encourage them to move to the towing direction (also shown in Plate 1-8).

Periodic observations were made behind the net to check for loose scales in the water. Towing speed was adjusted to maximize towing speed while minimizing scale loss.

Fish behaviour varied considerably in each set and in each tow. But, in general, rapid swimming inside the net with frequent boiling at the surface and in the seine web was common in every instance immediately after the rings were

Plate 1-8. Plunging. The fish are being plunged near the trailing part of the net to encourage forward fish movement. Note also the heavily buoyed cork line.

up and while the net was being drummed. Erratic behaviour ceased after one-half hour to one hour of towing. Fish eventually became quite evenly distributed throughout the net volume, and swam more calmly in school formation.

1.2.4 Fish Transfer

The fish were transferred from the net to the pond in a conventional manner. The configuration is shown in Figure 1-4, the details of the transfer are shown in Plates 1-9, 1-10 and 1-11.

The gate structures on all ponds were large, making transfer easy and minimizing fish damage.

In order to transfer herring from the net to the pond, the net must be drummed to reduce the volume of the net and to encourage fish movement towards the pond. Web folds near the stern rollers are inevitable and cause some fish loss. During the second through fourth fish transfers, the seine net was retrieved using the power block which was hoisted to the top of the boom. Bags of fish could thus be more easily removed from the folds of web and released into the pond without damage.

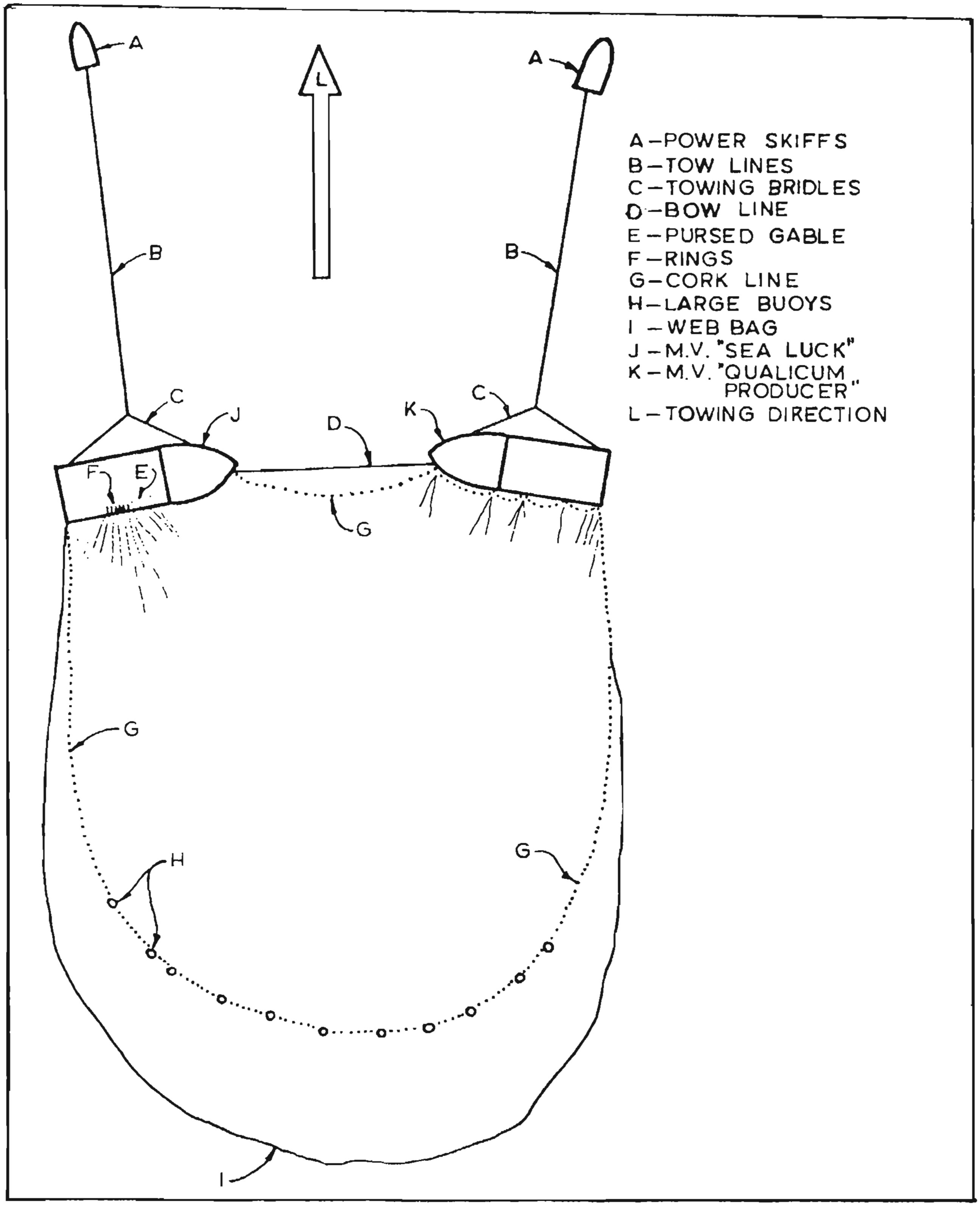


Figure 1-3. Towing Configuration.
(Scale: 1" = 30'0")

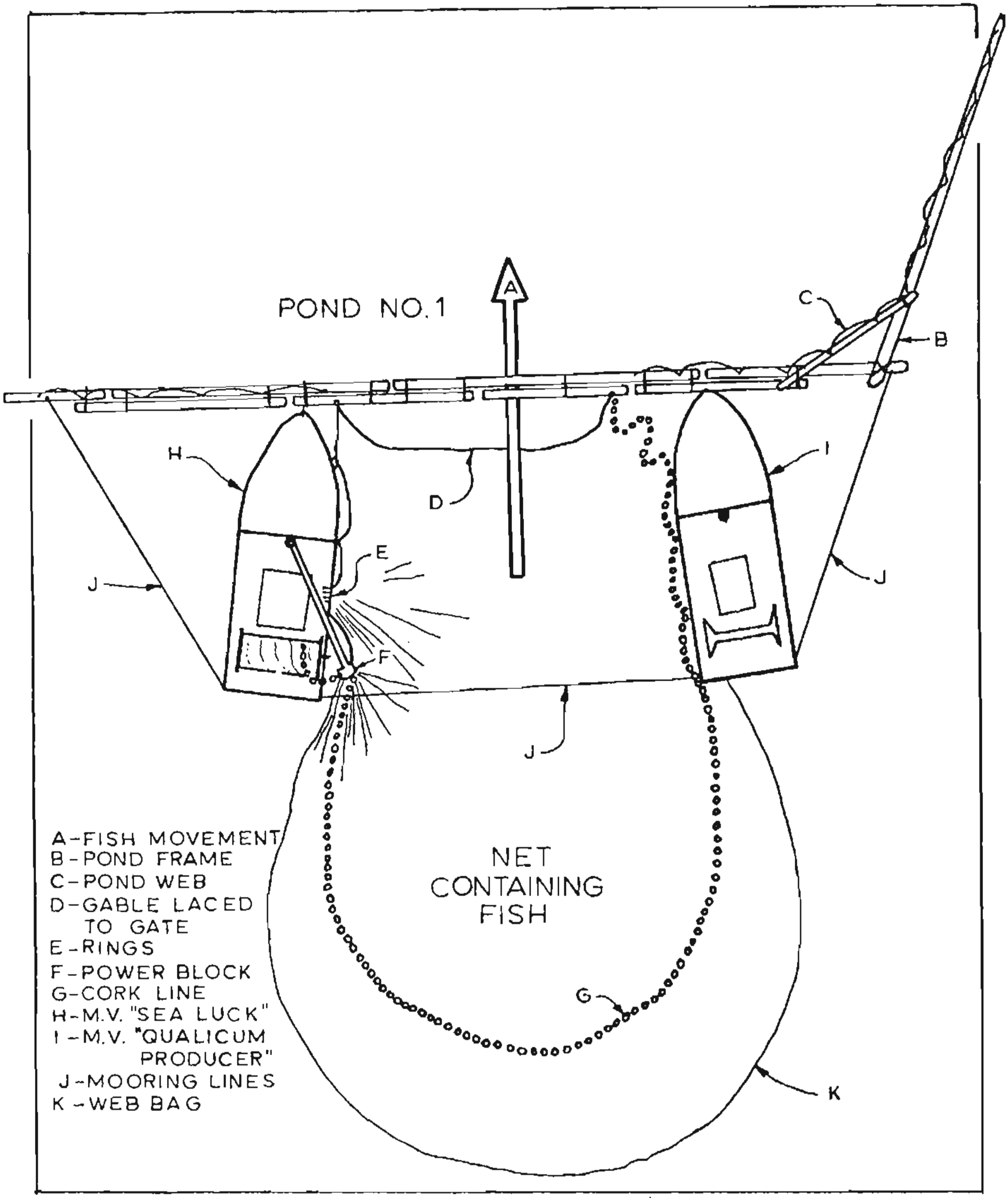


Figure 1-4. Fish Transfer Configuration.
(Scale: 1" = 30'0")

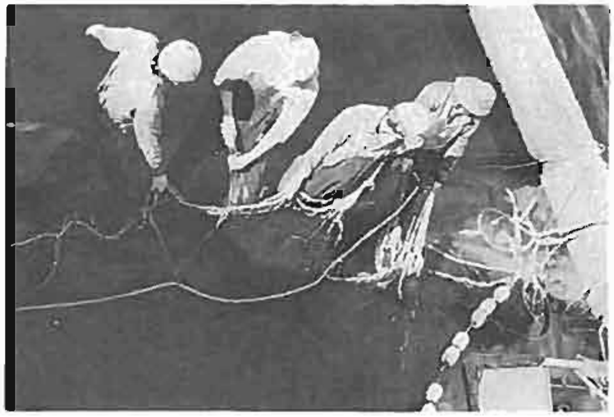


Plate 1-9. Positioning the gable in front of the pond gate.

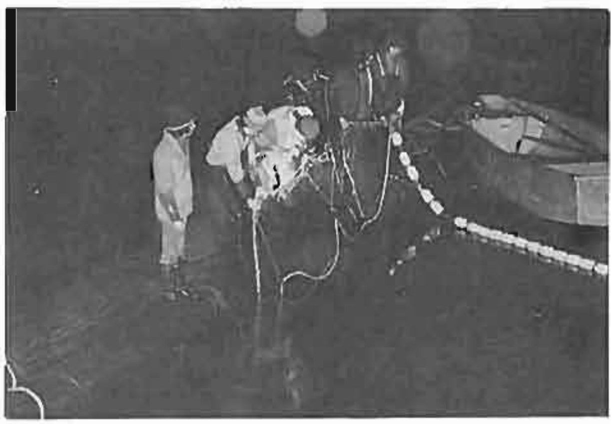


Plate 1-10. Lacing the gable to the pond-drop gate.

Plate 1-11. Fish passing from the net into Pond No. 1.

1.2.5 Pond Loading Density

Pond loading densities for each pond can be found in Table 1-1 (p.3). Plates 1-12 and 1-13 show Ponds No. 1 and 2 fully loaded. Pond No. 1

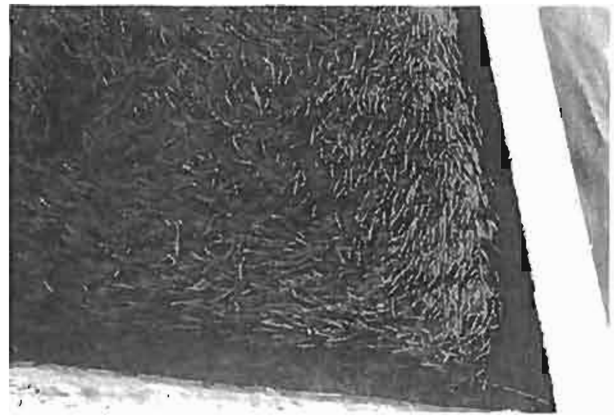


Plate 1-12. Fish density in Pond No. 2. Fish density is about two pounds of fish per cubic foot of water.

Plate 1-13. Fish density in Pond No. 1. Fish density is about one pound of fish per cubic foot of water.

was loaded to a density of 0.6 pounds of fish per cubic foot of pond; Pond No. 2, to 1.8 pounds per cubic foot; and Pond No. 3, to 0.5 pounds per cubic foot.

1.2.6 Capturing Herring Inside the Ponds

A small bait seine about 40 fathoms long by four strips deep was used to capture herring inside the ponds. Each end of the net was equipped with a gable and purse line, and the bottom of the net could be pursed from both ends. Most of the net was constructed of standard body web, but the bunt, about five fathoms in length, was constructed of tarred, knotless nylon. This feature played an important role in minimizing fish damage during drying up and brailing.

Plates 1-14 through 1-22 show the various steps in capturing herring in the ponds.

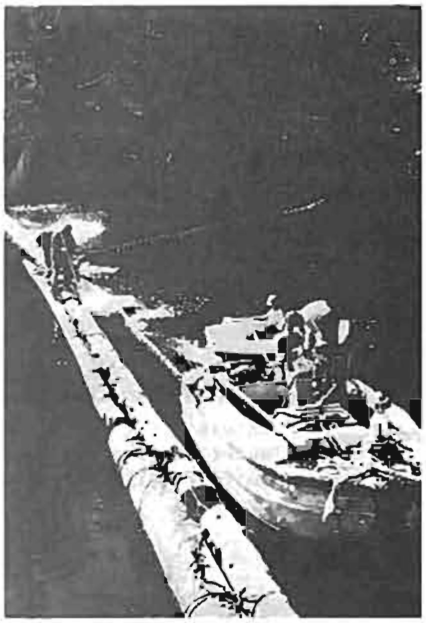


Plate 1-14. Setting the bait seine.

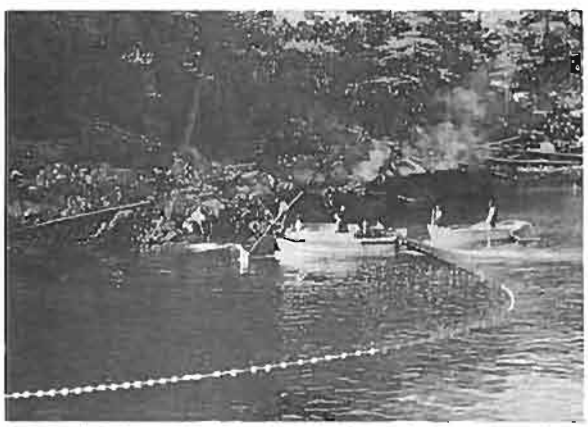


Plate 1-15. Closing the bait seine. Plunging chases fish toward the middle of the seine.

In one fishing and brailing sequence, the fish were dried up to the point where nearly all the fish within the bait seine died. Most of these sank to the bottom, where the pressure squeezed large amounts of milt in the water, producing a cloud that eventually filled the entire pond. There was some concern that this stimulus would initiate spawning in the remaining ponded fish, but this did not occur.

Pond No. 2 was emptied easily in relatively few sets. However, the final sets scraped up some of the dead fish (of which there was about a ton). These were brailed along with the live fish and degraded the total catch in some sets.

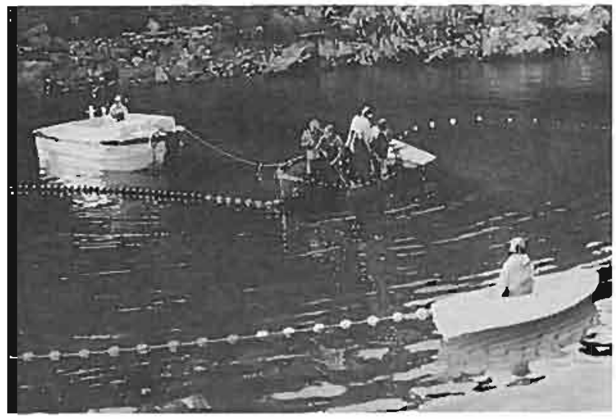


Plate 1-16. Pursing the bait seine. The bait seine has been closed and is being pursed from both ends.

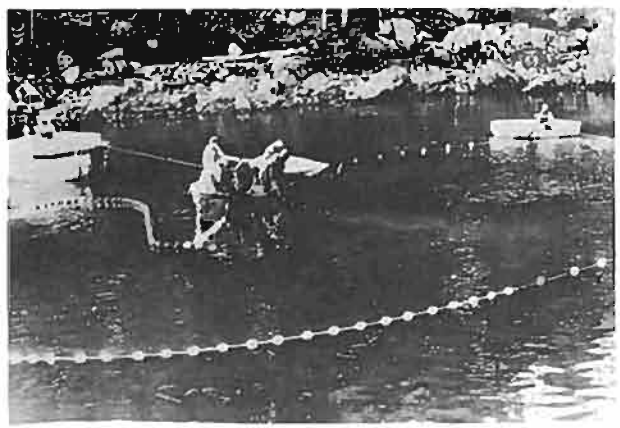


Plate 1-17. The lead line fully pursed. The net enclosure is complete.

Plate 1-18. Supporting the cork line to prevent fish loss.

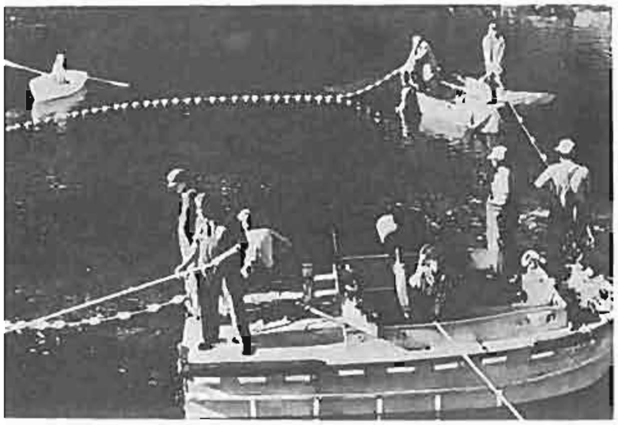


Plate 1-19. Bait net full. The net full of fish is being towed to the seine boat Sea Luck preparatory to brailing.

Plate 1-20. Captured fish. Herring are boiling near the cork line. Little scale loss is evident.

Capturing fish in Pond No. 1 was more difficult because of its huge volume. The first few sets with the bait seine went smoothly since the fish were dense enough to permit easy fishing. But as the density was reduced, a different method had to be used. Of the several ones tried, the most productive was to set the net in one corner of the pond and herd the fish into the open net before closing and pursuing.

In all instances, the pursed bait seine was left fully expanded following the fishing sequence to avoid premature crowding. A line was passed from the seine boat to the skiff holding the lead line and gables. Then the net and skiffs were winched in beside the seine boat. The net was

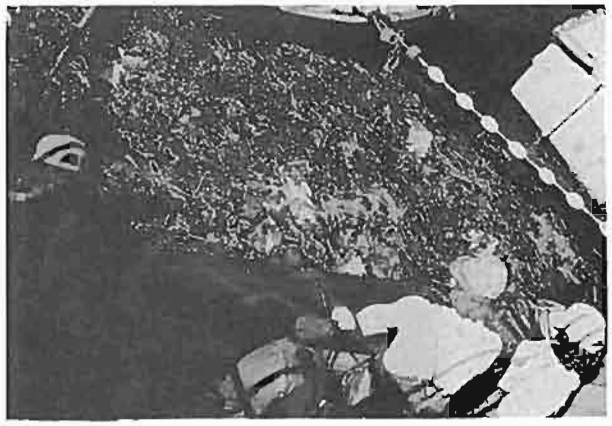


Plate 1-21. Excess net is being pulled from the water in order to render the fish sufficiently dense for effective brailing.

Plate 1-22. Removing debris. Seaweed *(Laminaria)* and bits of wood are being removed prior to brailing.

hauled from the water using the single fall; and once fish were in sufficient density, brailing commenced.

1.2.7 Brailing and Tote Loading

The brailer used was conventional in design and function. Its diameter was four feet and its empty depth was about two-and-one-half feet. The web was a soft, knotless nylon, and although the mesh size appeared large, only about one fish in 10,000 was gilled during brailing. While loading totes destined for the Sliammon plant, the brailer was loaded to a depth of about one foot (500 to 600 pounds) (see Plate 1-23). The fish were in the brailer for less than 20 seconds. Some scale loss was observed, but not measured.

The totes were made of polyethylene and measured three feet high by three feet square at the top. Of the several methods of tote loading tried, the best one involved loading the totes with slush (a mixture of half ice and half sea water) to a depth of six to

Plate 1-23. Brailing. This brailer load contains between 400 and 500 pounds of fish.

Plate 1-25. Loading totes. Each tote received about 500 pounds of fish.

Plate 1-24. Preparing slush. Totes were filled about one-quarter full of ice and seawater prior to filling with herring.

ten inches (see Plate 1-24), placing about 500 pounds of fish on top (see Plate 1-25), and then adding some ice and sea water. (Additional sea water entered the mixture with the brailed fish.) The result was a suspension that supported each fish with the same pressure on all sides of its body (see Plate 1-26). Pressure bruising and deformation from tote loading were thus eliminated.

Plate 1-26. Fish in slush for transport from pond to Lund.

1.2.8 Fish Transport

Most fish were transported to the processing plants by sea truck in totes filled with slush (see Plate 1-27). But a few were taken to Vancouver by boat in fish tanks filled with 'champagne', a mixture of ice and aerated sea water.

1.2.9 Fish Processing

Deliveries were made to the various plants when the roe yield had reached approximately 10 percent and were

Plate 1-27. Tote transfer. Full totes are being loaded onto a truck for transport to the processing facility.

continued until the stock of ponded fish was depeleted. At that time, roe yield had reached approximately 14 percent.

The first delivery from the Lund ponds was made on March 9th and the last on March 19th, for a total of 11 processing days. It is estimated that deliveries could be continued for a further four days for a total processing period of 15 days.

1.3 OBSERVATIONS

1.3.1 Spawning

In each tow, some of the captured fish spawned on the seine web, shown in Plate 1-28. The incidence was low, however, and any reduction in roe yield could not be detected in the roe-yield tests. The stimulus that induced spawning behaviour was not apparent, but several factors are suspected. Chief among these are -

1. Available substrate. The seine web appeared to be a favourable and favourite substrate for spawning. This was also apparent when herring were placed in ponds.

2. Stress stimulus. Stress on the herring was generated by their being captured, being towed, being near the surface in daylight and being harassed by sea lions. Stress is known to initiate spawning and is used by roe-on-kelp operators.

3. Chemical stimulus. Spawn was squeezed from a few fish that had become trapped in folds of web and died. Chemical stimulus from the spawn released might have played a role in initiating spawning.

Fish continued to spawn after their transfer

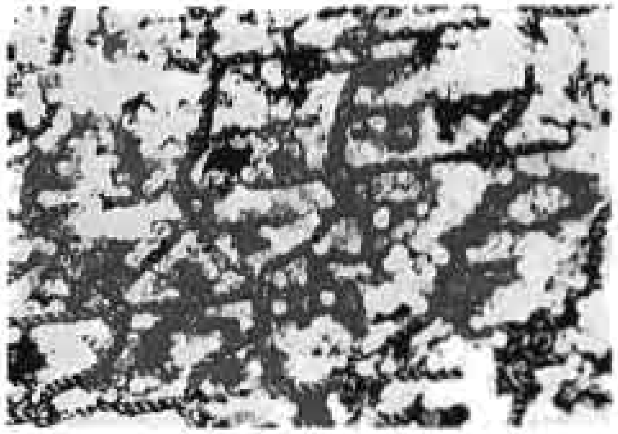


Plate 1-28. Spawn on web. Some mature fish spawned while being towed to the pond resulting in egg deposition on the web.

to the pond (see Plate 1-29). In Pond No. 1 spawning ceased after 24 hours. While relatively few fish were actively spawning, the ones that

Plate 1-29. Spawning herring. Mature fish continued to spawn on the pond web after transfer to the pond.

were probably spawned out during this period. The pond web soon became completely covered with spawn, increasing its resistance to current. Spawning was not seen again until March 19, when the last fish were removed from the pond.

In Pond No. 2, spawning also ceased after an initial 24 hours and was not seen again until March 19.

Fish from Set No. 4 in Pond No. 3 began to spawn as soon as they were transferred into the pond and did not stop until they were released. These fish were heavily stressed by sea lion predation. Sea lions were always near the pond, and they could not be induced to leave.

A residue of the wild herring that had

followed the seine nets to the pond sites stayed in the immediate vicinity of the ponds. The fish actively spawned on the outside of the pond web, possibly in response to spawning within the pond.

At no time were female herring seen releasing eggs in midwater. They always chose a substrate, and the one they chose was always the pond web.

