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Assessments and Observations of a Cod Farming Operation in Newfoundland

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ASSESSMENTS OF A COD FARMING OPERATION IN NEWFOUNDLAND

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ABSTRACT

Fisher, Robert, 1988. Assessments and Observations of a Cod Farming Operation in Newfoundland. Can. Ind. Rep. Fish. Aquat. Sci. 194:vii+81p

A unique concept for increasing revenues from the Newfoundland cod trap fishery was tested by private industry in 1986-87. Live Atlantic cod (Gadus morhua) ranging in length from 30cm - 60cm were collected from cod traps operated by commercial fishermen. These fish were purchased at the trap site and transferred to tanks on collector boats and transported to a marine farm for maintenance and grow-out. Mortalities were assessed during transportation and grow-out and possible causes were identified. The tagging and measuring of individual fish provided an assessment of growth during the grow-out period. This, as well as data on feed types, amounts and schedules, general observations on farming logistics and suggestions for improvement are included.

Résumé

Fisher, Robert, 1988. Evaluations et observations de la morue dans une pisciculture à Terra-Neuve. Rapport technique canadien des sciences halieutiques at aquatiques. NO. 194.

Un concept spécial visant à augmenter les revenus tirés de la pêche de la morue aux trappes à Terre-Neuve a été étudié par le secteur privé en 1986-1987. On a prélevé des spécimens de morue franche (Gadus morhua) dont la longueur était comprise entre 30 et 60 cm dans des trappes exploitées par des pécheurs commerciaux. Ces poissons avaient été achetés sur les lieux de capture et transférés dans des viviers à bord de bateaux qui ramassent les captures et transportés dans une ferme marine pour la stabulation et le grossissement. La mortalité a été évaluée pendant le transport et la période de grossissement et on a identifié les causes possibles de décès. Le marquage et la mesure de chaque poisson ont permis d'evaluer la croissance pendant la periode de grossissement. Ces données, ainsi que celles sur les types d'aliments, la quantité et les horaires, des observations générales sur la logistique de l'élevage et des suggestions d'amélioration figurent dans le présent article.

PREFACE

R.F. Services provided project monitoring, co-ordination and technical assistance to commercial cod farmers on behalf of the Department of Fisheries and Oceans, St. John's, Newfoundland under DFO/DSS Contract No. FP001-7-2055/01-XAQ.

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INTRODUCTION

In the last two years there has been a resurgence of the interest shown earlier in this century in the rearing of cod in Newfoundland. Earlier efforts, starting in the 1880's, focussed on spawning and development of fertilized eggs and larvae to provide higher recruitment (as yolk-sac larvae) to the natural population. These efforts were carried out at the Dildo hatchery and were later terminated because no significant enhancement of recruitment to wild stocks could be demonstrated. The focus of the present project is the on-growing of adult and near adult cod. This approach circumvents the problems and costs associated with the maintenance of early stages in the life-cycle.

During the summer of 1986, Sea Forest Plantation Company Ltd. (SFP) of St. John's, Nfld. conducted a small scale experiment to evaluate the potential of farming cod in Nfld