1.3.2 Effects of Pond-Loading Densities

The fish in Ponds No. 1 and 3 showed no ill effects from ponding density. Such was not the case for fish in Pond No. 2. The problems associated with high initial ponding density were compounded by problems with the pond itself.

Initial spawning activity loaded the pond web with spawn. In addition, drifting threads of *filamentous diatoms* were caught in the pond web and grew rapidly, fouling the net even more. The pond net thus became very resistant to the passage of water, and swayed considerably in the current, reducing the internal pond volume. At times, the fish density within this pond was over two pounds per cubic foot.

These fish appeared to be highly stressed: they did not swim in a large circle in school formations, but in small groups and in constantly changing directions; discoloured gill covers and fin bases were common; and fish swimming near the pond surface showed damage to their noses from colliding with the pond web.

Their stress might have been augmented by the dissolved oxygen level. As shown in Table 1-3, which presents the results of a variety of water-quality measures taken inside and outside Pond No. 2, the dissolved oxygen at the three-meter level inside the pond was a long way below the half saturation level generally considered dangerous for ponded marine fishes.

A modification of the Hach (Winkler) titration was used to measure the dissolved oxygen. It was sensitive to 0.2 mg/l and repeatable to ± 0.2 mg/l.

After emptying the pond, about one ton of corpses was found on the pond bottom, and a further ton of fish was probably lost to bird predation. Mortality directly related to loading density was about 2.7 percent. It is estimated that this figure would have doubled or tripled within a few days had this pond not been harvested when it was.

1.3.3 Predation

At the Lund ponds, predation consisted of seagull and bald eagle predation from the air, otter predation from the land and attempted predation from rockfish. A few dogfish that were captured in Set No. 2 and transferred to Pond No. 1 were removed from the pond by divers and were never a problem. Dogfish were not seen approaching the outside of the pond. However, Ponds No. 1 and 2 were approached by a school of copper rockfish *(Sebastes caurinus)*. Though the time and date of this event are not known, the event was made evident by the 20 rockfish found tangled in the meshes of the predator net.

Eagles and seagulls fed on injured and dying herring near the pond surface, and thus performed a valuable service.

Sea lions were actively feeding on schools of herring within a mile of the Lund pond site, but only approached Ponds No. 1 and 2 on a single occasion, and did no damage.

At the Nanoose pond the sea lion was the main predator. They approached the ponds in groups of two to seven. At no time did they cause any direct damage to the pond or the fish in it, but by

Table 1-3. Pond Water Quality
March 9, 1981 11:05 a.m.
Sunny, No Overcast

	Inside Pond No. 2		Outside Pond No. 2	
Fish Density (lbs/foot^3)	1.8		0.0	
	Depth		Depth	
	Surface	3M	Surface	3M
Temperature (°C)	8.0	8.0	8.5	8.0
Hydrometer Units	23	23	15	23.5
D.O. (mg/l)	12.2	8.8	10.2	9.8
Secchi (feet)	*13		34	

*Note: Not reliable due to fish density.

ERRATUM

page 15 1.3.2. Effects of Pond-Loading Densities

change paragraph 4 to read ...

The results of various oceanographic parameters, measured both inside and outside Pond No. 2, are presented in Table 1-3. The single notable difference in water quality was the reduced dissolved oxygen (D.O.) at the three metre level inside the pond. The D.O. was well above the half saturation level generally considered dangerous for ponded marine fish, but may have been sufficiently depleted to contribute to the stress load on fish in this pond.

inducing stress, they were probably instrumental in initiating and maintaining spawning activity in fish taken in Set No. 4.

Of the several methods used to keep sea lions away from the ponds, the most effective was to chase the sea lions away with the power skiff. Once they were clearly on the run, sea lion bombs (underwater firecrackers) were thrown. It was hoped that the sea lions would associate the noise of the power skiff with the bombs, so that on subsequent approaches, simply starting the skiff would scare them away. But they did not respond as hoped.

1.3.4 Roe Maturation and Yield

Figure 1-5 is a maturation graph prepared on the basis of test data collected daily from Ponds No. 1 and 2, using the Standard Fisheries and Oceans roe-test method. (The fish in both ponds were taken from the same location and from the same body of fish.) Roe yields are expressed as a percentage of the total volume of fish that had mature roe. Although the method is crude, the greatest error in the results is probably related more to the difficulty of obtaining representative samples from the ponds then to the method of calculation. The results show that the roe yield increased from 2 percent on initial capture to over 14 percent in a 20-day period.

No spent female fish were found in the first samples taken immediately after fish capture. Towards the end of the sample program, 7.1 percent were spent. This was probably due to spawning activity during towing and during the first day of confinement. Had the incidence of spent females been 0.0 percent, the total roe yield might have topped 16 percent. Note, though, that the ratio of females in this population was 60.2 percent. In a population consisting of half male and half female, the yield would have been less.

1.3.5 Product Quality and Presentation

Delivery Quality. Herring delivered to the processing plants in totes and in champagne were of high quality and were vastly superior to those delivered from the sac roe fishery. This difference is illustrated in Plates 1-30 and 1-31. The first shows fish delivered to Vancouver from the Ponds, and the second, fish delivered from the sac roe fishery.

Table 1-4 indicates that fish chilling within the totes was reasonably uniform.

Scale loss while the fish were thrashing and dying within the totes was significant, but not measured. Though it was greater than in any previous or subsequent operation, the cumulative scale loss during tote loading could have been reduced by increasing the tote preload of slush with a greater proportion of sea water, which would have provided more cushioning.

Belly burning was seen in some of the fish delivered in totes to Vancouver from the Lund ponds. All the belly-burned fish had been feeding on eggs that had fallen away from the pond web and on hatched larval herring.

Plate 1-30. Fish delivered to Vancouver from the pond site. Transport time was about 11 hours in champagne.

Plate 1-31. Fish delivered to Vancouver from the sac roe fishery. Transport time was about seven days. Fish were loaded into the hold "dry."

Roe Content. The fish in Pond No. 1 were divided into feeding and non-feeding for the purposes of roe content analysis. About 95 percent were not feeding. (The feeding fish tended to be smaller on average.) The results of the sampling are presented in Table 1-5.

Sixty-seven percent, or 102, of the fish were female. Of these, 34 were in No. 1 roe condition, none were in No. 2 condition, and 23 were in No. 3 condition. Forty-five females were spent. The No. 1 quality roe yield from this sample was 5 percent of total fish weight. (These figures differ significantly from the pond sample averages obtained on or about the same time.)

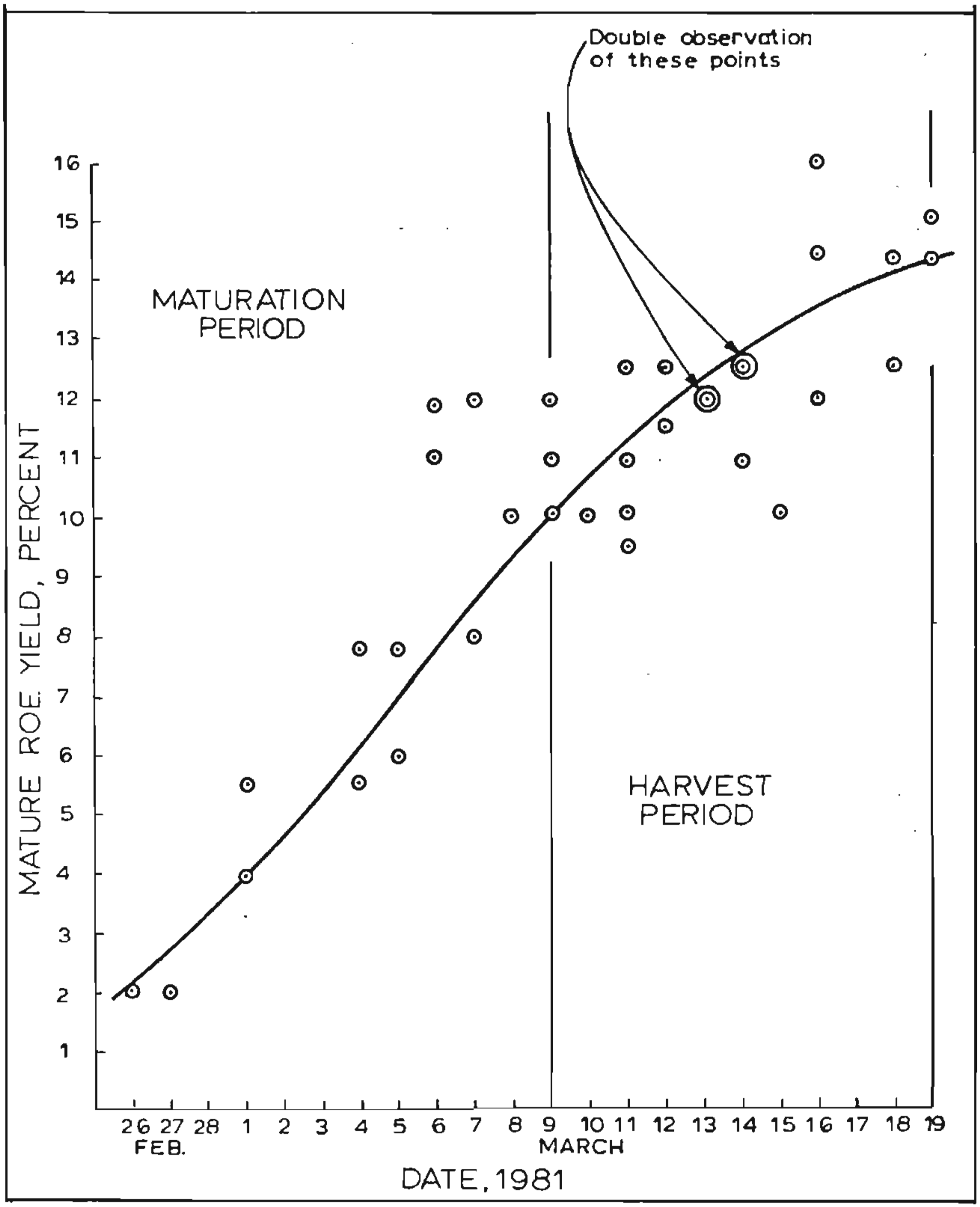


Figure 1-5. Roe Maturation Graph.
Ponds No. 1 and 2

Table 1-4. Fish Temperatures
(First load to Vancouver)

Sample No.	Loading Temp. (°C) March 9 3:00 pm	Temp. at Time after Loading (°C) 4:05 pm	5:15 pm	Randon Sample Delivery Temp (°C) March 10 7:00 am
1	8.0	6.2	+ 1.5	+ 1.0
2	7.5	7.0	+ 1.0	+ 5.0
3	8.0	4.0	- 1.0	+ 7.0
4	8.0	5.5	- 1.0	+ 3.0
5	8.0	5.5	- 1.5	+ 4.0
6	8.0	5.5	- 0.5	0.0
7	8.5	6.0	- 0.5	+ 3.5
8	8.0	6.0	- 1.0	0.0
9	8.5	6.5	- 0.5	0.0
10	8.5	6.5	- 1.0	- 0.5
MEAN	+ 8.1	+ 5.9	- 0.5	+ 2.3

Table 1-5. Feeding Versus Nonfeeding Fish
March 16, 1981

	Feeding	*Nonfeeding
No. all pcs.	108	152
No. Male	50	40
No. Female	102	69
Percent Female	67	72
No. Ovary Condition 1	34	63.5
No. Ovary Condition 2	0	2
No. Ovary Condition 3	23	0
No. Spent Females	45	3.5
Percent Mature Roe Yield	5	15.25

Packaging. Tail damage resulted from freezing the fish individually on trays before packaging. Because the tails were brittle, they broke easily. This could be avoided by freezing the fish in their final packages, but this would require more time in the freezer, and thus would slow turnover time.

The fish at the Sliammon plant were packaged in two kilogram cartons. The method of packaging was unattractive and thus unsuitable for presenting directly to the Japanese consumer. However, it might be acceptable to the Japanese restaurant trade.

1.4 CONCLUSIONS AND RECOMMENDATIONS

1.4.1 Pond Types

Floating ponds are generally preferable to beach ponds. While beach ponds can enclose large volumes of water with relatively little ponding matter, and hence cost less for a given volume, the number of small bays close to fishing grounds and suitable for beach ponds is limited. So fierce competition for better sites could easily develop. Further, initial curiosity by upland owners could be replaced by annoyance and resistance. In addition, regulating beach-pond location and use would be difficult. So, although beach ponds should not be excluded from consideration, preference should be given to floating ponds.

Because much time was used in locating pond materials (logs, wires, staples, etc.) and in pond construction, the feasibility of using prefabricated, folding, portable pond frames should be investigated. Portable ponds could be set up in a few minutes, which would leave more time for locating suitable schools of fish, and could be located close to the fishing site. Preliminary design and cost investigations should be followed by prototype construction and testing.

1.4.2 Pond Location

During the course of the ponding investigations, we noticed that the fish spawned out in ponds located close to, or in, wild spawning territory or in areas frequented by maturing spawners; but they did not spawn out in ponds located in areas where there was no wild spawning nor maturing spawners. If this trend were to hold over a significant number of observations, grounds for choosing a pond location would be clear: it should be close to the fishing grounds in order to minimize towing, but not in an area frequented by maturing or spawning herring.

1.4.3 Ponding Density

On the basis of ponding data and observation, we can conclude that ponding densities greater than one pound of fish per cubic foot of water should be avoided for ponding periods greater than four or five days (assuming pond volume to be calculated at low tide in the case of beach ponds). This limit should be exceeded only if fish are to be ponded for a period of one to three days, and ponding densities greater than 1.5 pounds per cubic foot should be avoided at all times.

Ponding densities greater than the recommended level can be expected to take their toll in physical damage and stress-related disorders, manifested in blood entering the operculum, eyes and fin bases, and small spots on the body. Other disorders related directly to overcrowding include scale loss and eroded noses and fins from abrasion with the pond web. Oxygen depletion also results from overcrowding, contributed further to stress disorders, decreased resistance to disease and increased mortality rates.

1.4.4 Predators

Birds are not a threat to ponds of herring loaded to the recommended density.

Predatory fishes can be effectively controlled by using predator nets. These structures will not be necessary in all pond locations, but should be used where dogfish are common.

Some method needs to be devised to discourage seals and sea lions from frequenting the ponds, since their presence is stressful to the herring. A method discussed at the time of ponding, but not tried, was the use of Orca sounds emanating from an underwater speaker. This method has some promise since, when Orca approach, seals and sea lions usually leave the vicinity or haul out on the nearest beach. And it may be the only non-violent way of keeping these predators away from the ponds. However, the ponded herring might react unfavourably to the Orca sounds. So the method needs to be studied both for its effect on the seals and sea lions and for its effect on the ponded herring.

1.4.5 Spawning and Roe Yield

Investigations should be conducted into spawning substrate preferences. Observations indicated that in all spawning instances tarred, knotted-nylon, herring-seine mesh was the preferred and only substrate used even in the beach pond where there was some *Laminaria* and *Fucus*. Spawn was never seen on the white lacing that held strips together, on the bright red onion sacks used (with rocks) for weight, on the bright white onion bag labels, nor on the blue poly line suspending the bags. So factors worth investigating are substrate colour, texture, brightness and chemical makeup. Both preference and avoidance should be investigated.

Though captured fish spawned on the net during towing and in the pond, after an initial 24 hours, spawning ceased except in Set No. 4. The fish captured in that set had reached a mature roe ratio of approximately 5 percent as opposed to 2 percent in the other sets. So capturing the fish before the roe has matured may eliminate, or at least reduce, the spawning incidence. In order to satisfy this requirement and the requirement that the ponding period be kept to a minimum, fish should be captured when there is a high proportion of maturity No. 3 roe, a low proportion of maturity No. 2 roe and no maturity No. 1 roe.

In Ponds No. 1 and 2, the spawning cycle was clearly disrupted. Fish were held about one-and-one-half weeks beyond the time when the wild stocks from which the ponded fish were taken appeared to have spawned. (They *might* not have been the same stocks.) The nature of this disruption is not understood. Institutionalizing the fish might have disrupted behaviour patterns, physiological changes and adjustments, migratory patterns or other factors that lead to full reproductive maturity. These factors need to be understood and thus deserve intensive study.

Being able to predict roe yields and when a particular pond of fish will reach marketable maturity would be advantageous to the fisherman, who must harvest the fish, and to the processor, who must attend to numerous details before processing. In order to make such predictions, we must consider a number of variables including the ratio of male to female fish, the number of females in each category of maturity, the number of spawned-out females, water temperature, and the amount of available feed. This seasons's data will probably not be sufficient to formulate such a predictive method, but future research should strive to do so.

Being able to extend the processing period would also be advantageous, since processing fish in small, carefully handled batches is essential to maintaining product quality. This could be done if mature herring could be held in ponds for extended periods without spawning. Some preliminary information from the Biological Station at Nanaimo is relevant here. Apparently feeding a pond of fish, all from the same stock, increases the rate of roe maturation. So the processing period might be extended by feeding one pond of fish and starving another (inferred from personal communication with J. R. Brett , scientist in charge of herring impoundment studies in Pacific Biological Station at Nanaimo). Because of the importance of extending the processing period for product quality, further investigations should be made into this and other means of holding herring without their spawning.

1.4.6 Fish Towing, Transferring and Brailing

This project demonstrated that large catches of fish could be towed without scale loss or other damage providing the towing speed is slow enough.

The use of the power block rather than the seine drum to retrieve the net during fish transfer is recommended. This method will permit the seine crew to unfold large folds in the net that may trap and damage fish.

The use of soft, knotless nylon mesh is recommended whenever net material must come in contact with fish. This reduces scale loss and prevents net marks on the fish. Knotless nylon is essential for the brailer web and the bunt of the bait seine.

In brailing, the fish should be dried up to the point where they are sufficiently dense to permit easy brailing, but not to the point where fish are killed in the bait seine nor to the point where the fish at the bottom of the pile are under such pressure that they are bruised or have their roe and milt squeezed from them. The fish should not be killed before or during brailing except when a very small amount of fish (three or four tons or less) is in the bait seine. In such instances killing the fish in the net by electric shock or other means might be preferable to brailing live fish.

1.4.7 Fish Transport

Totes filled with a mixture of ice and sea water proved to be the best method for transporting fish to the processing plants. Holds filled with champagne was the second best.

Two different dry vacuum fish pumps were tried in the course of this project. Both caused pressure bruising and scale loss, and flexed the fish out of their state of rigormortis. So such pumps apparently do not have a place in the production of high-quality herring products.

1.4.8 Fish Processing

Sexing, sorting and packaging were all done by hand at the Sliammon plant. These techniques appear quite well suited to the production of a high-quality frozen roe herring product.

1.4.9 Packaging and Presentation

The use of high-quality presentation and packaging is essential to establishing a strong market for this product. Marketing and packaging investigations are recommended.

1.4.10 Future Prospects

The prospects for the production of a high-quality frozen food and roe herring product using ponding techniques appear very promising. But various aspects, mentioned here, require further investigation before the ponding of roe herring can be adopted as a widespread method of producing high-quality herring products.

2. THE 1981 NIMPKISH FISHING COMPANY PROJECT IMPOUNDMENTS

2.1 BACKGROUND

2.1.1 The Contract

In January of 1981, Nimpkish Fishing Co. Ltd., under the direction of Chris Cook, Jr., Captain of the fishing vessel Nimpkish Product No. 1, received permission from Fisheries and Oceans Canada to impound 200 tons of roe herring in Statistical Area 12 under the condition that Nimpkish Producer would not engage in the 1981 roe herring fishery elsewhere. A second vessel, the Kitgora, operated by Roy Crammer, acted as a support vessel. Fishing, ponding procedures and maturation of impounded herring were monitored by field biologist, Chris Whiting.

Upon reaching suitable maturity, impounded herring were to be delivered to the Central Native Fishermen's Cooperative facilities in Beaver Cove for subsequent transport to their facilities in Ucluelet for processing. The product was to include high-quality female herring with the roe intact, frozen for the consumer market in Japan.

2.1.2 Statistical Area 12

Area 12 encompasses an especially complicated piece of coastline between northern Vancouver Island and the mainland. It is a region with numerous island passages, inlets and bays. Herring spawn in this intricate shoreline from March through May. Although most recorded spawning takes place over a two-month period, herring appear to spawn in localized areas well into the summer. Some localities are favoured by herring year after year, but generally the timing, location and density of spawning are somewhat unpredictable.

Area 12 seems to possess numerous small populations, which are probably somewhat specific to numerous small locations. Their relative abundance is open to debate since they are inclined to mix with migrating populations from other areas. These mixed populations have not been open to the commercial roe fishery since 1978, a year in which only 46 tons were taken from Area 12. Prior to that, between 1972 and 1976, approximately 1,500 to 2,500 tons of roe herring were fished commercially each year. For the past four years, a roe-on-kelp fishery has taken approximately 45 tons of local stocks. In addition, herring have been seined for bait sales. These fish have probably included migrating populations.

2.1.3 The Fishing and Impoundment Plan

Schools of locally spawning fish were to be located prior to their spawning maturity, and ponds established in their vicinity. Several small ponds, capable of holding 20 to 30 tons of herring each were to be established at a variety of locations as suitable populations of herring were located. Two locations were ultimately used, one in Cramer Passage and the other in Parson Bay (see Figure 2-1).

What was seen to be a relatively straightforward opportunity to catch, pond and deliver roe herring, proved to be fraught with difficulties. One problem was locating schools of herring that would generate enough roe to represent at least 10 percent of the total tonnage delivered. Others were the male/female mix and varying sizes. Ideally, a school of herring to be ponded for sale as whole roe herring should contain at least 50 percent female fish of uniform roe development, and the fish should exceed 20 cm. in length. In the course of this venture, 33 sets were made of which none met the ideal ratio of maturing females. The fish samples were of mixed sizes, sexual maturity and ages. (Scale analysis from each set was not completed at time of writing.) As fishing continued, the incidence of spawned-out fish increased in the catches and reduced the proportion of useable maturing fish. Thus, of those sets that were impounded, the highest maturing female ratio obtained was approximately 40 percent. In addition, the size of schools tended to be small. The largest catches were about 20 tons; the majority were between five and ten tons.

2.1.3 Outcome

By April 30, the day of the last fishing attempt, only 60 to 70 tons of herring had been ponded and of these only 30 to 35 percent were maturing females. Maturation was slow. Because of the low yield of mature roe, delivering and processing these fish as planned was not economically feasible. So they were sold as halibut bait, a disappointing outcome for a venture that had taken considerable time, effort and money on the part of the boats and crew involved. This project did, however, generate a great deal of valuable information.

2.2 METHODS

2.2.1 Cramer Passage Pond Site

Sampling from sets No. 2, 3, 5 and, particularly, 6 indicated that the herring in the Cramer Passage area were suitable for ponding. Thus, three ponds were established in a small unnamed bay on the Gilford Island shore of Cramer Passage opposite Evans Point (see Figure 2-2). This bay was flat bottomed, had a wide mouth partially protected by small islands, and narrowed into a shallow mud flat exposed at low tide. Its depth was approximately 27 feet (at low tide). The shore was rocky, steep and wooded above the high-tide line. Immature *Fucus* grew on the rocks. The three ponds were strung in a row along a line secured to each shore of the bay near the entrance (see Figure 2-3 and Plate 2-1).

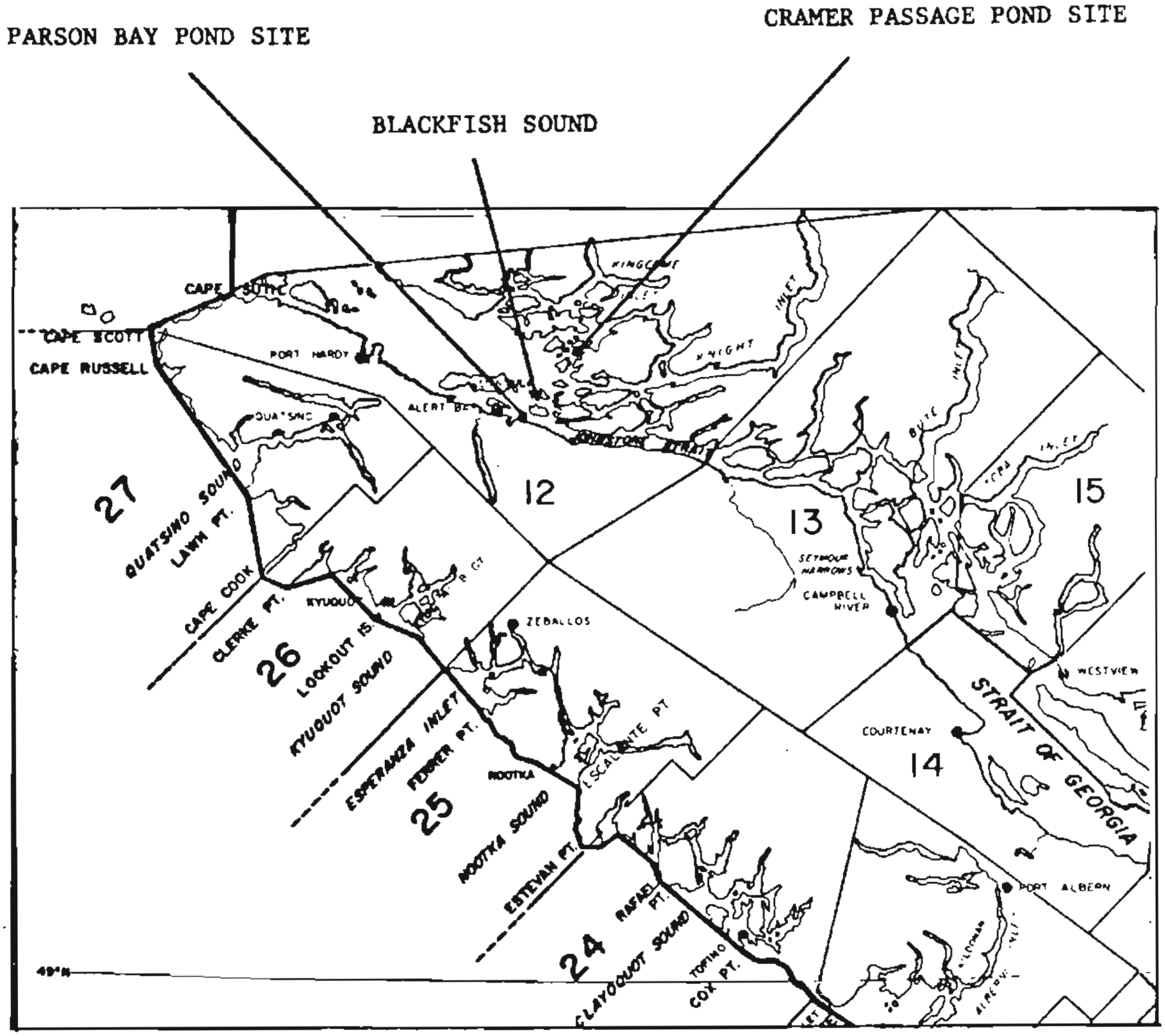


Figure 2-1. Key Map - Northern Vancouver Island

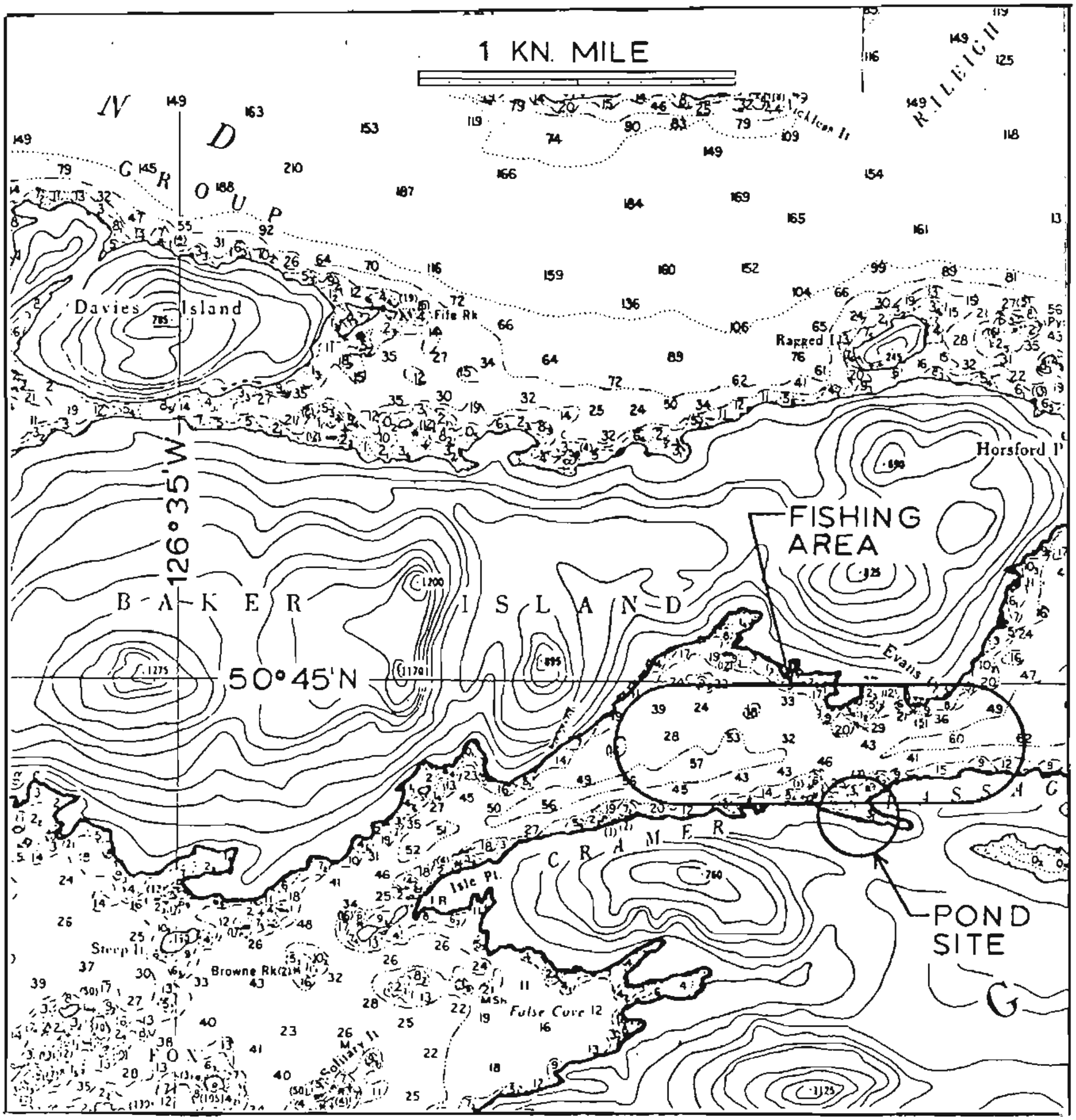


Figure 2-2. Cramer Passage pond site and fishing area.

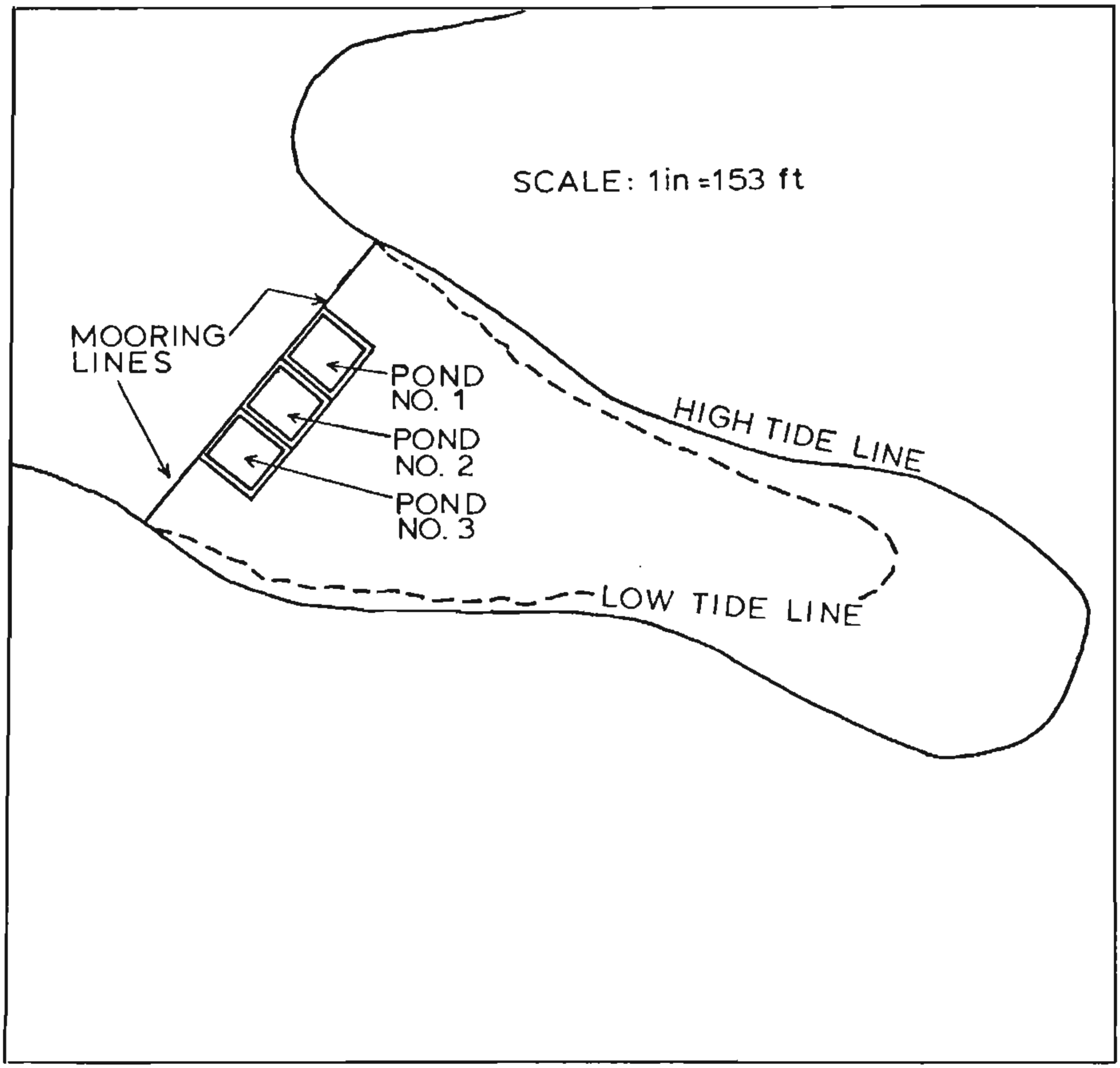


Figure 2-3. Site Plan of Cramer Passage Ponds.

Plate 2-1. Cramer Passage pond site.

2.2.2 Parson Bay Pond Site

Parson Bay is a large bay on the western end of Harbledown Island at the head of Blackfish Sound (see Figure 2-4). It is approximately a mile wide and almost two miles long. At its head are several smaller unnamed bays, the most northerly of which was selected as a pond site. This bay terminated in shallows; its shores were rocky and boulder strewn; its bottom, flat and sandy. The depth ranged from 15 to 30 fathoms. Dense forest came down to its shores.

Ponds were located in the middle, about one-third of the way into the bay and secured to the shore by moorings. At low tide, the lowest part of each pond was about ten feet off the bottom (see Plate 2-2).

Plate 2-2. Pond site Parson Bay. Pond No. 1 (b) being installed.

Initially, two ponds were established. These were towed from the Cramer Passage pond site on March 31. A third pond (1(b)) was installed on April 10 (see Figure 2-5).

The Parson Bay site was exposed to the prevailing westerlies, which blew down Queen Charlotte Sound and Blackfish Sound into Parson Bay; and to southeasterlies, which blew out of the low valley at the head of the bay. When it was windy, tying the fishing vessels alongside the ponds strained the pond's moorings, and on two occasions, wind forced both vessels out of Parson Bay altogether. The boomsticks that formed the ponds and the mooring lines attached to shore trapped a lot of floating debris, especially after storms and high tides. Nonetheless, except for one mooring breaking, the ponds and their impounded herring survived the wind very well.

2.2.3 Pond Construction

All of the ponds used in this project were prefabricated, floating ponds, 60 feet square. Except for the boomsticks used for floatation, the ponds were assembled in a net loft in Alert Bay prior to the commencement of fishing. The assembled web, lines and booming hardware were stored aboard the Kitgora.

When a pond was required, suitable boomsticks were towed to the area (see Plate 2-3).

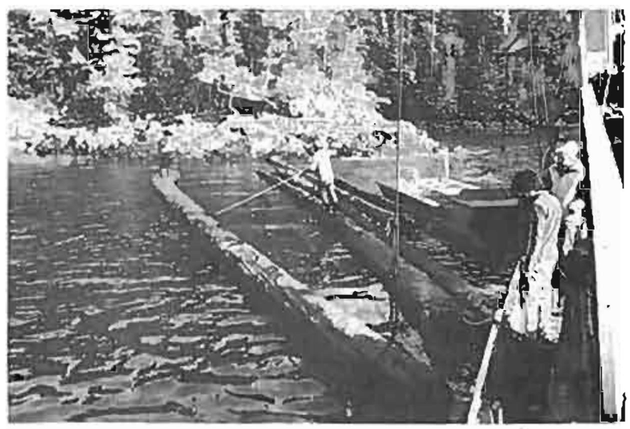


Plate 2-3. Salvaged logs ready for pond frame assembly.

(These had often been moored at accessible places along the shore beforehand.) The logs were flat notched (see Plate 2-4) on the ends to interlock with each other, and arranged to form a floating square.

At each corner, the more buoyant log was placed under the less buoyant to give it support. The corners were lashed together with two to four wraps of steel cable held in place with boom staples (see Plate 2-5). Then, using the double block from the boom of the Kitgora (see Plate 2-6) the corners were lifted and the cable tightened.

Once the logs were notched and lashed to form a rigid floating square, the pond web was suspended inside the floating boomsticks (see Plates 2-7 and 2-8). The web was hung from a half-inch blue nylon line. This line was nailed or stapled to the inside of the boomsticks except for a ten to 15 foot gap left for the gate. The pond web was

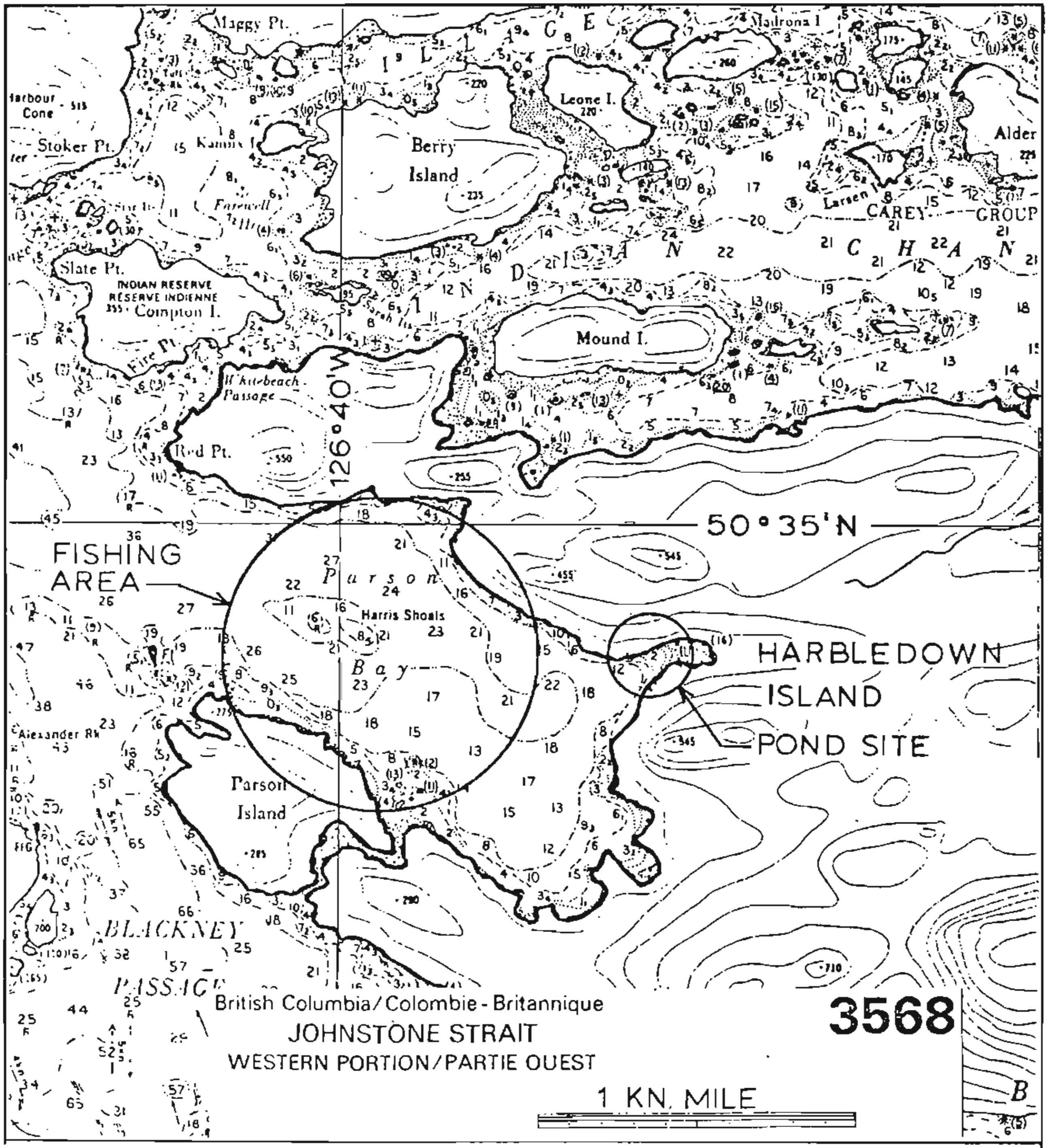


Figure 2-4. Parson Bay Pond Site and Fishing Area

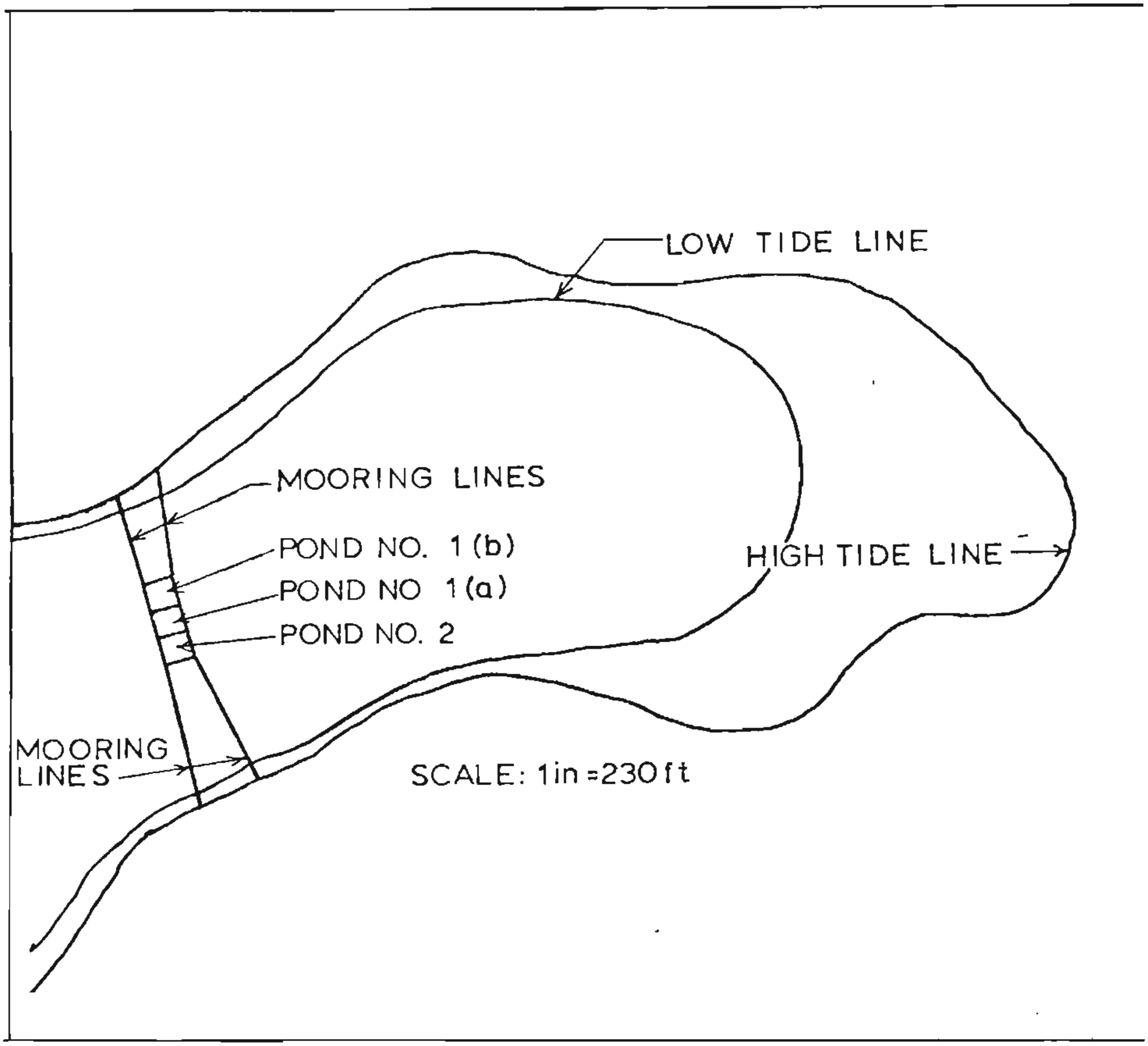


Figure 2-5. Site Plan of Parson Bay Ponds

Plate 2-4. Notching the ends of logs.

Plate 2-5. Double block holds end of log out of water. This will be top corner of log. Note how wet (bottom) side of log is being notched.

three strips deep. At this stage of assembly, the pond web would hang straight down inside the boomstick frame. The web was not tapered toward the bottom, so if the pond had to be towed, the web could be pulled up and piled on top of the perimeter logs.

On the bottom border of the web, a becket line was hung with two-inch nylon rings at eight-foot intervals. A half-inch blue nylon line ran through the rings to serve as a purse line. The bottom of the pond could then be closed by drawing up the purse line. The nylon rings afforded easy passage of the purse line ensuring that it closed evenly and tightly. A weight, such as a piece of boom chain, was hung from the centre and supported by a line to the surface secured to a floating "scotsman." The length of this line determined the depth at the centre of the pond, usually 15 to 25 feet. By hanging additional weights (rocks in onion sacks) at the corners and along the sides, the shape of the pond and the depth of its walls could be adjusted.

Plate 2-6. Cable being tightened at corner.

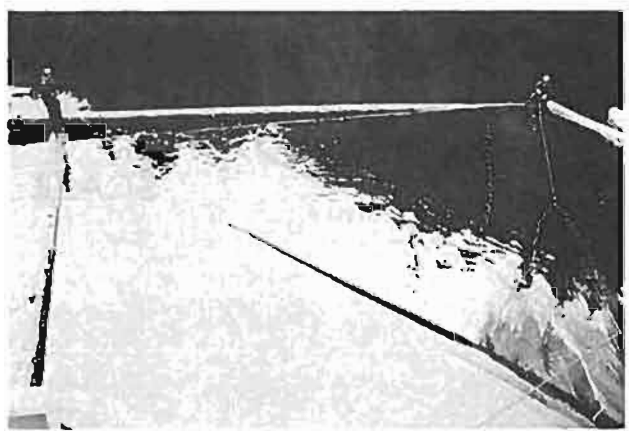


Plate 2-7. Web being installed inside pond frame.

2.2.4 Fishing

Description of Vessels and Gear. The primary vessel, Nimpkish Producer No. 1, is a steel boat, displacing 160 tons and measuring 24.4 meters long by 6.1 meters wide. Her draft is 3.6 meters when fully loaded, and her hold capacity 130 tons. She is equipped with a bow thruster and a refrigeration unit capable of maintaining a champagne system in her fish holds. She carries an Ekolite Mark 5 Special Herring sounder (frequency 29, wet paper, with the sensitivity set at 1.5), a Comdev Marine sounder (Model CDM-105), and a Wesmar Scanning Sonar SS160. Her seine is of maximum length and

and 30 fathoms deep.

Plate 2-8. Edge of web being nailed or stapled to logs.

The second vessel, Kitgora, is a classic salmon seiner. She was used as the towing vessel and was most valuable in pond construction since her deck was lower than Nimpkish Producer's. She carries an Ekolite 15 D 4 sounder (dry paper, frequency 39) and assisted in all fish surveys.

An inflatable skiff and a herring punt, both outboard powered, were used for pond construction and reconnaissance.

In addition to the two Skippers and a Field Biologist, five crew members were aboard. A few crew changes occurred in the course of this study; three of the original complement stayed till the end.

Locating Herring. Reconnaissance for herring occurred during the daytime. Areas were patrolled at about four knots, with the sounder on. Any activity on or near the surface prompted sounder observations at that spot, but often nothing would be seen beneath the surface.

If an area showed numerous schools, it would be surveyed again at night by both vessels. With darkness, herring tend to spread out at a uniform shallow depth to form a skimmer, which appears on the sounder as a diffuse band running parallel to the surface. A typical medium skimmer would occupy a depth from five fathoms to 12 fathoms. With practice, the size and density of fish can be guessed by the density and graininess of the sounder printout. Small fish tend to show as a dark dense band; larger fish appear lighter and grainier.

Most fishing occurred at night. After locating the best sounder showing, sets were made by the Nimpkish Producer.

In a 24-hour period, herring will spread out uniformly as an evening skimmer, fracture into small groups during a daytime slack tide and aggregate into large schools with the running of the tide. This made finding the ideal school, uniform in size and maturity, difficult.

Fishing in Cramer Passage. At the time the Cramer Passage site was being established (March 14 and 15), the Nimpkish Producer had to go to Vancouver for hull repairs. As a result, fishing was delayed until March 23. In the meantime, the type of herring frequenting Cramer Passage changed. Set No. 7, of which approximately ten tons were ponded at the Cramer site, was a mixture of sizes and maturities. The fish from this set were eventually released from the pond and no other sets were impounded from Cramer Passage. One empty pond was left there throughout the study in case suitable fish were found in the area. Surveys of Retreat and Cramer Passages continued into mid-April, but the ratio of small and spawned-out herring was too high to justify ponding for roe.

Fishing in Parson Bay. Set No. 12, made in Parson Bay at 12:15 a.m. on March 31, indicated the presence of a large number of herring suitable for ponding. About ten tons were caught of which 179 were examined before the set was released. Of these, 52.5 percent were males, 14.5 percent were slinks (spawned-out herring) and 33 percent were females. The females carried large immature roe of somewhat uniform development. The test indicated an undesirably high proportion of males, but the number of slinks was lower than had been found elsewhere. (Because the slinks were generally smaller than the roed fish, their percentage by weight was lower than 14.5 percent.) Although the proportion of females was low, they were large (25 cm. average) and of uniform maturity (No. 3 roe).

Between March 31 and April 30, 14 sets were made in Parson Bay, ten of which were ponded. Six sets made over two consecutive nights' fishing, March 31 and April 1, were ponded in Parson Pond No. 1; four sets made over three days, April 3, 6 and 9, were ponded in Pond No. 2. On most sets, the net touched bottom. Nearly all sets were made at night when the herring were in skimmers, usually between five and 12 fathoms. Sets varied from five to 20 tons per set.

2.2.5 Sampling From Sets

A total of 33 sets were made from which we attempted to collect the following data:

1. A sealed sample for laboratory analysis. A 50-pound sealed sample was taken for analysis to the Fisheries and Oceans herring laboratory in North Vancouver. Samples could not always be delivered at once, and sometimes they were five or six days old before they reached the lab. They were kept cool, but freezing facilities were not available. (At time of writing, analysis of these samples was not available.)

2. Length measurements. One hundred fish were taken at random from each set for a length measurement. Sets No. 20 and 21 were missed because measurement sheets were unavailable. A length data sheet was improvised for Sets 22 to 30 inclusive.

3. Roe test. One to three roe test buckets were examined for sex ratios, roe maturity and roe quantity. Roe quantity was measured initially using the Standard Fisheries and Oceans roe test method used in the roe herring fishery, i.e. using a volumetric cylinder and a test bucket of stand size. This test provided information about the quantity of mature roe in herring from each set. Later in this study, particularly when roe maturation was being monitored at the ponds, roe maturity was determined directly by weight, using scales and larger samples, rather than the standard roe test.

Samples were secured either from the bunt of the seine or by dip netting.

1. From the bunt of the seine. The size of this sample could be regulated by holding the bunt end from the deck by a line and releasing fish slowly until 100 to 300 pounds remained. This method was inclined to produce an unrepresentative sample, since the slower fish tended to be the last to escape.

2. By dip netting. Herring were dip netted from the folds in the net while drumming in the seine. This method also tended to produce an unrepresentative sample, since the herring in the folds were probably from one school and thus of uniform size. But this was the only convenient means of obtaining a sample by dip netting; fish swimming freely were very difficult to capture with the dip net. The fish could have been concentrated more by drying up the seine, thus disrupting school formation and causing the fish to boil. Samples could then have been taken from the boils. While this might have produced more representative samples, to concentrate the fish was to risk crushing damage, mortality and quality loss. So this method was not tried.

2.2.6 Fish Towing

Generally, the distances and durations of tows were short. The longest tow to the pond site took two hours; most took less than one hour.

The Nimpkish Producer was towed broadside by means of a bridle and tow line pulled by the Kitgora. Towing speed was one to two knots. The rings were held by means of hairpin and single fall. The net flowed away from the direction of travel, creating "shallows" in the folds of web near the fishing vessel. Occasional boils occurred along the cork line. These tended to subside after a minute or so and then reappear elsewhere along the cork line. This activity was most common at the beginning of the tow. After 20 to 30 minutes the herring seemed to settle and swim normally as the net established a fairly permanent shape in the current produced by the tow. If the sets were 20 tons or less and the towing speed was not excessive, the herring were not crowded and so were not crushed in the seine.

Samples were taken during towing to establish size, sex and maturity of the fish being ponded. Scale loss was observed among fish in the samples, but this probably occurred during and after removal from the seine, not during towing. Net wounds were not seen on fish sampled during the tow.

2.2.7 Fish Transfer (See Figure 2-6.)

As the fishing vessel under tow approached the ponds, the running line from the fishing vessel was taken to the pond via power skiff. The end of the running line was secured to the corner of the pond, enabling the vessel to winch itself toward the pond without using its propeller, which could have become entangled in the net. As the vessel and net approached the pond, the angle of the vessel to the pond was adjusted by using the bow thruster. The vessel had to be secured to the pond with the vessel's stern away from the pond. This was done by shortening the bow line so that the forward curve of the hull was forced against the side of the pond, which made the stern lay at about 20 degrees to the pond. The running line served as a second mooring, preventing the stern from drifting away from the pond. This arrangement cleared the stern of any moorings that might have interfered with the transfer operation.

The gable end of the net was tied along the boomstick and the gable laced to the pond's web at the gate. A wind line held the cork line near the gable end away from the gate, and the power skiff stood by to pull out the cork line if the bag of net drifted or collapsed. To induce the herring to swim through the gate into the pond, the bag size was reduced by drumming in the seine. The gate of the pond was patrolled with gaff and pike pole to prevent unwanted species from entering the pond. When almost all the net was drummed in, the remaining bag was reduced by pulling web into the fishing vessel by hand. When most of the herring had entered the pond, the gate was closed and the gable end dropped. Unwanted species were caught, and the remaining herring released.

The operation became very efficient: three sets of herring could be caught, towed and transferred in one night.

2.2.8 Pond Loading Density

Volume of Ponds. The pond depths were difficult to measure because of the rounded shape of the suspended web. The depth at the perimeter was determined by the length of line supporting the weights used to keep the pond open or by sounding with the Sechi disk until it came to rest on the web. The depth at the middle was determined by the length of line between the float and the vent. In addition, several dives were made in and under the ponds to examine the pond's shape. Fifteen to 20 feet was considered a fair estimate of average depth. The approximate volume of each pond, therefore, given that they were all 60 feet square, was 60,000 cubic feet. At a ponding density of one pound of herring per cubic foot of pond, each pond should have been capable of carrying 30 short tons of free-swimming herring.

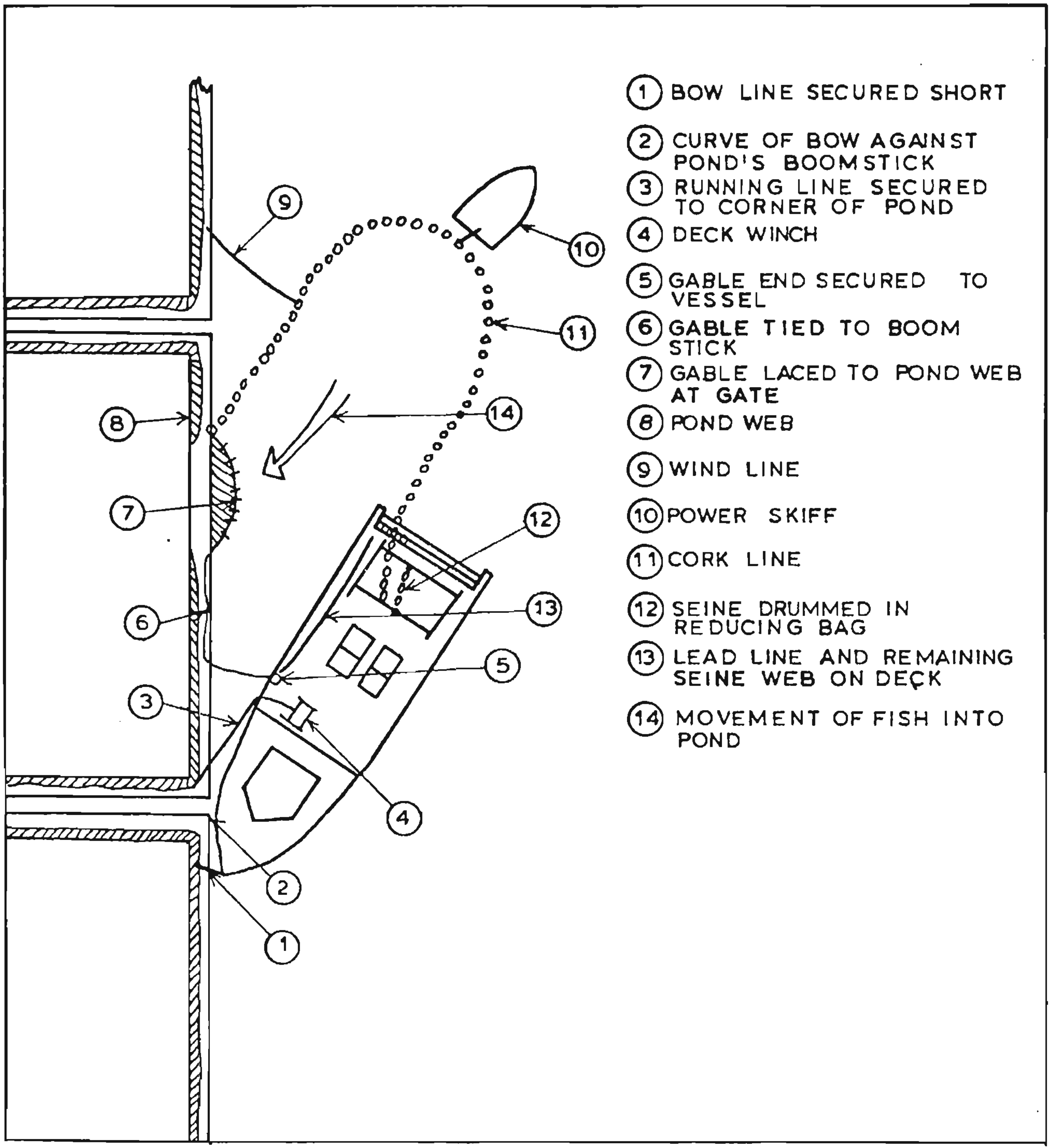


Figure 2-6. Transfer of fish from seine to pond.

Density of Cramer Passage Pond No. 1. About ten tons or less were ponded at Cramer Passage for eight days. No damage as a result of ponding was observed on their release. This was to be expected from a light ponding density of one pound of herring per three cubic feet of pond.

Density of Parson Bay Pond No. 1. It was estimated that 60 tons were ponded in Parson Bay Pond No. 1, twice the maximum density for sustained impoundment (i.e. two pounds of herring per cubic foot). But this estimate was subject to error as it was made by watching the herring enter the pond and guessing their tonnage. Nevertheless, Pond No. 1 was obviously overcrowded. The fish were too crowded to move in schools; they milled up to the surface as they encountered the pond web, especially in the corners; and when groups met, the fish would boil to the surface as they tried to find more space.

Because the fish in Pond No. 1 were obviously overcrowded, half were moved into another pond. The second pond, which was alongside Pond No. 1 would have been convenient, but it was receiving fish from Parson Bay, and we felt that if the two ponds were joined, the damaged fish from Pond No. 1 would reduce the quality of the fish already in Pond No. 2. Furthermore, it would have confused the data being collected from the two ponds. Therefore, a third pond frame, which had been assembled in Baronet Passage nearby, was towed alongside Pond No. 1. The pond web was installed, and a gate was opened between Pond No. 1 and the new pond. With the aid of a small seine, about half of the fish in Pond No. 1 were transferred to the new pond. These ponds became Pond No. 1(a) and Pond No. 1(b). This was done on April 10, ten days after the first fish entered Pond No. 1.

Density of Parson Bay Pond No. 2. After five to six weeks of impoundment, 23 tons of herring were removed from Pond No. 2. Later the web of the pond was pulled up to reveal three to five more tons. No dead fish were found on the bottom. Pond No. 2, therefore, held 26 to 28 tons of herring for five to six weeks. This would represent a ponding density of just under one pound of herring per cubic foot of pond.

2.2.9 Roe Maturation

An attempt was made to monitor the ponds at Parson Bay at least every two days. This was usually done when the Nimpkish Producer was fishing in the area, but later in the study a special trip had to be made from Alert Bay in a small boat to secure samples and return with them to Alert Bay for analysis. This was a round trip of about 15 miles, so sometimes had to be foregone because of bad weather or lack of time. The longest period without sampling was four days. In all, the Parson Bay ponds were sampled 22 times over a 38-day period, from April 1 to May 8.

Initially, samples were dip-netted by walking out on the boomsticks and catching fish from concentrations near the surface. During the period of overcrowding in Pond No. 1, the fish near the surface were not representative of fish deeper in the pond. To correct this, a small seine was used. This was pulled across the pond entrapping a one- to three-ton sample. The lead line was pulled up until the herring in the seine reached a concentration dense enough to dip net. Two large sample buckets, containing between 60 and 70 pounds altogether, were taken from each pond.

The roe content of sampled herring was initially measured using the standard volumetric roe test. But this method proved to be unsuitable for our purposes since we wanted to be able to relate various factors with one another (such as maturity to size) and to differentiate between sexes. The volumetric roe test was developed to overcome difficulties of weighing samples on a tossing vessel. But this was not a problem for us since ponds had to be moored in sheltered waters. Thus we could obtain accurate measurements from scales. So a large accurate set, capable of measuring 30 pounds to the nearest ounce, was found and a new method for making pond maturation measurements developed. A two-bucket sample was divided into slinks, males, immature females and mature females. (Grouping females according to whether they had No. 1, No. 2 or No. 3 roe was found to be too arbitrary. They were either immature or mature—they made the transition quickly.) The number of pieces and the total weight of each of these four categories was recorded.

2.3 OBSERVATIONS

2.3.1 Effects of Fishing on Local Stocks

The 60 to 80 tons of herring caught at the Parson Bay site did not present a threat to local stocks. No appreciable decline in the herring population of the area was detected over the fishing period, although the locations and density of skimmer varied from one night's fishing to another.

2.3.2 Damage to Herring During Sets

Scale loss was minimal during sets, and the only net damage observed was on those fish gilled or trapped in the folds of the web. Most of these fish were drummed aboard and therefore did not enter the ponds. The proportion of gilled and entrapped fish probably reflected the degree of turmoil caused during each set.

2.3.3 Gut Voidance

The gut contents of ten fish were weighed at the time of capture and at the time of release from the Cramer Pond. The entire digestive tract was removed, and the liver and spleen discarded. The digestive tract was weighed together with its contents to determine the ratio of digestive tract weight to total body weight. At the time of capture, the digestive tract with food in it represented 2.8 percent of the total body weight. Eight days later, when the fish were released, the digestive tract, which was presumably empty by this time, represented 1.65 percent of the total body weight.

This procedure was repeated at the Parson Bay ponds, but we had only limited success in repeating the results.

This data was collected to determine whether "belly burn" could be avoided.

2.3.4 Spawning

By midnight on March 23, Set No. 7 was impounded in Cramer Pond No. 1. By noon the following day, captured herring were spawning on the web inside the pond (see Plate 2-9), and wild herring were spawning on the web outside the pond, making it impossible to determine how much of the spawn on the web had been deposited by captured fish. The wild herring also spawned on the two adjacent empty ponds. The herring spawned on clean herring web, on the orange plastic scotsman supporting the centre of the pond, but not on the blue poly lines (see Plate 2-10). The accumulated eggs formed a mass five to ten mm thick (see Plate 2-11). Due to the density of milt, the visibility in the water near the ponds dropped from nine meters at 12:00 p.m. to two meters by 6:00 p.m. No spawning was observed on the *Fucus* along the shore of the bay, nor had spawning been recorded in this bay in previous years.

Plate 2-9. Herring spawning on web.

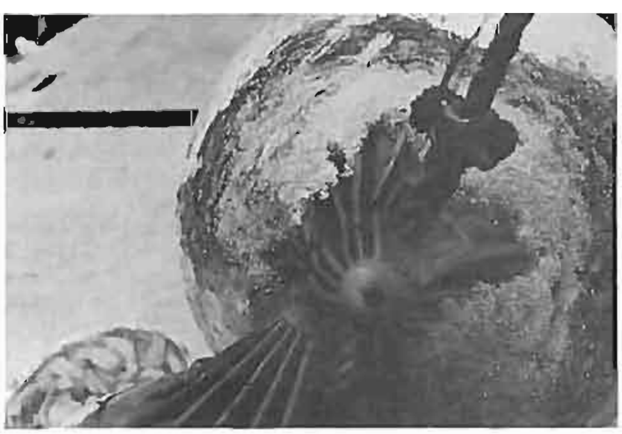


Plate 2-10. Spawn adhering to scotsman. Note absence of spawn on (blue) colored line and eye made of different colored plastic.

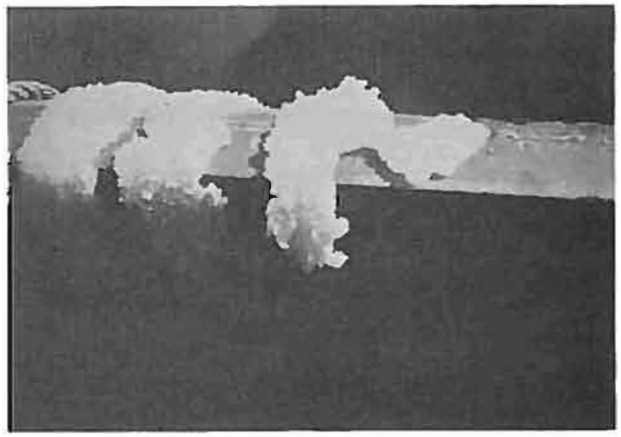


Plate 2-11. Spawn peeled from pond web.

The spawning of herring in Pond No. 1 was speculated to have resulted from their recent impoundment, the presence of a suitable substrate, and the spawning activity of herring in the area.

For the next week, the ponds were not observed. (We left Cramer Passage searching for herring with a better maturing female ratio.) On March 31, we returned to the pond site. All three ponds were covered in spawn, and we suspected that the herring in Pond No. 1 had all spawned out. We tried to collect a sample using a gillnet, but the herring were nearly all too small to be gilled. However, a few larger herring were caught of which sixteen--six males and ten females--were 26 cm. They were all mature herring; the females had well-developed roe No. 1 and No. 2 maturity.

A small seine was then used to secure two buckets of herring for testing. The ratio of slinks was now 83 percent. Some mature females (2½ percent) and immature females (7½ percent) were still present. Interestingly, *large* maturing females impounded in the pond had not spawned. This was taken to indicate that schools of herring of mixed maturity do not all spawn together, and thus the importance of finding herring of uniform maturity. Because of the variation in size and maturity, the ponded herring in Cramer Passage would have been far more valuable in a roe-on-kelp or a roe-on-branches operation than in a roe herring operation.

2.3.5 Effects of Pond Loading Density

Parson Bay Pond No. 2. When herring were removed from Pond No. 2 (April 7), 100 fish were examined for scale loss and any damage associated with being impounded for one month at the optimum ponding density of one pound per cubic foot of pond. From a 100-fish sample, two showed minor abrasions, possibly inflicted by the web or predators; seven showed red patches—a hemorrhaged area on the operculum, belly, or side; and all showed some scale loss, much of which was attributable to their being sampled and to their dying. Scale loss varied from 5 percent to 75 percent of the body area, with the average estimated at 20 percent.

Fifty fish had been sampled in a similar fashion before entering Cramer Pond No. 1 on March 23. Of these, all showed some scale loss, varying from 2 percent to 60 percent of the body area, with the average estimated at 15 percent. None showed any abrasions or hemorrhaging. This suggests that some damage resulted from ponding in Parson Bay Pond No. 2, but not very much: average scale loss—5 percent; incidence of hemorrhaging—7 percent; incidence of minor abrasions—2 percent.

Parson Bay Pond No. 1. Stress damage as a result of overcrowding was anticipated and observed in Pond No. 1 (see Plate 2-12).

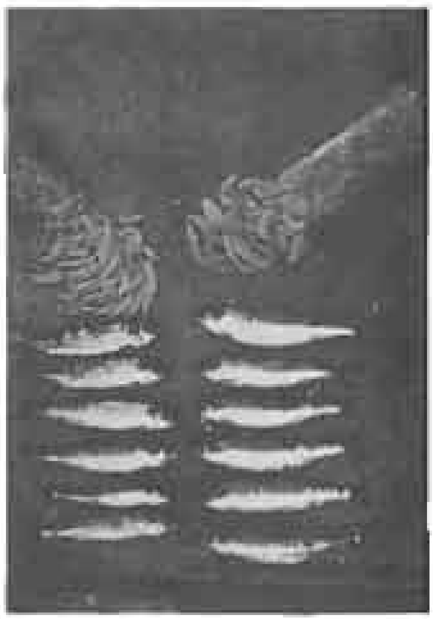


Plate 2-12. Comparison of fish and roe sampled from Ponds No. 1 and 2, Parson Bay. Pond No. 1 fish show stress due to overcrowding.

Three days after entering the pond, hemorrhages were observed on sides, bellies and opercula of 3 percent of the fish sampled (see Plate 2-13). After six days, 18 percent showed this kind of stress damage. A dive under the pond revealed 500 to 1000 dead fish on the bottom. After seven days, 41 percent showed stress damage. In addition to redness, fish showed deterioration of fins and tails (see Plate 2-14). After eight days, almost all sampled fish showed some form of damage: hemorrhaging, scale loss, fin and tail wear, or deterioration of the mouth and lower jaw. Many swam on their sides and their movements lacked direction.

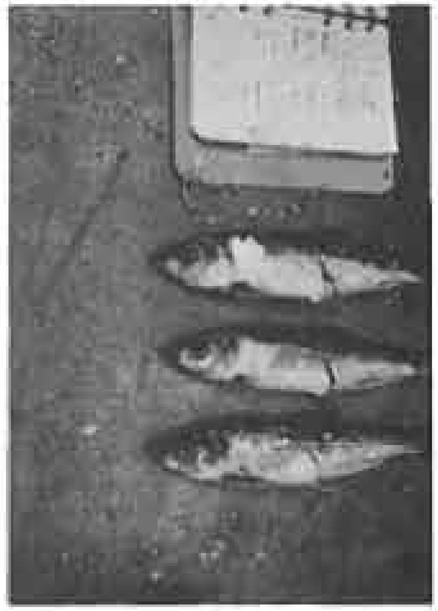


Plate 2-13. Hemorrhaging that resulted from overcrowding (slashed belly to to examine roe).

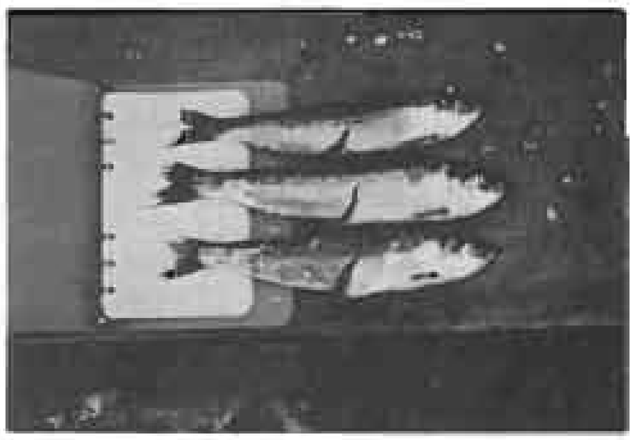


Plate 2-14. Deterioration of tail fins resulting from stress by overcrowding.

The sample probably reflected a higher incidence of stress damage than actually took place since undamaged fish stayed deep in the pond, while damaged fish tended to swim near the surface. So the latter were more susceptible to capture when samples were taken with a dip net.

In addition to overcrowding, two other factors might have contributed to the stress experienced by fish in Pond No. 1:

1. A lot of small sets went into the pond. As new fish were introduced, the fish already in the pond became excited. In addition, the all-night activity of people working on the boomsticks,

the seine boat running or manoeuvring alongside, and the propeller wash, particularly from the bow thruster, all combined to alarm the fish, causing them to damage themselves by rubbing against the web.

2. Three very windy days followed the installation of Pond No. 1. One of the moorings broke and a lot of floating debris entered the pond. The movement of entrapped debris and motions of the pond itself under the influence of wave action could also have disturbed the fish.

The male/female/slink ratio changed during the period of stress damage and death. Unfortunately, the maturing females appeared to incur the most damage. At the time they entered Pond No. 1, about 41 percent of the fish were maturing females. But by the time Pond No. 1 was divided, the proportion had dropped to about 30 percent. That the females suffered more damage is also supported by the following observations:

1. A sample of dead fish from the bottom of the pond had a higher percentage of roe than normal.

2. Samples taken when herring in Pond No. 1 were showing their worst stress symptoms indicated that the percentage of roe was increasing. But samples taken after the pond was divided, showed that the percentage of roe had declined.

3. Decaying carcasses from the bottom of Pond No. 1(a)'s web on May 8 contained a lot of females with roe. (The roe and skeleton decay last.)

We do not know precisely how many fish died as a result of overcrowding in Pond No. 1. However, it was estimated that Pond No. 1 contained 62 tons of herring and that Ponds No. 1(a) and 1(b) together contained between 25 and 40 tons at the end of the ponding period. This indicates a loss of a least 37 percent. The number of carcasses was less than five tons, so predators must have consumed the remainder.

Once Pond No. 1 was divided into Pond No. 1(a) and 1(b), the behaviour of the herring changed dramatically within 24 hours. The fish formed large, well-coordinated schools, which moved slowly in a circular pattern deep in the ponds. Damaged fish were still near the surface, but their numbers declined as they either died and sank to the bottom or succumbed to predators, particularly gulls, crows and eagles.

2.3.6 Predation

Birds. Crows, gulls and eagles were always present at or near the ponds. As many as 20 bald eagles were observed at one time. The birds fed mainly on dead fish or caught damaged fish swimming near the surface.

Mammals. A small black bear was seen on two occasions, once on the beach and once swimming near the ponds. On both occasions, it retreated as our craft approached. No damage to the web was evident, if indeed, it had been at the ponds. Otter, seals and sea lions were not seen.

Dogfish (Squalus acanthias). No predator barriers were used and as a result many dogfish found their way into the ponds. Pond No. 1(a) became particularly heavily infested, apparently because the seine vent was partially open. About 100 two- to three-foot dogfish were shot as they approached the surface in the pond corners. Several of the large dogfish killed were cut open to expose their viscera and hung by the tail around the pond. The scent of dogfish guts is rumored to act as a dogfish repellant. The incidence of dogfish did seem to drop off somewhat.

Grey Cod (Gadus macrocephalus). Grey cod were usually observed during seining herring, some of which were inadvertently ponded. Others apparently gained access later, since the number of grey cod in the ponds increased, especially in Pond No. 1(a). Large numbers of grey cod congregated outside the ponds as well. These were easily jigged; one morning two men took in 400 pounds. The number of herring lost to grey cod could not be determined, but the stomachs of three- to five-pound grey cod usually revealed at least three herring.

Sablefish (Anoplopoma fimbria). A lot of small sablefish--not much bigger than large herring--entered the ponds, apparently through small holes in the web. Hundreds were in each pond by the end of the study. The herring carcasses at the bottom of Pond No. 1(a) and on the sea bottom below the ponds probably attracted them.

Predatory fish only became a problem after the ponds had been in place for several weeks.

2.3.7 Roe Maturation and Yield

Cramer Passage. The two buckets of herring put aside from Set No. 7 for analysis, produced the following information:

1. Forty-four percent of the ponded fish showed no gonad development, either because they were too immature or had already spawned;

2. Eighteen percent were mature females with No. 1 mature roe;

3. Fourteen percent were immature females.

(We know, in retrospect, that this ratio of females would not have been sufficient to produce a 10 percent roe yield.) The absence of maturing roe in so many fish was puzzling as this condition was inconsistent with the size of the fish.

Because the sex of the immature fish could only be guessed, we subsequently grouped all herring showing no roe development together regardless of sex. These were the "slinks," a term used by many herring fishermen. The classification was useful since the important fact in ponding herring for roe herring is not the proportion of *females*, but rather the proportion of *mature* and *maturing* females. Besides, true sex ratios could be determined at the herring laboratory, which received samples from every set.

Parson Bay. Roe percentage usually refers to the amount of mature roe in a sample of herring, but in this study it refers to total roe. Roe data is given in Graphs I, II and III for each of the three ponds at Parson Bay. When mature roe first appeared in the ponds, there was not enough mature and immature roe to permit their being measured separately in the graduated cylinder of the roe test kit, so they were measured together until April 21. Beginning on that date, total roe (the sum of mature and immature), mature roe and immature roe were all measured. Generally, as mature roe increased, immature roe decreased; total roe showed a gradual increase over the time of impoundment.

The irregularities in the graphs are thought to be due to variations in the samples. To try to correct for some of the variation, and to see what the roe percentage would have been had females always represented 50 percent of the sample, we constructed a second table; the data from it were plotted along with that from the real situation.

As can be seen in Graph I, on May 8 (the last day that Pond No. 1(a) was monitored), the total roe was 9.8 percent, of which 7.5 percent was mature and 2.3 percent was immature. Had the herring been 50 percent females, the total roe would have been 12.7 percent, 9.7 percent of which would have been mature roe, with 3.0 percent still maturing.

The roe percentage of the fish at Parson Bay was relatively low, making it questionable as to whether the ponds would generate the 10 percent yield needed to market the herring as roe herring. This was due to the low percentage of females, not the maturity of the roe.

In the early parts of this study, when occasional mature females were being caught in the Cramer Passage area, we observed that mature roe represented about 25 percent of the total weight of these individual females. (It varied between 24 and 29 percent.) Roe percentages in the immature females were also measured to determine how far the roe was from maturity. This was especially relevant to the fish ponded at Parson Bay. At the time of their impoundment, no females were mature, and we were concerned that these fish would never develop mature roes. But, as shown in Graph IV, roe growth was evident. It was gradual, but appeared to take place at a constant rate of 0.27 percentage points per day. Given a linear growth rate and sufficient sampling to map the progress of maturation, we should be able to predict how long we have to hold herring and to determine how much time to allow for harvesting.

Roe maturation can also be determined by the physical appearance of the roe. Immature roe is opaque and the gonads are heavily veined. Mature roe is larger, venation almost disappears on the surface of the ovaries and the roe shows segmentation and a general translucent quality. Colour of both immature and mature roe is variable. Developing roe probably follows a predictable sequence of stages regarding size, vascularization, colour, detectable segmentation and translucency.

Graph V shows the rate at which the immature females impounded at Parson Bay matured. (Presumably, the incidence of mature females would have approached 100 percent as the roe-weight-to-body-weight ratio moved towards 25 percent.) The smoothness of the curve implies that we could anticipate when and how many unripe females would reach maturity. The curve would probably level off before the females reached a marketable condition of maturity.

The ratio of mature females to total females can be easily determined by visual inspection of roe; no weighing is needed.

2.3.8 Environmental Data

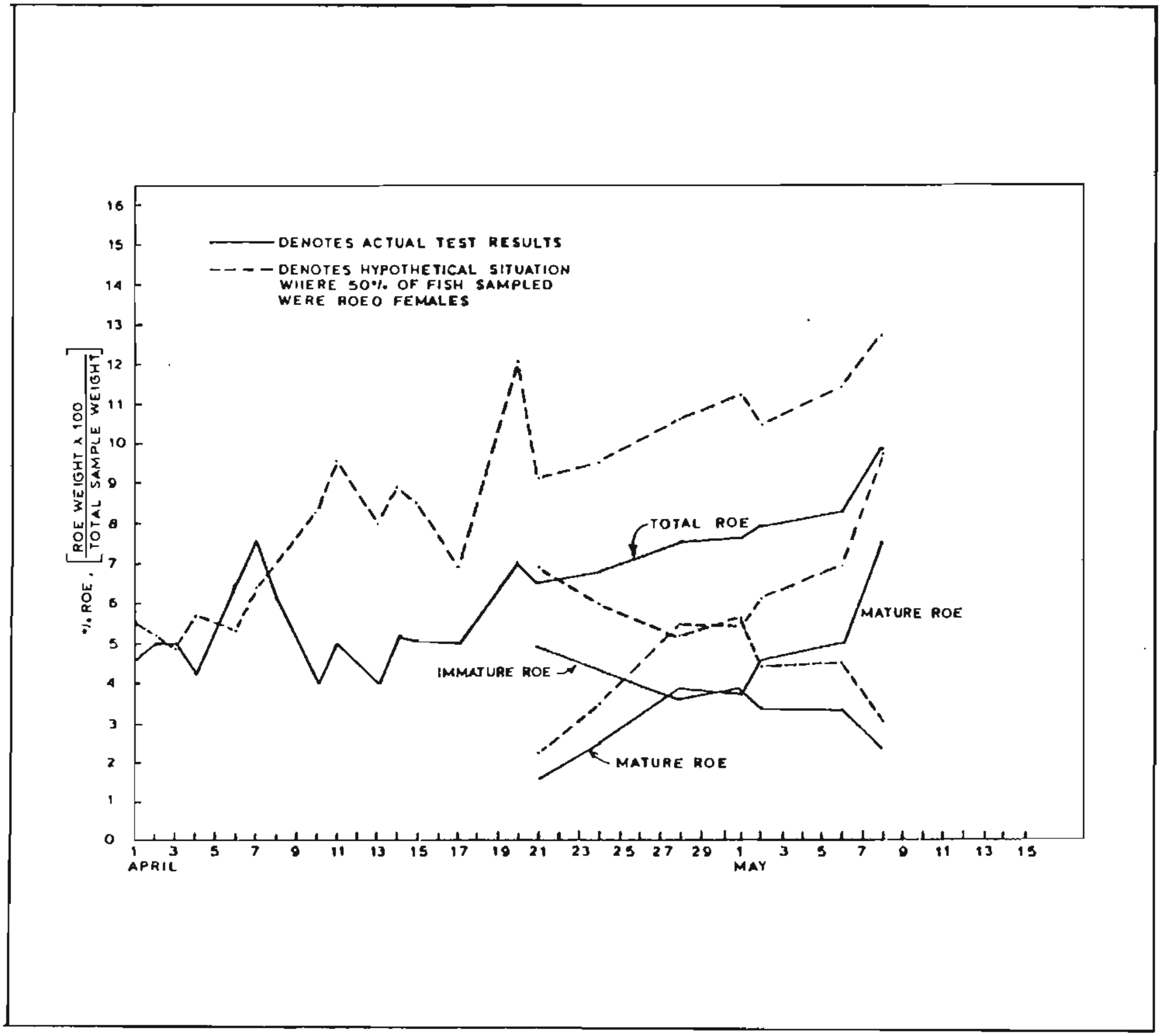
Water Temperature. Water temperatures were recorded throughout the duration of this study. They were taken at the time of each set, at the ponds whenever a sample was taken, and at random intervals while passing by. Temperatures fluctuated greatly, which was to be expected in an area with so many quiet pieces of shoreline and active tides. During the two-and-one-half months the temperatures averaged 8.3° ± .4°; by early May, they had reached 9.0°C ± .4°. The warmest reading was at the Parson Bay pond site one sunny afternoon when the tide came in over a warm beach. Surface temperature was 9.9°C.

Turbidity. Turbidity was measured using a Sechi disk on most of the days when the ponds were visited. Considerable variation was observed. Visibility ranged from five to 12 meters.

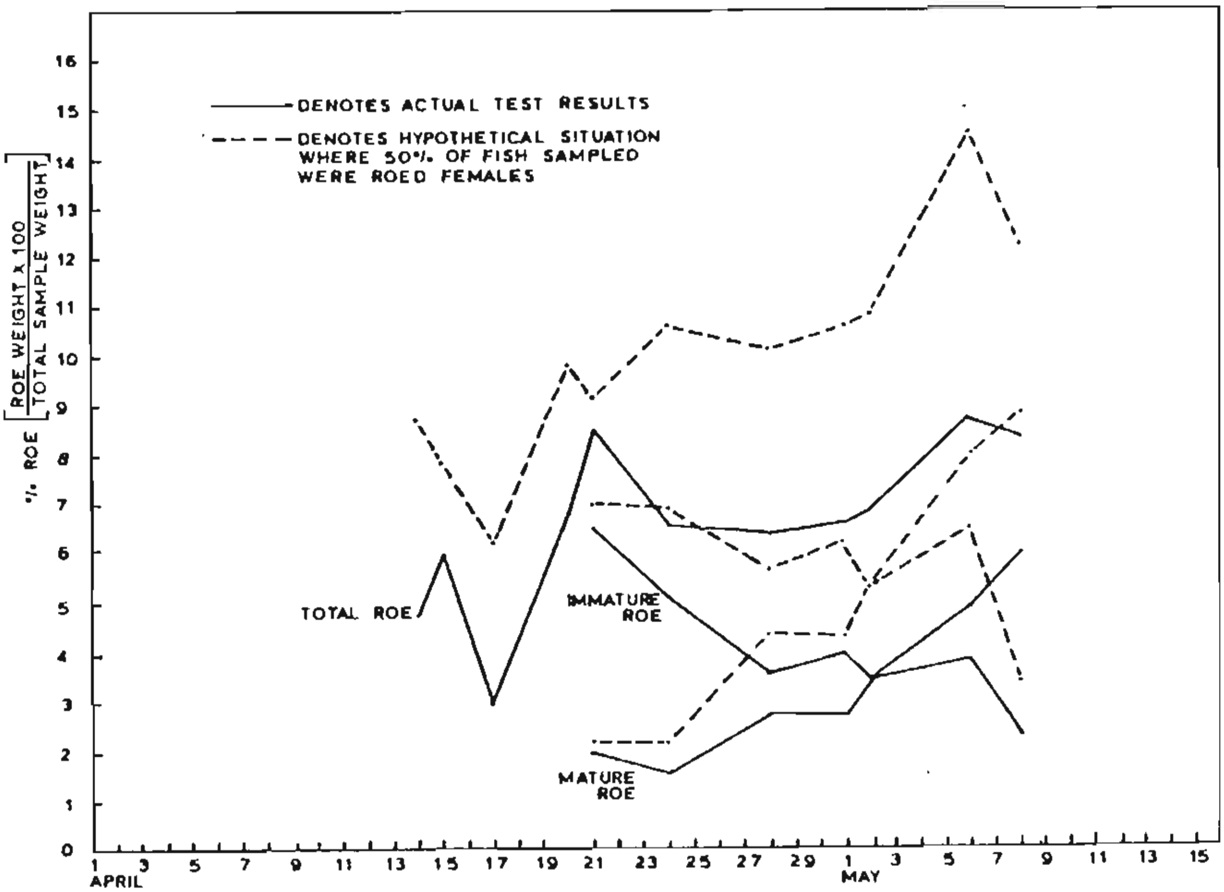
Dissolved Oxygen. Dissolved oxygen readings were obtained using a titration method with a HACH field kit. A compromise between the long and short titration was used by doubling the quantity of sample titrated in the short method. This doubled the accuracy of the short test without the likelihood of running out of titrant. Surface dissolved oxygen was taken during most visits to the ponds. Results varied, but were always between 7.0 and 9.0 mg. per litre. On several occasions, water samples were taken at various depths within the ponds. The results never differed from the surface readings by more than 1.0 mg. per litre.

Even during the time of extreme overcrowding at Parson Pond No. 1, dissolved oxygen depletion did not seem to be a contributing factor to the stress and damage experienced by the impounded fish there. Dissolved oxygen was never found to fall below 7.5 mg. per litre even when measured at the bottom of the pond.

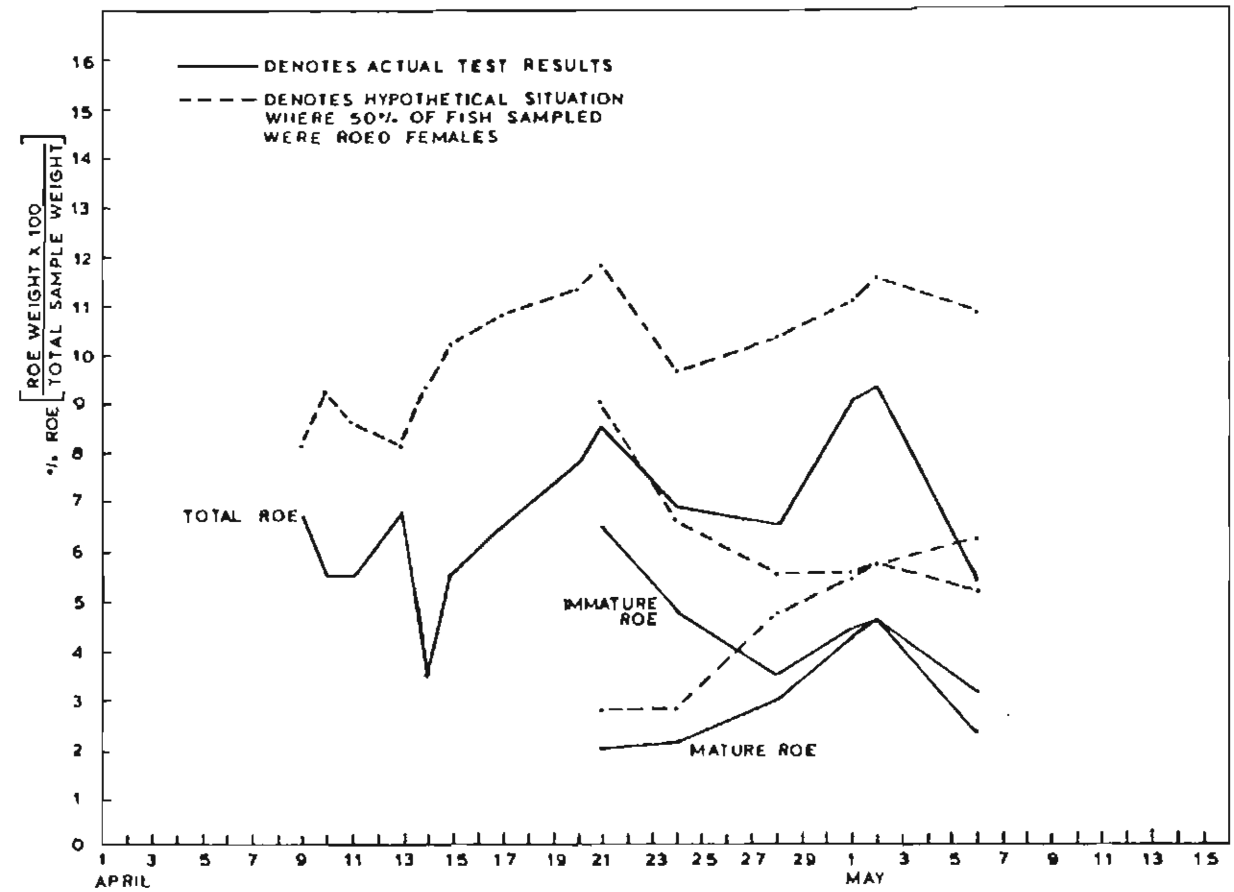
Salinity. A salinometer was taken aboard the Nimpkish Producer. Readings were attempted initially but were dropped because they were considered unreliable. The sensitivity of the



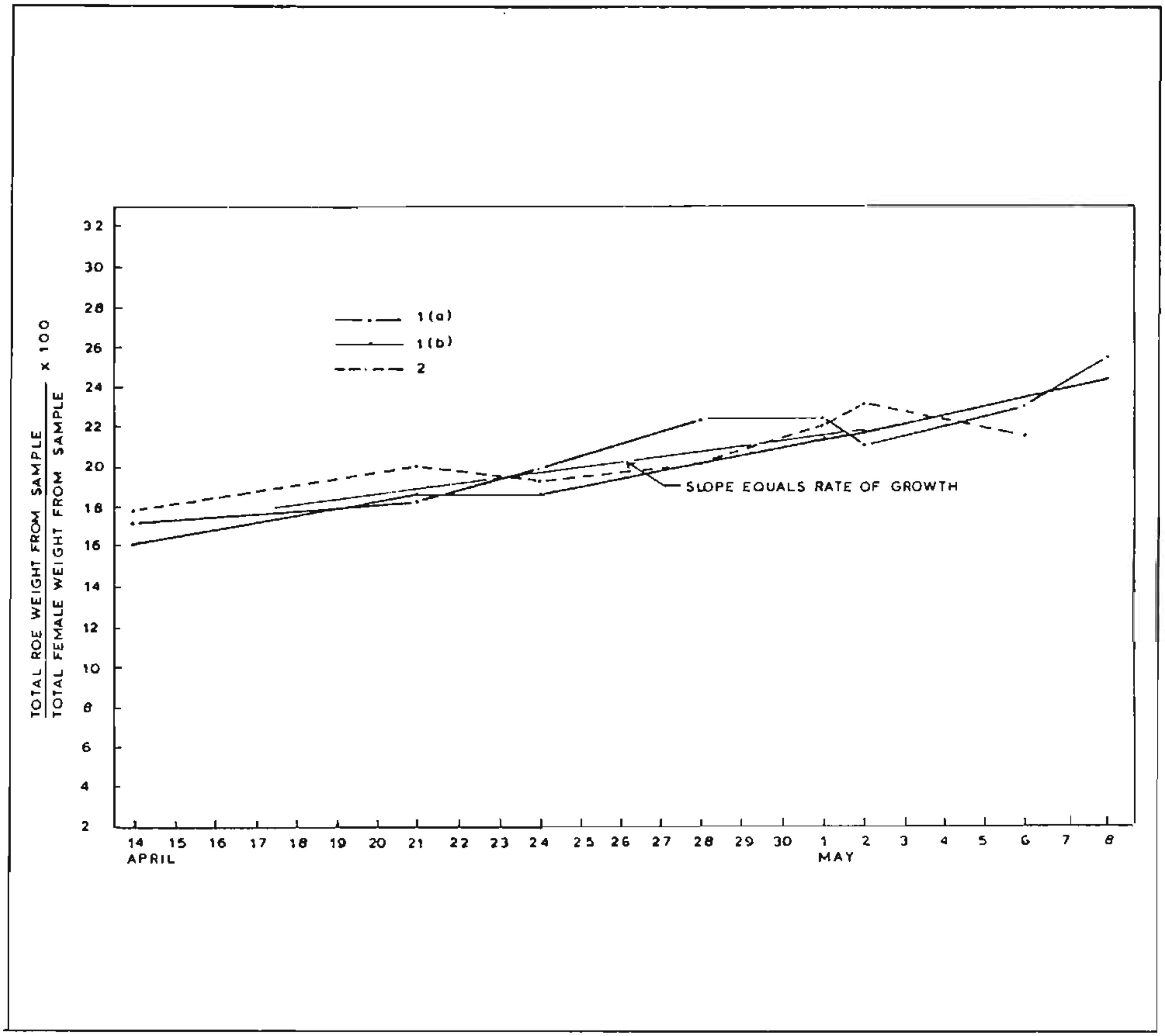
Graph 1. Roe tests from Pond No. 1(a), Parson Bay



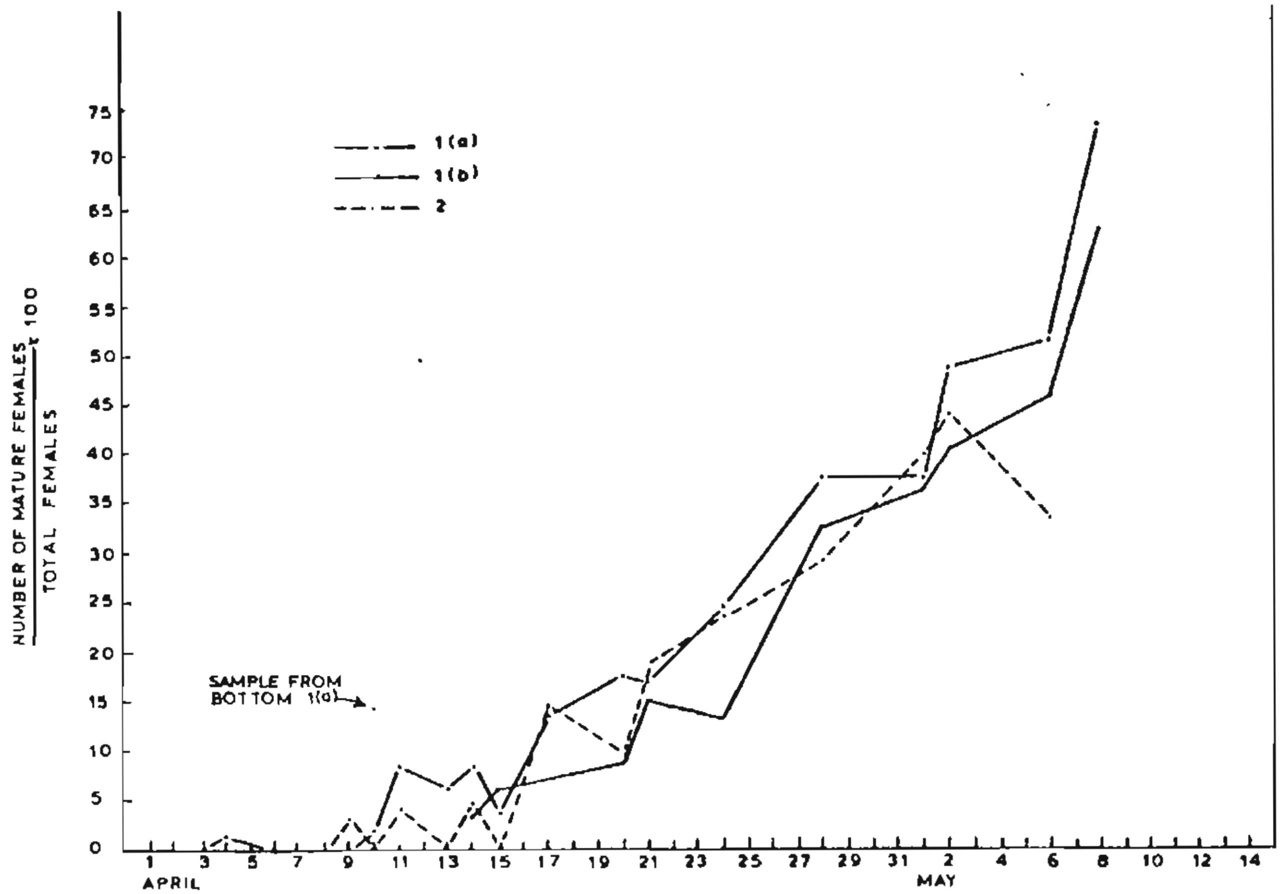
Graph II. Roe tests from Pond No. 1(b), Parson Bay.



Graph III. Roe tests from Pond No. 2, Parson Bay.



Graph IV. Growth of female roe in Ponds No. 1(a), 1(b) and 2.



Graph V. Incidence of mature females in Ponds No. 1(a), 1(b) and 2, Parson Bay.

instrument was too fine and was probably influenced by the electromagnetism of the all-steel hull.

2.4 CONCLUSIONS AND RECOMMENDATIONS

2.4.1 Suitability of Area 12 for Ponding Roe Herring

Most fish caught in Area 12 during the time of this project were of mixed sizes and maturities with some slinks present. In 33 sets, the best ratio of large maturing females was 41 percent of the total. Obviously, a market requiring large whole fish with roe intact cannot be satisfied with mixed fish. Two alternatives are available:

1. Develop ways of using the mixed sizes. If herring other than the mature females could be used by the processors then the roe percentage would not have to be as high as 10 percent. Perhaps small fish could be "popped" for their roe and the carcasses reduced for meal. Slinks could be frozen and sold as bait. Or perhaps markets that use a variety of herring products could be developed in addition to those generated by large females with roe.

2. Herring in Area 12 could be ponded for a roe-on-kelp type of industry. This might be more suitable to the area since as long as fairly large numbers of fish are spawning, their percentage of the total is not critical. The fish would be released after they had spawned. Roe might also be collected without ponding as is often done now in this area. Hemlock branches are merely submerged in areas of spawning activity.

Research on suitable substrates from which spawn could be easily removed might be worthwhile.

2.4.2 Herring in Area 12

The herring populations in Area 12 are interesting and worthy of further investigation. We noticed that the larger populations tended ro consist of small fish; for example, the largest school encountered (about 2000 to 3000 tons) contained fish all between 15 and 18 cm. And certain locations, for example, Simoon Sound, are reputed to always have small fish. These observations raise certain questions: Do small fish habitually occupy specific areas? Are small fish a small race, or are they of uniform age and destined to go elsewhere the following year, being replaced by another group of young ones? Perhaps many of the areas in Area 12 are rearing grounds for fish that ultimately spawn elsewhere.

The mixture of fish travelling together in Area 12 is another puzzling phenomenon, Neither size nor maturity appeared relevant to what fish schooled together, alrhough sometimes a school seemed to consist of two or three size groups. The results from laboratory analysis might generate some information regarding the age composition of these fish and the relationship between age and size. We have assumed that larger fish are older fish, but that might not be true.

2.4.3 Ponds

The prefabricated ponds used in this project had several advantages:

1. Ponds could be installed in various locations if suitable herring were found nearby.

2. The ponds could be set up quickly. Given suitable logs or boomsticks, which were generally available, a log frame could be assembled and the prefabricated pond web installed in a day by three men and a seine boat.

3. The ponds were portable. The boomstick frame or frames could be easily towed using a towing bridle attached to two corners of the pond. (Towing a pond from one corner tended to collapse the pond.) If web had already been installed, it could be pulled up onto the logs and tied. This could be done easily once the vent was released.

2.4.4 Pond Loading Density

One pound of herring per cubic foot of pond proved to be the optimum pond loading density. Pond No. 2 at Parson Bay held 20 to 30 tons of herring within a 60,000 cubic foot space for over a month. These fish experienced very little damage as a result of impoundment.

A greater density of fish produced stress damage from overcrowding as in Pond No. 1 at Parson Bay, which was loaded to approximately twice the optimum density. Some fish showed physical damage after only three days. And after eight or nine days, all fish visible near the surface appeared damaged.

Mature female fish appeared to be more sensitive to overcrowding, dieing earlier than males or spent fish.

Fish suffering from damage were more abundant near the pond's surfaces; healthier fish tended to remain deeper.

2.4.5 Environmental Considerations

Various environmental factors such as water temperature, turbidity and dissolved oxygen content may influence the suitability of an area for ponding and the subsequent maturation of the impounded herring. These parameters were measured and showed considerable variation over time and location. However, no conclusions can be drawn from the measurements obtained except that if the effects of environmental factors were adverse, they were minimal.

2.4.6 Sampling

Samples from a group of herring, whether taken from a seine or from a pond, must be as representative of that group as possible. Thus it is recommended that -

1. Two samples be examined, particularly if sex ratio and roe yield are being determined. If the difference in results is great, a third sample should be examined.

2. The sample should be as large as is practical. Two to three buckets containing 50 to 100 pounds of herring are considered adequate.

3. Samples should not be drawn from among "surface" fish, since these fish can differ considerably, in size, roe development and, particularly, degree of damage, from fish occupying deeper areas.

2.4.7 Measuring Scale Loss

A method for measuring scale loss on free-swimming fish should be devised. Collecting samples by dip-netting causes a great deal of scale loss itself, making it impossible to obtain an accurate measurement of scale loss due to ponding activities. Underwater photographs might be taken and examined later to determine scale loss. Or samples might be taken by killing the fish prior to removing them from the water, either with electric shock or anaesthetic. This would prevent them from losing scales during their death throes. However, doing this without harming the fish that remained in the pond might be difficult.

2.4.8 Roe Maturation

Roe maturation did take place in spite of impoundment as shown by an increase in the incidence of mature fish and the subsequent increase in mature roe yields from samples taken during the time of impoundment.

Evidence from this study suggests that by measuring the ratio of roe to body weight, we might be able to predict when roe would mature. We found that the roe-to-body-weight ratio increased linearly at a rate of 0.27 percent per day. Given that the roe-to-body-weight ratio was known to be about 25 percent for maturity, one could estimate when the females would collectively reach that percentage.

Further investigations should be conducted to determine -

1. if all ponding situations show this straight line increase in roe-to-body-weight ratios over time; and

2. if this growth rate is constant for all ponding situations; or

3. if there are measurable factors that influence the growth rate.

This would be very important information for future ponded roe herring endeavours.

Measuring roe-to-body-weight ratios requires weighing equipment capable of accurately weighing samples of fish totalling 20 kilograms. Future field investigations of ponding operations should include a set of scales capable of doing this.

Roe seems to pass through a sequence of colour changes during maturation. But the colours seem to vary, making interpretating their significance difficult. An individual might learn to interpret roe maturity by colour, but this ability would probably be difficult to teach to others. Thus, roe weight as a ratio of body weight is considered the best method for measuring maturity.

The high incidence of slinks was detrimental to this project since they could not be marketed. Their presence served only to dilute the percentage of roe-producing females and reduce the value of the entire ponded stock.

3. THE 1981 SEINING AND PUMPING OPERATION

(PACIFIC RIM MARICULTURE LIMITED)

3.1 BACKGROUND

3.1.1 The Vessels

All three fishing vessels were of similar design and construction.

The Salli J Rogers is an all-aluminum vessel, 59 feet in length and 19 feet in beam, powered by a 350 hp Caterpillar diesel engine. She has a refrigerated sea water system for holds of 85 tons capacity. She is equipped with an Ekolite Mark 5 Special Herring sounder, and a seine of standard construction, maximum length and 25-fathom depth. A hydraulic fish pump (Marco, Model-U 400) was also on board.

The Cape Russel is of aluminum construction, 54.1 feet in length and 18 feet in beam, powered by a 365 hp Caterpillar diesel engine. Her draft is 8.7 feet. She has a dry-hold capacity of 40 tons. Her seine is of standard construction and maximum length with a depth of 27 fathoms. A hydraulic fish pump (Westec, model unknown), with 8 inch inlet and outflow ports, was on board.

The Cape Perry has the same vessel specifications as her sister ship, Cape Russel. The Cape Perry, however, had a Marco U-400 fish pump.

The barge, the Pacific Spray, owned by Pacific Rim Mariculture, was used to transport fish from the grounds to the processing plant. It is built of aluminum, is 80 feet long and 24½ feet wide and is propelled by GMC Twin 671 diesels with a combined horsepower of 392. Its ten holds have a capacity of 120 tons.

3.2 METHODS

3.2.1 Fishing Operations

Sets were made in Barkley Sound, Area 23 and near Tofino, Area 24. For exact set locations, see Figures 3-1, 3-2 and 3-3.

Typically, all three vessels would scout the area using sounders to locate and approximate the tonnages of schools in the area. The scope of scouting was restricted since all vessels had to remain reasonably close to the vessel with the observer. When a school of appropriate size was located, the vessel next in line would make the set using a power skiff. The net was then drummed in until the tonnage in the seine could be estimated. If there appeared to be too many fish for the processing plant's projected capacity (25 tons per day), some fish would be released by discontinuing the pursing operation or dropping the breast line.

Before the seine was dried up, samples of fish were taken to determine roe yield and size distribution. If these factors were acceptable (i.e. roe yield greater than 10 percent), the net was dried up and fish pumped into the champagne holds of the Pacific Spray. Each hold on this packer/barge was about half full of slush (75 percent ice, 25 percent water), leaving room for six to seven tons of fish. Depending on how smoothly pumping proceeded, some other physical parameters were measured at this time.

When the Pacific Spray had departed, the fishing vessels would anchor or go into port. Scouting operations resumed several hours before the barge was due to arrive for its next load, although no sets were made until the barge was actually standing by. This was to ensure that fish would be in the seine for as little time as possible in order to reduce net damage.

Several modifications of the standard procedure described above were necessary to accommodate changing conditions on the fishing grounds and to improve fish quality. The following were the two main modifications:

1. As fish became scarce after spawning began, the vessel that found fish would set on them immediately.

2. When we discovered that the Westec pump on the Cape Russel caused less damage than the other pumps, the Cape Russel came alongside the cork line of the vessel that had made the set and used its pump to transfer fish. This procedure also allowed for a larger spread of the cork line and, thus, less crowding of fish.

3.2.2 Sampling Procedure

Samples were taken from the seine using a standard herring-web dip net, 14 inches in diameter. Roe content was determined volumetrically using a standard fisheries roe test kit. Normally, two roe tests were made, and the standard lengths of 50 to 100 fish were measured before the fish were dried up prior to pumping.

During pumping, several other parameters were measured when possible. These included measuring dissolved oxygen in the seine and in the ambient water. Water samples taken from the seine often contained roe and scales. Their effect on the oxygen measurement taken by Hach Kit is unknown. Surface water temperature and specific gravity, as well as fish anal temperature, were also measured.

One bucket of fish from each set was taken for analysis to the Fisheries Laboratory in North Vancouver, and another one or two buckets taken for fish damage assessment. Generally, these fish stood in the buckets for several hours before being examined.

Scale loss was determined in the following way: (1) each fish was chosen randomly from the sample bucket and examined for cuts and abrasions; (2) the scaled areas on each side of the fish were reproduced proportionally on a transparent gridded herring silhouette with a

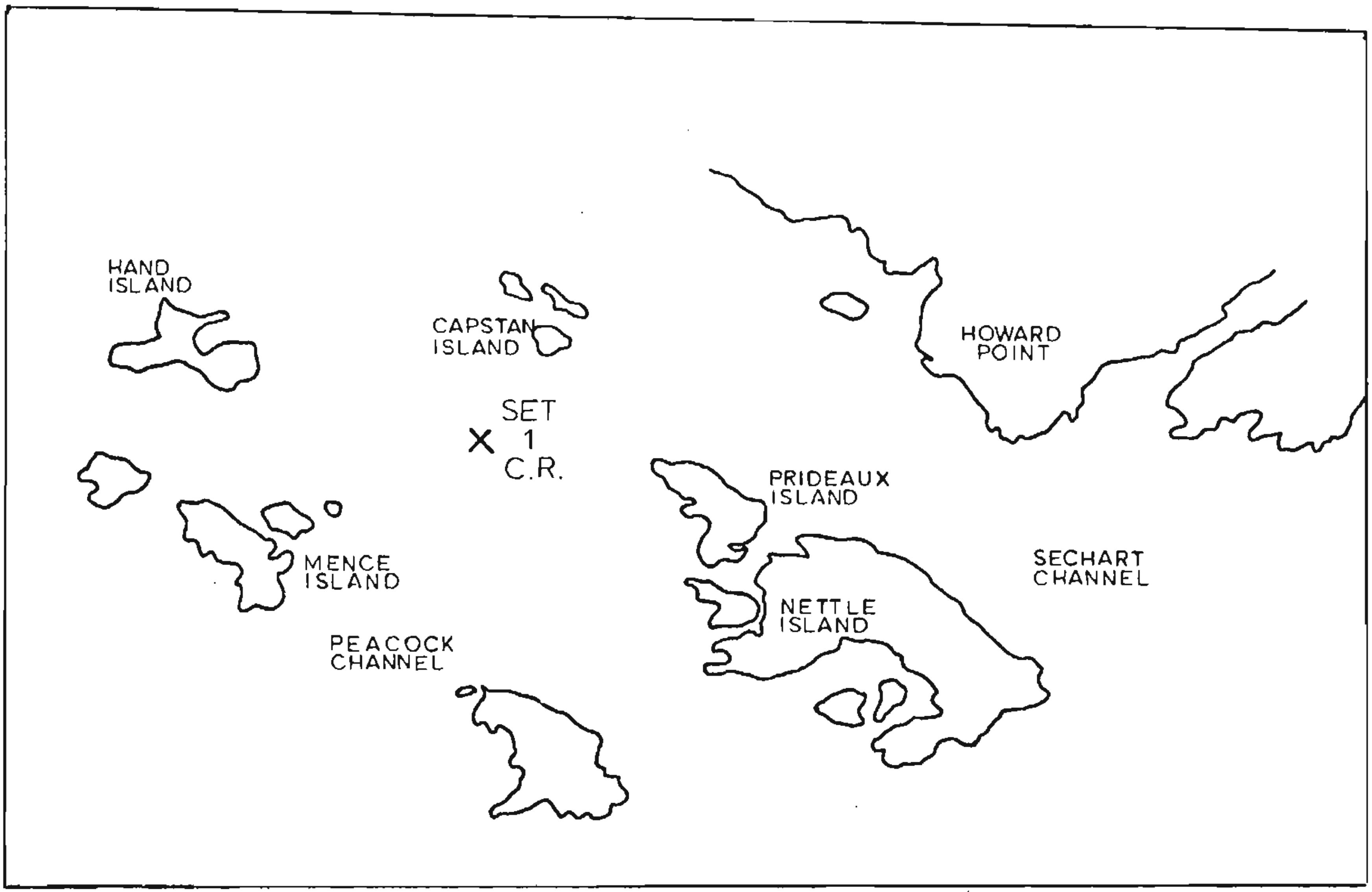


Figure 3-1. Set No. 1.

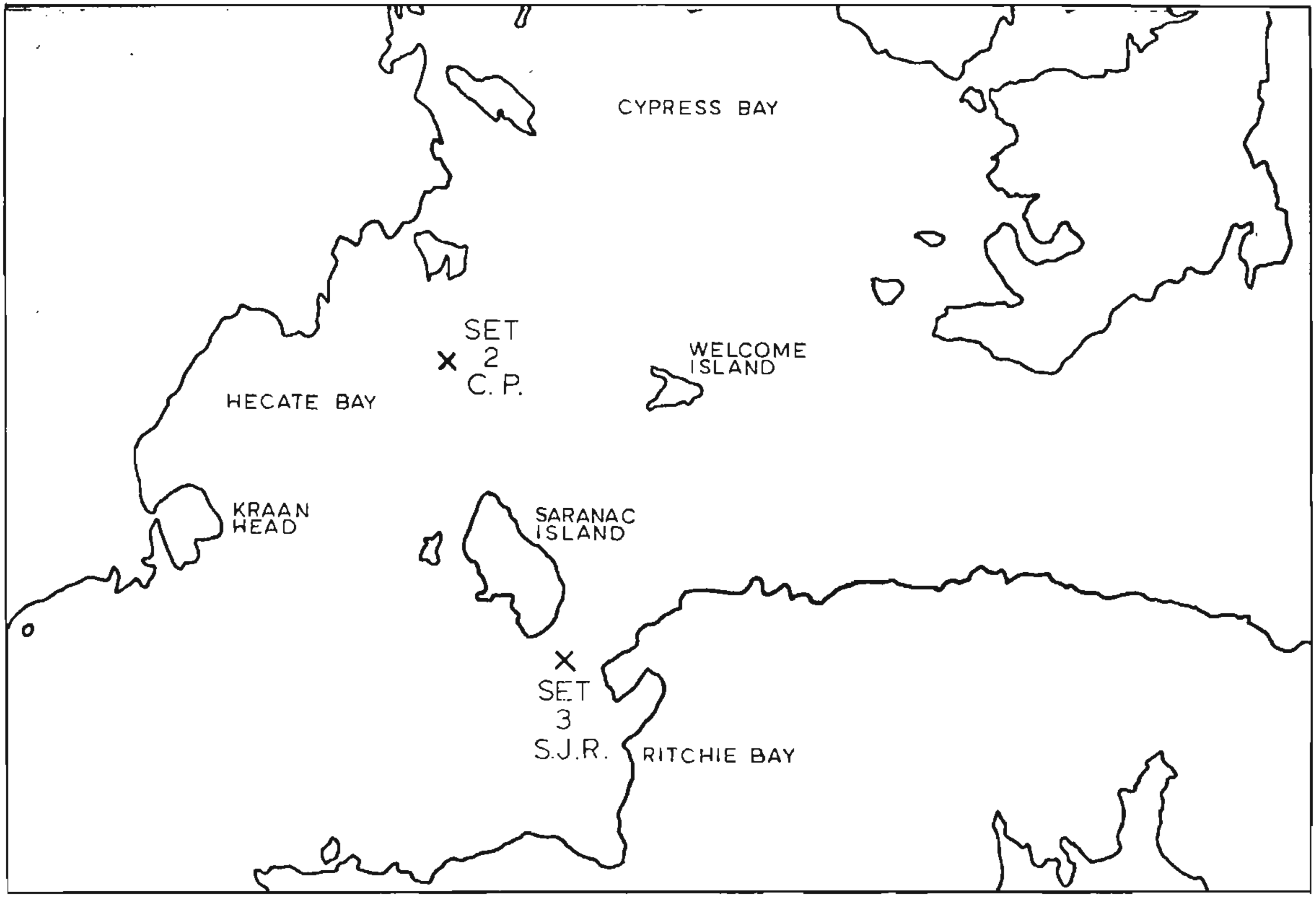


Figure 3-2. Sets No. 2 and No. 3.

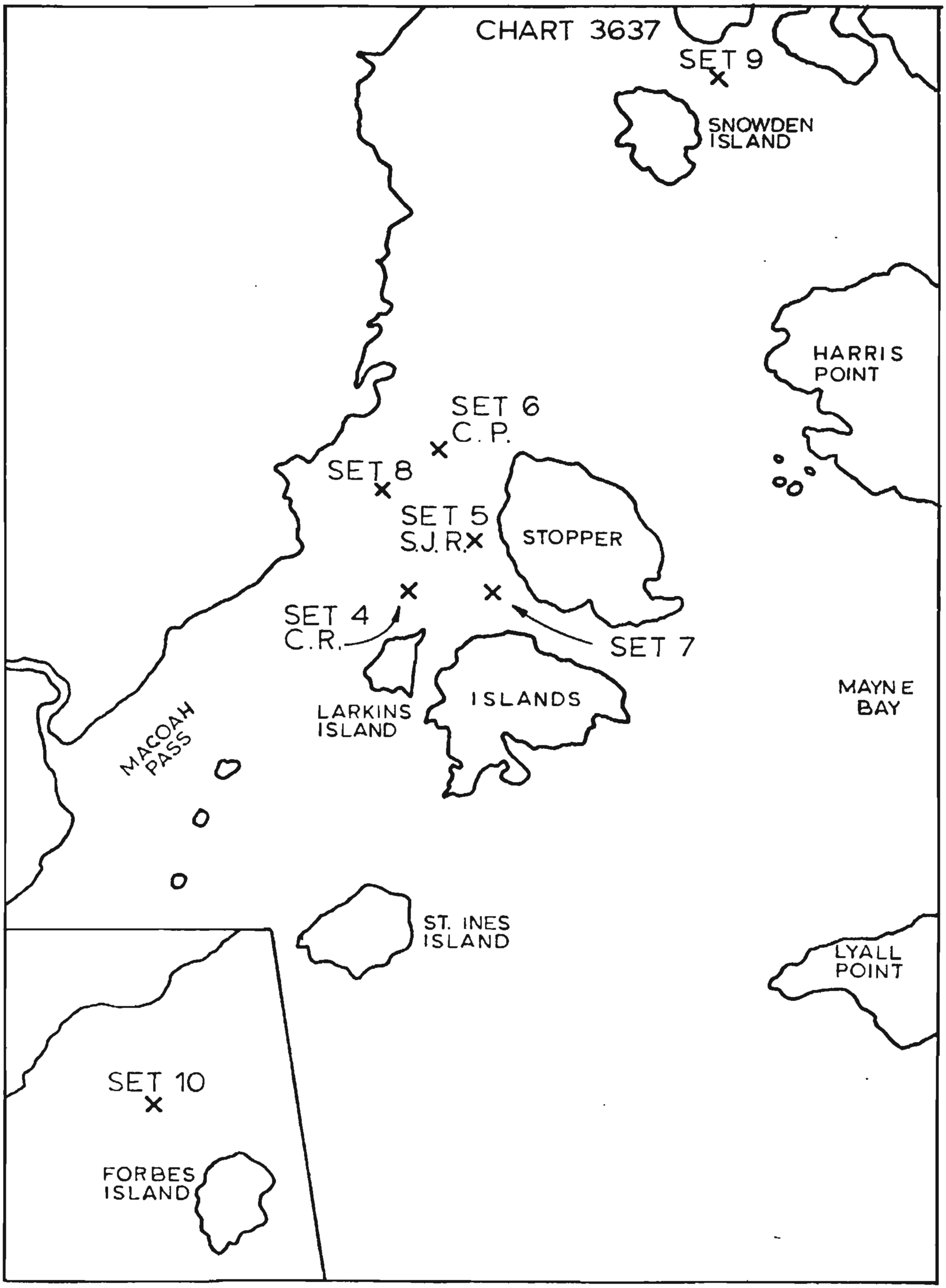


Figure 3-3. Sets No. 4 to No. 10.

total area of 194 (large) squares; (3) the number of squares on the grid corresponding to those areas of the fish from which scales were missing was counted and recorded.

When it was raining, or the spray was too heavy, drawing on the transparency was difficult. In these cases, the scaled areas were "squared off" to convenient geometric shapes. This squared-off area was transferred to the transparency for square counting.

Once 50 fish had been examined in this way, the total number of squares of scale loss for all fish was calculated and divided by 50 to yield the mean number of squares of scale loss. Since the fish silhouette comprised 194 squares, or 388 squares for both sides of the fish, the mean number of squares of scale loss was divided by 388, then multiplied by 100 to give mean percent scale loss for that 50-fish sample.

The presence or absence of feed in the gut was also recorded for these 50 fish.

If no cuts or abrasions were observed in the 50-fish sample, a further 50 or so fish were examined for this type of damage.

Some samples were taken after pumping and brailing to determine pump damage to the fish during transfer from the seine to the barge. These were collected either by scooping from the top of a full hold, or by directing the pump outflow pipe into a bucket.

3.3 OBSERVATIONS

3.3.1 Daily Fishing Account

Set No. 1

March 8, 1981:	Vessel Cape Russel
Weather:	Clear, Sunny, Calm - Surface Temperature 9.5°C
Time of Set:	16:00
Location of Set:	Sechart Ch - Captain 1 (see Figure 3-1)
Tons Set On;	50
Tons in Catch:	25

Data Summary

% Over 195 mm	74.9
Mean Roe Yield (%)	10.0
Mean % Scale Loss in Net	6.83
% With Net Cuts	0.67
% With Net Abr	2.0
DO in Seine mg/l	9
Do Ambient	-
Fish Anal Temp	-

Comments

The Cape Russel set on a 50-ton school and released approximately 25 tons by releasing the breast line. Initially, the power skiff pulled the Cape Russel away from the seine. When it stopped doing so, the seine drifted under the vessel, resulting in a three-fathom tear in the web, and the loss of an undetermined amount of fish.

The first two holds were pumped, and the second two holds were brailed to determine how much damage was caused by each of these methods. Results indicated that while scale loss was slightly less from brailing than from pumping (9.4 percent versus 10.75 percent), other damage - red gill covers, blood in the eyes and body bruising was much greater from brailing.

Pumping was resumed to fill the last hold. However, a break in the hydraulic line (20:15) caused considerable delay. Hydraulic fluid was sprayed on deck but none reached the seine. The remaining fish were pumped into a separate hold to keep them isolated in case any oil reached the water. Pumping was completed by 20:45.

Set No. 2

March 10, 1981:	Vessel Cape Perry
Weather:	Slightly Cloudy, Calm - Surface Temperature 9.8 C
Time of Set:	14:30
Location of Set:	Hecate Bay (Area 24)
Tons Set On:	75
Tons in Catch	65

Data Summary

% Over 195 mm	84.4
Mean Roe Yield (%)	13.4
Mean % Scale Loss	9.5
% With Net Cuts	4.0
% With Net Abr	2.0
DO Seine mg/l	0.6
DO Ambient mg/lt	6.0

Comments

The marginal maturity of the fish caught in Barkley Sound by the Cape Russel prompted all three vessels to depart for the Tofino area where roe maturity was known to be higher.

The Cape Perry set on an estimated 35-ton school. No fish were released. Pumping was begun using the Cape Perry's pump, a Marco U-400; however, much head and gill damage, as well as blood in the effluent were observed. For this reason, the Cape Russel came alongside the cork line to pump. At this time, we decided that the Cape Russel would do all subsequent pumping. By 20:30, all champagne holds were full (approximately 35 tons). To accommodate the fish, still left in the seine all champagne holds except two were pumped dry and topped up with fish. While these holds were being topped up, a break occurred in the hydraulic line near the pump. The fish that remained in the seine were fast-pumped into two dry forward holds to isolate them in case of oil contamination. In total, approximately 65 tons of fish were loaded into the packer.

Set No. 3

March 13, 1981: Vessel Salli J Rogers

Weather:	Overcast, Light Rain, Slight SE - Surface Temperature 9.7°C
Time of Set:	16:45
Location of Set:	South Sarnac I (Area 24)
Tons Set On:	80
Tons in Catch:	45

Data Summary

% Over 195 mm	72.5
Mean Roe Yield (%)	12.7
Mean % Scale Loss	48.17
% With Net Cuts	0.73
% With Net Abr	1.46
DO Seine mg/l	2.2
DO Ambient mg/l	6.0

Comments

The Salli J Rogers made the set at 16:45 on an 80-ton school. Very few schools of fish were in the area; therefore, the set was made on the first school found.

These fish sounded heavily in the net, pulling the cork line down to a depth of more than one fathom and making it very difficult to obtain samples without drying up excessively and damaging the fish. Scale loss in the seine was high (48.1 percent), probably due to sounding. Scale loss increased by 17.6 percent after pumping in spite of the very slow rate - it took approximately two hours. This was probably due to the fish being small.

Set No. 4

March 17, 1981:	Vessel Cape Russel
Weather:	Clear, Sunny - Surface Temperature 11.0°C
Time of Set:	15:00
Location of Set:	Stopper Island (Area 23)
Tons Set On:	15
Tons in Catch:	15

Data Summary

% Over 195 mm	62.9
Mean Roe Yield (%)	11.6
Mean % Scale Loss	7.80
% With Net Cuts	-
% With Net Abr	-
DO Seine mg/l	3.8
DO Ambient mg/l	-

Comments

This set went very smoothly with no delays or unusual events. The Cape Russel pumped the fish aboard the Pacific Spray at a very slow rate.

Set No. 5

March 17, 1981:	Vessel Salli J Rogers
Weather:	Clear, Sunny - Surface Temperature 11°C
Time of Set:	16:50
Location of Set:	Stopper Island (Area 23)
Tons Set On:	15
Tons in Catch:	0

Comments

The Salli J Rogers set on approximately 15 tons of fish close to the bottom in about seven fathoms of water. The seine lead line was obviously scraping the bottom since much mud and debris were stirred up. When most of the seine was drummed up with no fish showing and at least one large tear in the web, the purse line was let go, and no fish taken. No samples were available.

Set No. 6

March 17, 1981:	Vessel Cape Perry
Weather:	Clear, Sunny - Surface Temperature 11°C
Time of Set:	16:50
Location of Set:	Stopper Island (Area 23)
Tons Set On:	40
Tons in Catch:	35

Data Summary

% Over 195 mm	57.1
Mean Roe Yield (%)	12.5
Mean % Scale Loss	8.38
% With Net Cuts	-
% With Net Abr	6
DO Seine mg/l	0.8
DO Ambient mg/l	-

Comments

This set was made with no difficulty or unusual events. Pumping was conducted by the Cape Russel, which picked up the cork line.

Set No. 7

March 19, 1981:	Vessel Salli J Rogers
Weather:	Sunny, Clear, Calm - Surface Temperature 9.1°C
Time of Set:	12:45
Location of Set:	Stopper Island
Tons Set On:	15
Tons in Catch:	0

Comments

This set was made in five to 15 fathoms of water 100 yards off Stopper Island. The purse line was extremely taut, and a roll-up caused about one-and-one-half hours delay. Much mud and debris were observed in the seine, including kelp bearing herring eggs. When it appeared that the seine was empty, it was let go. A three fathom tear was found in the back of the net.

Set No. 8

March 19, 1981	Vessel Cape Russel
Weather:	Sunny, Clear, Calm - Surface Temperature 9.1°C
Time of Set:	14:20
Location of Set	Stopper Island
Tons Set On:	35
Tons in Catch:	10

Data Summary

% Over 195 mm	62.0
Mean Roe Yield (%)	10.4
Mean % Scale Loss After Pump	50.2
% With Net Cuts	-
% With Net Abr	3
DO Seine mg/l	5.0
DO Ambient mg/l	-

Comments

Fish were very difficult to find following the spawning of the previous day. The Cape Perry set on ten tons of fish close to the beach. These fish were sounding heavily, but were routinely sampled and pumped using the Sikich pump. No specimens were taken from the seine to assess damage. However, fish examined after pumping showed considerable damage. Three percent had impeller blade slashes, 7 percent had crushed or broken heads, and 2 percent were headless. Eight-and-one-half percent of these fish were spawned out, which decreased the roe yield considerably.

Set No. 10

March 20, 1981	Vessel Salli J Rogers
Weather:	Clear, Sunny, Calm - Surface Temperature 9.5°C
Time of Set:	11:00
Location of Set:	W. Forbes Island
Tons Set On:	20
Tons in Catch:	10

Data Summary

% Over 195 mm	56.0
Mean Roe Yield (%)	8.3
Mean % Scale Loss	-
% With Net Cuts	-
% With Net Abr	-
DO Seine mg/l	-
DO Ambient mg/l	-

Comments

The fish were very small and 27 percent of them were spawned out, resulting in a low roe yield. They were pumped using the Salli J Rogers pump, a Marco U-400. No samples were taken from this set to assess net or pump damage.

Several days of extensive scouting of east Barkley Sound, Sechart Chanel and the Bamfield area failed to locate any non-spawned fish. For this reason, fishing in Area 23 and 24 was concluded.

3.3.2 Herring Cooling

Figure 3-4 shows the rate at which herring cooled when loaded in a bucket of champagne mix at the same rate as herring loaded into a hold. The herring took 34 minutes to cool from 10.5°C to 1.1°C.

3.4 CONCLUSIONS AND RECOMMENDATIONS

3.4.1 Conclusions

Table 3-1 summarizes data collected regarding damage caused to fish by seining and pumping. While it reveals few recognizable trends, it does indicate the herring in smaller sets sustain fewer net cuts and less scale loss than larger sets. No relationship appeared to obtain between set size and net abrasions.

The considerable scale loss occurring in the seine can only be explained by the behaviour of the fish in the net. In all cases, the fish sounded heavily, with few or no fish showing at the surface. This behaviour seemed to be associated with the maturity of the fish - more mature fish sound more heavily. Thus, the larger the set and the more mature the fish, the greater the pressure exerted on the fish near the bottom, and thus the greater the net and crushing damage.

Attempts to keep the set sizes small were thwarted by the difficulty of estimating school sizes and amounts of fish in the net due to the absence of sonar on any of the vessels and to the sounding behaviour of the fish. With less mature fish, fairly accurate estimates of tonnage in the net can be made because the fish show near the surface. But because the mature fish sounded into the bottom of the seine, no visual estimate of tonnage could be made. Attempts to minimize net damage by keeping a large spread on the cork line were also largely ineffective because the fish sounded.

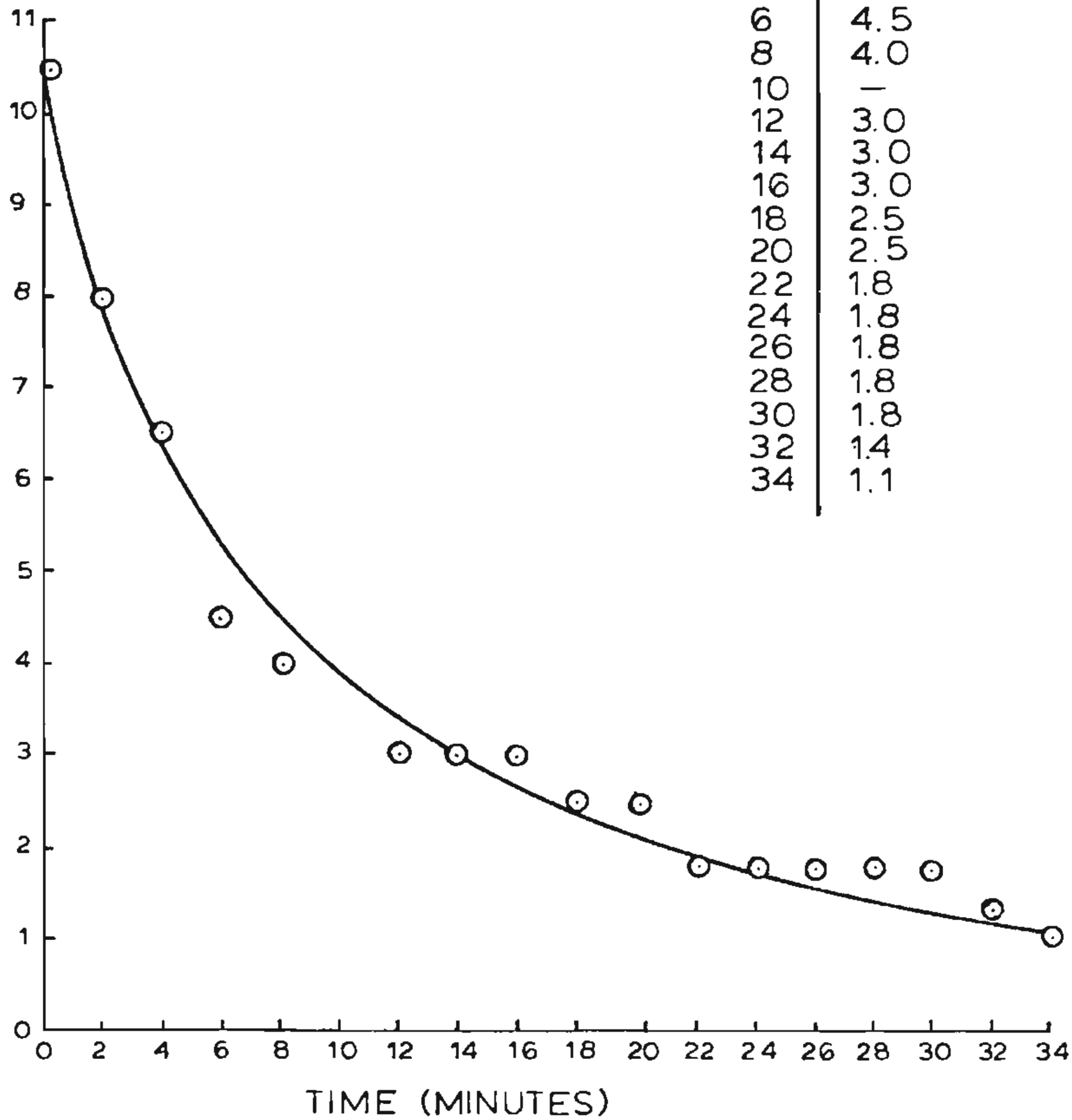
Data collected from Set No. 3 reveals considerable damage associated with pressure or crushing in the seine. The incidence of blood spots in the eyes, redness of the gill covers and body bruises was widespread in samples taken from the seine, and was even greater after pumping.

In both cases in which damage was assessed before and after pumping (Sets No. 1 and 3), the incidence of cuts, scale loss and redness of the gill covers was greater after pumping.

The first pump used was the Marco, Model U-400. Its outflow port was connected to a 12-inch aluminum conduit which traversed the cabin top and led to the dewatering device. This was S-shaped and consisted of three-eighth inch round aluminum bars banded together to form a conduit. Water drained out through one-quarter inch gaps between the parallel bars, while fish continued through to a ten-inch aluminum conduit leading to the packer holds. Fish pumped with the Marco pump were heavily damaged. The water into which the fish were pumped was reddened with blood, and many fish had gross head damage. For this reason, the Westec pump was tried.

The Westec pump had eight-inch intake and outlet ports, and operated on the same "Archimedian Screw" principle as the Marco pump.

TIME (MIN)	TEMP.* (°C)
0	10.5
2	8.0
4	6.5
6	4.5
8	4.0
10	—
12	3.0
14	3.0
16	3.0
18	2.5
20	2.5
22	1.8
24	1.8
26	1.8
28	1.8
30	1.8
32	1.4
34	1.1



*Note: Temperature of herring in bucket of champagne mix loaded at same rate as hold.

Figure 3-4. Cooling curve for herring in champagne mixture.

Table 3-1. Damage to Fish in Seine and by Pumping

Set No.	Tons in Set*	% With Net Abr.	% With Cuts		Mean % Scale Loss		% With Red Eyes		% With Blood Gill Covers		% With Body Bruise		% With Gross Head Damage	
			Seine	Pump	Seine	Pump	Seine	Pump	Seine	Pump	Seine	Pump	Seine	Pump
1	30.07	2.0	0.7	0.0	6.83	10.76	-	84.6	-	0.0	-	7.7	0.0	0.0
2	65.92	2.0	4.0	-	9.50	-	-	-	-	-	-	-	-	-
3	49.74	1.5	0.7	4.0	48.17	65.77	43.70	28.0	2.40	36.0	20.7	-	0.0	0.0
4	17.42	-	0.0	-	7.80	-	-	-	-	-	-	-	-	-
6	29.04	6.0	0.0	-	8.38	-	-	-	-	-	-	-	-	-
9	16.33	3.0	0.0	3.0	-	50.52	-	0.0	0.0	0.0	-	-	0.0	9.0

* From purchase slips.

It had the additional feature of a cone-shaped flange around the intake port, which may have oriented the fish in a more effective way as they entered the pump. While causing some additional scale loss, this pump resulted in less gross damage to the fish. For this reason the Westec pump was used for the balance of the fishery.

Pump damage seemed to occur in four places. First, the pumps available were constructed in such a way that the impeller blades came into direct contact with the fish. Since the blades rotate at a high speed, slashing and bruising of some fish was inevitable.

Damage also occurred within the conduits. These were welded around their circumferences at the four to six bends and joints. This left one-quarter inch beads of metal around the inside of the conduit, on which fish abraded.

The third damaging component of the pumping system was the dewatering device, in which fish were simultaneously dewatered and deflected downwards toward the packer holds. Since the fish were moving very rapidly, their impact on the dewaterers was considerable. In addition, the parallel bar construction of the device allowed fish heads, gill covers and tails to be caught and torn between the bars, as evidenced by the heads and gills lodged between the bars.

The last point at which damage probably occurred was as the fish entered the packer hold. Usually, they emerged from the conduit with enough velocity to strike forcibly against the wall of the hold. Even when directed into the slush, the impact was considerable.

Brailing, the only alternative to pumping, was also tried for two packer holds of fish from Set No. 1. The brailer was of knotless nylon web, 3.5 ft in diameter and about 4 ft deep. It was usually about one-third to one-half filled. Table 3-2 gives damage estimates for fish pumped and brailed.

Although incidence of scale loss and presence of small blood spots in the eyes were reduced slightly by brailing, the amount of body bruising and red gill covers increased significantly. Since these latter defects are more important in marketing than scale loss, the Westec pump was used for the balance of the project.

Table 3-2. Damage estimates for fish pumped and brailed.

	Mean % Scale Loss	% With Eye Blood	% With Gill Cover Blood	% With Body Bruises	% With Cuts	% With Abr.
Fish from seine	6.83	18.0	4.0	0.0	0.67	2.0
Fish pumped	10.76	84.6	0.0	7.7	0.0	0
Fish brailed	9.48	8.0	24.0	14.0	2.0	0

Note: Data showing decrease in damage from seine to pump or brailer is result of smaller sample size for pumped and brailed fish. Fish from seine were sampled until some fish with cuts and abrasions were found.

3.4.2 Recommendations

1. Since most scale loss on the fishing grounds occurred when mature fish sounded, small sets should be made to reduce crushing and abraiding of fish against the web by those above them.

2. If whole herring, pumped from seines are to be of high quality the following modifications to the pumps must be made:

(a) Pumps must be developed which will allow herring to be transferred without contacting impeller blades.

(b) Conduits leading from the pump to the fish holds should be free of abrasive surfaces. The entire conduit system might be made of the same vinyl tubing that is presently used to couple the pump to the aluminum conduits. The vinyl tubing could be held in the usual place near the after top of the deck house and prevented from kinking by being enclosed in a flexible spiral housing.

(c) Dewatering devices need either to be redesigned to prevent fish from being damaged on their bars or to be eliminated by discharging fish and water beneath a grating set over the hold. This would retain fish and slush but allow excess water to escape. After partial filling, the holds could be topped up with ice.

(d) Curves in the conduit (and the dewatering system if retained) should be gradual to minimize the impact of fish against the walls of conduit.

(e) Pumping should proceed slowly to reduce abrasion and impact between the fish and the conduits.

(f) Pumping should allow enough water to accompany the fish to lubricate their passage through the conduit, but not so much that the slush ice would be excessively diluted and chilling times increased.

3. Fish should enter the holds via flexible tubing which could discharge fish below the surface of the slush. This would eliminate impact with the walls of the holds, ice and other fish. It would also eliminate the thick layer of fish that tends to accumulate on top of the slush, thereby reducing the total chilling time.

4. Fish should be pumped live if possible. This seems to result in the fish entering the pump head first, rather than sideways, thus reducing damage.

5. This fishery should concentrate on the largest fish possible, since smaller fish seem to sustain greater scale loss and more belly tearing than larger ones. This would increase the value of the catch by providing larger, more valuable fish for the market, in better condition. Thus, the fishery should take place in areas with the largest average fish size.

6. The fishery should begin as early in the season as possible, especially when low-capacity processing facilities, such as the one used in this project are to be used. Alternatively, processing capacity should be increased to eliminate the gluts that inevitably occur when large sets have been made.

7. Each vessel should have its own technician to sample fish. This would allow boats to separate when scouting and to set immediately on small schools which would otherwise be lost.

4. PROCESSING AND FISH QUALITY

4.1 BACKGROUND

Only two of the four companies to whom permits were issued actually processed herring - Sliammon Indian Seafoods Limited and Pacific Rim Mariculture Limited. The latter rented the plant of Alberni Fish Limited instead of using its home plant at Bamfield, which lacked facilities for blast freezing.

The operations of Sliammon Indian Seafoods involved ponding, capturing fish within the ponds by means of a bait herring seine, brailing of the fish into totes, delivering the totes by sea truck to either the Sliammon dock at Okeover or to the public dock at Lund for subsequent transport by truck to the Sliammon plant or to Sunshine Seafoods plants. All operations after transport of the fish were manually performed.

The operations at Pacific Rim involved pumping the herring from the seine into the packer Pacific Spray, then brailing them from the packer into totes at Port Alberni. The totes were stacked inside the plant. As fish were needed totes were dumped mechanically. The fish were also washed, conveyed, size sorted and sexed mechanically before being manually packed into containers.

The Sliammon operation has been called a seine-to-pond manual operation, and the Pacific Rim operation, seine-to-pump mechanical operation.

4.2 SEINE-TO-POND MANUAL OPERATION (SLIAMMON)

4.2.1 Processing Method

Totes. The totes were loaded with approximately 100 pounds of ice, which formed a layer about eight inches deep on the bottom. For the first two days of operations, March 9 and 10, no water was added. Fish were brailed into the totes to a depth of 14 to 18 inches. This method did not effectively cool the fish (see Table 4-1.) From the third day, the totes were loaded with two inches of ice on the bottom, and two pails full of sea water. After the fish were loaded, approximately four inches of ice were added as a top dressing. More water was added until the mixture of fish, ice and water moved easily when the surface was pressed. At this point the fish were supported by the ice. After this practice was adopted the herring cooled much better (see Table 4-1, March 11 to March 17).

As Table 4-1 also shows the temperature varied considerably between totes and between surface, middle and bottom zones within the totes. On average, the surface temperature was lower than the middle and bottom temperatures.

The fish obviously cooled slowly, since after periods of between half an hour and one hour they had cooled only to between -0.5°C and 7°C. In future perhaps more rapid cooling could be achieved by aerating each tote during transport. If this were done, the totes should be covered with lids to protect the fish from the weather and seagull droppings rather than being covered collectively with a tarpaulin as was done.

The totes were left outside covered with metal sheets until they could be taken inside for processing. Although totes were left outside overnight (on one occasion for over 18 hours), the ice did not melt completely. Internal fish temperatures were maintained at 0°C to 2°C.

Processing. When the totes were brought inside, the ice was removed and the fish put in herring roe baskets, which (in the last three to four days of operation) were stacked and weighed. The fish were rinsed in water at 6.5°C to 7°C, then packed randomly and unsexed (because the sex sorter failed to function) in poly bags filled to a weight of two kg, put into cardboard boxes and placed on freezer trays. The two kg boxes took six to eight hours to reach -25°C. The fish were random packed for two days, after which they were laid out individually on the freezer trays (still unsexed), blast frozen and temporarily stored in No. 1 cold storage at an air temperature of 0°C.

After March 15 manual sexing commenced. The males were placed three layers deep in herring roe baskets, which were stacked in No. 2 cold storage at an air temperature of -10°C to -20°C.

The females were laid out flat on freezer trays, which were placed on the wheeled freezer racks, 12 trays per rack. It took ten to 12 people four hours to fill six racks, during which time the temperature of the fish rose to between 6°C and 10°C. After the racks were filled, they were wheeled into No. 2 cold storage, where the temperature of the females dropped to between -5°C and -7°C. When there was room, they were transferred to the blast freezer for four to six hours. After four hours in the blast freezer, the temperature of the fish fell to between -14°C and -27°C.

After the fish were blast frozen, they were wheeled back into No. 2 cold storage to await packaging.

Packaging was done in No. 1 cold storage, where the fish were removed from the trays and packed in two kg containers. The containers were stacked into wooden totes that held 600 to 700 pounds of packaged fish. These were put in the mobile freezer, which was cooled to -23°C.

The six racks in the blast freezer could hold the females from eight totes, which held 600 pounds of mixed males and females. Thus, the plant could process between ten and 14 tons of herring in 24 hours. (On the evening of March 16, eight tons were processed in 14 to 15 hours.)

4.2.2 Observations Regarding Quality of Seine-to-Pond Manual Operation

The quality parameters considered important by the Japanese company buying the product, in descending order of importance, are as follows: (1) roe yield, (2) length, (3) absence of crushing damage

Table 4-1. Fish temperatures in Totes (Sliammon)

Date	Load No.	Water Temp°C	Air Temp°C	Fish Temp °C after Brailing	Fish Temperatures in totes °C Top	Middle	Bottom	Time After Brailing (Hours)
Fish on ice only								
Mar 9	1	9.0	5.5	8.0-10.0	5.0-6.5	7.0-8.0	6.0-8.0	½
Mar 10	2	9.5	10.0	8.5-9.0	8.5-9.0	7.5-9.0	6.0-9.0	1½
Fish in ice/water mixture								
Mar 11	4	9.0	10.0	8.0-9.0	0.5-3.0	2.0-2.0	3.0-5.0	1
Mar 11	4				3.0	2.0	4.0	1
					0.5	2.0	5.0	
					1.0	1.0	4.5	
					2.0	1.5	3.0	
Mar 12	6				3.0	5.5	5.0	3/4 to 1
					3.0	7.5	2.0	
					6.0	3.0	5.5	
	6				1.0	5.0	6.0	1 3/4
					2.0	4.0	5.0	
					1.0	2.0	5.5	
	7				4.0	6.0	5.0	½
					1.0	0.5	2.5	
					4.5	5.5	7.0	
	7				0.5	1.0	2.0	18
					1.0	0.5	2.5	
					0.5	2.0	2.0	
							1.5	
							2.0	
Mar 13	8				2.0	3.0	5.0	½
					2.0	4.0	4.0	
					2.5	4.5	4.5	
Mar 14	11				2.0	2.5	5.0	1
					2.0	4.0	6.5	
					3.5	3.5	5.0	
Mar 15	13				2.0	1.0	6.0	1
					2.0	4.0	6.5	
					3.5	3.5	5.0	
Mar 15	13				2.0	1.0	6.0	1
					2.0	2.5	4.0	
					-0.5	1.5	2.5	
					1.0	1.0	3.0	
Mar 17	17				3.0	5.5	5.0	1
					0.5	4.5	6.0	
					1.0	7.5	8.0	
Means					2.3	4.5	5.0	

and (4) scale loss. That loss of scales should have been considered important was somewhat surprising. It was explained that the Japaneae customer attaches a high value to the appearance of fish and likes the scale pattern to be as perfect as possible.

A representative of the Japanese buying company reported that his company intended to dry the flesh of poor quality males and poor quality or small females after removing the roe.

Roe Yield. Table 4-2 shows the various roe yields obtained (using the Department of Fisheries and Oceans standard roe yield measurement procedure) from samples of fish taken from the Sliammon ponds.

Table 4-2. Roe Yields

Date	% Roe Yields
March 11	9.5, 10.25, 11.5, 12.5, 10.5, 12.0
March 12	11.5, 12.5
March 13	12.0, 12.0
March 14	11.0, 12.5, 12.5
March 16	12.0, 14.5, 16.25
March 18	12.5, 14.5
March 19	14.5, 15.25
Mean	12.5

The average roe yield was high at 12.5 percent, two and a half percent greater than the maximum required by the Japanese buyer.

Length and Sex Ratio. Table 4-3 shows the mean lengths and proportions of fish greater and less than 200 mm in five samples taken from totes delivered to the Sliammon, Sunshine and Spetifore plants. Given that average lengths ranged between

Table 4-3. Length and Sex Ratios

Date	Mean Length mm	% ≥ 200 mm	% < 200 mm	Sex Ratio F/M
Mar 11	204	46	54	66/34
Mar 12	206	46	54	60/40
Mar 13	202	40	60	54/46
Mar 14	202	38	62	54/46
Mar 15	206	34	66	60/40

202 mm and 206 mm, the captain and crew of the Sea Luck were evidently successful in locating schools of large herring. The data also indicates that the sex ratio was favourably biased towards females.

Crushing Damage. Table 4-4 shows the incidence of crushing damage as evidenced by the entry of blood into the eyes, the gill covers and noses of fish from five samples drawn from totes at the Sliammon, Sunshine and Spetifore plants. Also shown are the depths of the fish/ice mixtures in the totes.

Table 4-4. Incidence of Crushing Damage

Date Samples	% with Red Eyes	% with Red Gill Covers	% with Red Noses	Depth of Fish in Totes
Sliammon				
Mar 11	8	0	0	21½-22-23
Mar 12	68*	26*	0	23½-23½
Mar 13	64*	26*	0	20-19-24
Sunshine				
Mar 15	56*	6*	0	22-22-24
*Only slight blood flecks in eyes, minor gill cover discoloration.				
Spetifore				
Mar 14	94	72	10	18-18-18

The herring that were manually processed at the Sliammon and Sunshine plants showed only minor symptoms of crushing damage. Neither red eyes nor red gill covers were conspicuous. The eyes contained only tiny flecks of blood, and the gill covers showed only slight pink discoloration.

But fish that were mechanically processed at the Spetifore plant showed a much higher incidence of crushing damage. Eyes, gill covers and noses were distinctly red with blood. This could not be attributed to overloading of totes since the fish were only 18 inches deep. However one hundred percent of the Spetifore fish had passed through rigor mortis, whereas in three of the four samples from the Sliammon and Sunshine plants 100 percent of the fish had remained in rigor, and in the fourth, 30 percent had remained in rigor. Gillis reported that the fish were in good condition when delivered to the Spetifore plant, but that they had suffered great damage in being pumped from the hold of the Sea Luck. This would account for the incidence of subcutaneous blood and loss of rigor in the fish sampled at the Spetifore plant.

Plate 4-1 shows the excellent condition of fish as delivered to the Sliammon plant, and Plate 4-2 the crushed condition of fish taken from totes at the Spetifore plant.

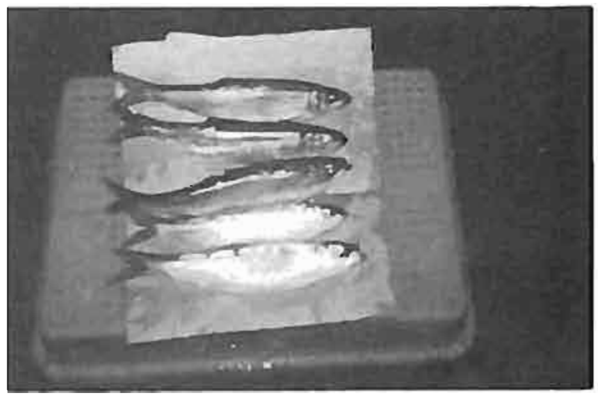


Plate 4-1. Herring as delivered to the Sliammon plant.

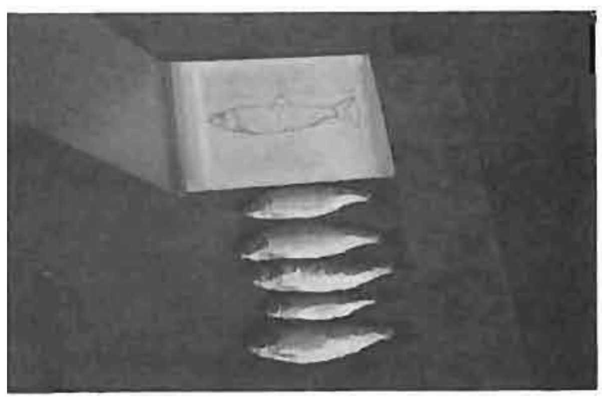


Plate 4-2. Herring taken from totes at the Spetifore plant (after being pumped from the hold of the vessel).

Scale Loss. As indicated in Table 4-5, even after the herring had been seined, ponded, brailed and transported from the Sliammon ponds, scale loss was minimal, between 1.6 and 4.8 percent.

Visual checks after the herring had been placed on the freezer trays indicated that no appreciable increase in scale loss had occurred

Table 4-5. Scale Loss

Date	Mean % Scale Loss
Sliammon	
Mar 11	4.2
Mar 12	4.8
Mar 13	2.2
Sunshine	
Mar 15	1.6

during the hand-processing operations at the Sliammon and Sunshine plants. But fish from the totes sampled on March 13 at the Spetifore plant showed an average scale loss of 23.4 percent, which was substantial when compared with the loss from manual processing. However, it was fairly modest when compared to losses in the seine-to-pump mechanical operation of Pacific Rim Mariculture Limited (see Section 4.3).

4.3 SEINE-TO-PUMP MECHANICAL OPERATION

4.3.1 Processing Method

The mechanical operation which was carried out by Pacific Rim Mariculture Limited is depicted schematically in Figure 4-1.

Seine --→ Screw impeller pumps--→ Packer holds --→ Dock —→ Brail --→ Totes --→ Tote Dumper --→ Washer/ Hopper —→ Elevator

S I Z E	Small males and females not sexed	bagged, loose packed in 2 kg boxes and frozen
S O R T E R	Extra large males and females hand sexed	Males laid head to tail in 15 lb. polybags and frozen in roe trays Females laid head to tail in 2 kg boxes, 3 per layer, 3 layers deep and frozen
	Arenco Sex Sorter	Large and medium males loose packed in 15 lb. polybags and frozen Medium females laid head to tail in 2 kg boxes, 5 per layer, 3 layers deep and frozen Large females laid head to tail in 2 kg boxes, 4 per layer, 3 layers deep and frozen

Figure 4-1. Depiction of the Pacific Rim Mariculture operation.

By slowing down the Arenco sex sorter from its rated capacity of 290 fish per minute to 190 fish per minute, 98 percent separation of females from males was achieved.

The cardboard boxes used to package the females were sturdy and attractively decorated. They bore the name and address of the exporter company, gave the weight (two kg) and the Japanese name of the product, "Komochi nishin," which means "pregnant herring." They measured ten and three quarter inches by one and a half inches by three inches deep. The three layers in each box were separated from one another by rectangles of white waxed paperboard. These separators prevented the herring in each layer from sticking to one another and facilitated the separation of individual fish from one another when the package was opened.

4.3.2 Observations Regarding Quality of Seine-to-Pump Mechanical Operation

Roe Yield. Table 4-6 shows the roe yields obtained from various sets made in Area 23 on the West Coast of Vancouver Island and in Area 13 in the Strait of Georgia.

Table 4-6. Roe Yields in Areas 23 and 13

Date	% Roe Yield in Area 23	Date	% roe Yield in Area 13
Mar 8	10.0	Mar 31	9.3
Mar 10	13.4	Apr 2	9.7
Mar 13	12.7		
Mar 17	11.6		
Mar 17	12.5		
Mar 19	12.4		
Mar 20	10.4		
Mar 20	8.3		
Mean	11.4	Mean	9.5

The roe yields obtained from fish taken in Area 23 were all above the acceptable level of 10 percent. Nonetheless, the average roe yield of 11.4 percent was appreciably lower than that of the Sliammon ponded herring, which was 12.5 percent. (A bonus of $130 US per ton for each percent above 10 percent was added to the base price of $1380 US per ton.) The roe yield from Area 13 fish was below the acceptable level.

Length and Sex Ratio. As Table 4-7 shows, the mean length of Area 23 fish was considerably higher (overall average of 207 mm) than those in Area 13. The prevalence of small fish in the Area 13 catches coupled with low roe yield and a high incidence of spent females in the catches were probably responsible for Pacific Rim's halting its operations after April 3, even though 50 tons of the 300-ton permit allocation had not been taken.

Crushing Damage. Every sample of fish taken from totes or from the end of Pacific Rim's processing line showed evidence of crushing damage (see Plate 4-2). The damage was high as shown in Table 4-8.

It is unlikely that crushing damage took place as a result of overloading the totes since the

Table 4-7. The Mean Lengths Derived from Samples of 50 Fish Taken Before Entering the Size Sorter

Date	Mean Length mm	% ≥ 200 mm	% < 200 mm	Sex Ratio F/M
From Area 23				
Mar 14	206	32	68	64/36
Mar 15	207	28	72	68/32
Mar 16	238	2	98	40/60
Mar 16	195	64	36	42/68
Mar 17	210	32	68	62/38
Mar 18	208	40	60	74/36
Mar 18	208	24	76	62/38
Mar 20	215	36	64	38/68
Mar 21	205	54	46	62/38
Mar 21	212	24	76	44/56
From Granite Bay (Area 13)				
Mar 31	183			
From Rebecca Spit (Area 13)				
April 4	182	88	12	56/44

Table 4-8. Evidence of Crushing Damage

Date Samples	% with Red Eyes	% with Red Gill	% with Red Noses	Depth of Fish in Totes (")
Mar 14	80	56	30	15-15-14
Mar 15	98	100	44	
Mar 16	94	96	28	
Mar 16	90	100	52	
Mar 17	92	100	34	13-14-15
Mar 18	76	26	0	
Mar 20	76	52	0	15-15-15
Mar 20	84	90	18	
Mar 21	14	34	6	
Mar 21	14	20	4	10-11-10
Mar 22	20	44	6	
Apr 1	70	52	4	20-21-20
Apr 1	70	72	10	
Apr 4	40	64	16	18-20-16

depth of the fish/ice mixture did not exceed 21 inches. Nor is it likely to have occurred in the packer holds since they were shallow (only 59 inches deep). The mechanical pumps used in the Pacific Rim operation coupled with large sets and the tendency of mature herring to sound in the seine undoubtedly were responsible for the high incidence of crushing damage.

Scale Loss. As Table 4-9 shows, scale loss caused by normal fishing operations varied between 7 and 9 percent. In Area 13, where small catches, five to 12 tons, were taken, the scale loss due to seining was low, from 2 to 5 percent, even though the fish were small.

Samples taken from the packer holds before unloading reflected the amount of scale loss

Table 4-9. The Average Percentage Scale Loss that Occurred Sequentially from Seining Through all Processing Steps.

Date	From Net	From Packer Hold	From Totes	After Sexing
Area 23				
Mar 14	48 (set 3)	-	60	95
Mar 16	-	75	59	84
Mar 17	-	-	79	81
Mar 18	8	28	21	-
Mar 20	-	-	40	67
Mar 21	-	-	41	63
Area 13				
Mar 31	-	17	26	53
Apr 2	5	45	-	-
Apr 3	2	21	35	52

incurred as a result of pumping and transporting the fish. The incremental loss was substantial, ranging between 19 and 40 percent as evidenced by the April 2 and April 3 data and is in keeping with the conclusions of the Area 23 boat observer, who commented at some length on the damaging effect of the screw-impeller pumps.

In relative terms, scale loss caused by brailing from the packer into totes at dockside was fairly small, being between 9 and 14 percent. This source of scale loss could have been reduced had personnel refrained from loading the brailer to more than a nominal depth of 14 to 18 inches.

Heavy scale loss, from 17 to 35 percent, took place as a result of tote dumping, washing, size grading and sex sorting. It is difficult to see how such damage could be reduced when fish are mechanically processed. One should bear in mind that the Pacific Rim operation was not highly mechanized. The fish were not pumped from packer to dockside or carried by conveyors from dockside to the size-grading machine. Nor were they blasted with high pressure water sprays at any point. The totes were dumped into a hopper, gently washed by flooding the hopper and then lifted from it by a short conveyor to the size grader. From there they were transported again by short conveyors to the sex sorter or some other outlets if they were small or extra large fish.

Freezing and Cold Storage Data. As shown in Table 4-10 the first six deliveries from Area 23, which involved packing the fish from Barkley Sound to Port Alberni, took times varying between 12 and 17 hours (the time taken to transfer fish from the seine to the packer is included in the delivery time). The last two deliveries, which were from Granite Bay and Rebecca Spit in Area 13, took only ten to 11 hours to arrive at the dock in Campbell River, where the fish were brailed into totes and transported by truck to Port Alberni.

Table 4-10. Tons of Fish Delivered by the Packer, Delivery Times, Processing Times and Freezer and Cold Storage Conditions

Deliveries (short) tons	Delivery time (hours)	Processing time (hours)	Hours 2-kg boxes were in freezer	Hours 15-lb blocks were in freezer	Lowest Temperatures in Cold Storage Trailers 0°C No. 1	No. 2
30	15	17	12-14	15-18	-40	-37
66	12	89[a]	12	frozen elsewhere	-37	-37
50	7	56[a]	9	10-14	-40	-35
39	17	36	12	12	-40	-35
12	11	17	12	12	-40	-40
20	14	16	12	12	-40	-35
18	11 CR[b]	17	12	12	-40	-40
17	10 CR[b]	36	12	12	-40	-40

a Fish were held in champagne aboard packer and totes were filled as required.

b Fish caught in Area 13 were unloaded at Campbell River and trucked in totes to Port Alberni.

The time taken to process the fish, i.e. from the time the first tote arrived in the plant to the time the last fish went into the freezer, was excessive. The plant which had been expected to have a capacity of 25 tons per day was severely overloaded by the second and third deliveries, comprising 66 to 50 tons, respectively. They took 89 and 56 hours, respectively, to process. The fish had to be held in champagne aboard the packer to prevent them from spoiling. This illustrates a serious shortcoming of a seine-to-pump-to-packer operation as compared to a seine-to-pond operation where the flow of raw material to the processing plant is controllable.

The length of time that the two-kilogram boxes and 15-pound polybags were held in the freezer was more than adequate, and the cold storage temperatures were well below the -26°C required to comply with Fish Inspection Regulations.

Nematode Incidence. In North American and European countries, herring are eviscerated before being cooked, but most of the female herring being sold in Japan would be cooked with the viscera left in the fish. This raises a potential problem. The nematode *Anisakis simplex* is found in British Columbia stocks of Pacific herring and was observed in all samples taken in the course of the project. (It is also found in Japanese herring stocks.) Whether the Japanese consumer will attach importance to the presence or absence of nematodes in the product will not be known until the product has been sold. If there is adverse feedback, little can be done. Practically all herring stocks in British Columbia have the nematode, so it would not be feasible to fish selectively. If the customer would accept an eviscerated herring, it might be possible to make a vent-to-throat incision and carefully remove the viscera without damaging the mesenteries that hold the ovaries to the walls of the body cavity. This would, of course, add to labour costs and make packaging a more difficult operation since the fish would require gentle handling to prevent the roe from being squeezed out of their open body cavities.

The data presented in Table 4-11, relating incidence to length, merely indicatea the magnitude of a potential problem to which there would probably be no easy solution.

Table 4-11. Incidence of Nematodes in Herring Viscera

Length-Range mm	No. of Fish	Mean No. of Nematodes/fish
Barkley Sound		
171-190	10	2.3
191-210	21	5.0
211-230	6	6.3
231-250	12	9.5
251-270	1	100
Off Lund		
171-190	7	1.7
191-210	21	2.7
211-230	19	5.7
231-250	3	5.0

As can be seen from the table, the overall incidence of nematodes was generally low, with the mean number increasing in larger and older fish.

4.3.3 Conclusions

The Pacific Rim operation, in which the herring were crowded during drying up of the seines, mechanically pumped and mechanically processed yielded a product of poor quality. The lack of a storage pond also caused problems. Deliveries had to be made directly to the plant. So, when catches were large, the plant, which was small, could not process the fish quickly enough to avoid the danger of spoilage. The size of the catches could have been regulated more easily had the seiners carried sonar.

A further problem was due to the fact that roe yield and sex ratio cannot be determined until the seine is dried up, by which time it is too late to release fish that are undersized or low in roe content. The Department was not prepared to allow catches to be made with the intention of retaining only those sets comprised predominantly of large mature females because of the high mortality rate that would have resulted.

Pond operations, in contrast, avoided these problems. Fish were not crushed in the net, nor did they display the tendency to sound that characterized ripe fish. A higher roe yield was obtained because harvesting could be postponed until the roe reached the acceptable level of 10 percent. Furthermore, manually processed fish were markedly superior on each of the quality parameters to mechanically processed fish.

Therefore, unless much less damaging techniques for pumping and mechanically processing herring can be developed, ponding followed by manual processing will be the only technically feasible way of producing high-quality komochi nishin or indeed other herring products that use the whole carcass.

4.4 RECOMMENDATIONS

In future, if permits are issued for ponding herring, it is recommended that -

1. Permits be issued only to processors who furnish evidence of

    a. Conformity with Fish Inspection Regulations for fresh and frozen fish processing
    b. Sufficient space to store totes under cover and space to conduct (manual) processing in an orderly and efficient manner.
    c. On-site possession of an ice-making machine or access to one, and a freezer and cold storage in good working condition.
    d. On-site presence of an adequate supply of durable containers. (Attractive, labelled two-kg boxes of the type used by Pacific Rim Mariculture or cryovac-covered containers similar to those used to sell bait herring on local markets would be suitable.)

2. If the product happens to be whole frozen roe herring, the quantity of fish caught and processed, as stipulated in the permit, should not exceed the plant's projected daily capacity multiplied by the time the herring can be held in the ponds. Conservatively, the latter should not exceed 15 days until more predictive data on factors influencing maturation have been obtained.

3. Except for analysis of roe yield and sex ratio (which should be done on site), herring should be shipped under ice in camp coolers to the laboratory for analysis of quality parameters. Tags bearing such information as date, time, source and conditions of sampling should accompany the samples to eliminate any ambiguity concerning source and to allow incremental damage to be assessed from time of capture through transport and processing to sampling after cold storage. The plant observer(s) could then concentrate on collecting detailed information about each processing step and, at the same time, collect samples and send them to the laboratory.

4. Call times by ship-to-shore radio must be instituted so that plant and boat observers can exchange information about the arrival of samples and events in the capture and delivery of fish.

5. A fast, seaworthy 16- to 18-foot runabout would make it possible for boat and plant observers to get together when needed.

5. MARKETING FEMALE HERRING WITH ROE

The following information has recently been obtained about marketing female roe herring (extracted from a report by Earl Wiseman, Department of Fisheries and Oceans, Trade and Development, International Directorate):

1. Promoting sales of this product will be difficult for several reasons:

    a. Selling roe herring to the consumer market is considerably less profitable for the importer than selling it to processors. Assuming herring roe is worth 5,000 Yen per kilogram, a single fish with a 10 percent roe content might be worth 500 Yen per kilogram in roe value; its carcass would be worth another 150 to 200 Yen per kilogram when dried to make migaki. Thus, the total value to a processor would be about 700 Yen per kilogram. But the same fish sold in the food market could not bring more than 500 Yen per kilogram.

    b. A female fish with roe is not particularly valued over other food herring. They are simply a food fish, and the roe is just an extra bonus. Thus, the female cannot be sold for much more than the male, which sells for about 300 Yen per kilogram. Furthermore, if the price approaches the 500 Yen per kilogram charged for other high-priced products, such as salmon or black cod, the consumer might buy the latter in preference.

    c. Female West Coast roe herring is not associated with kazunoko, herring roe, by Japanese consumers. Once the fish is baked, the texture and the taste of the roe within the fish is significantly different from that of kazunoko. And the consumer does not know how to extract the roe from the fish or how to treat it to produce kazunoko.

2. Under the new food herring import quota, trading companies can sell not only to consumers but also to processors. Apparently, most of the product imported under the new expanded import quota will be going to processors for roe extraction rather than to the domestic market.

3. Supermarkets have generally shattered the packages and sold the fish by the piece, in the traditional manner. The size of the consumer packages are therefore irrelevant.

4. Consumer packages have been selling for as low as 200 Yen per kilogram. About 40 percent had been sold by mid June; most of the remainder will go to processors.

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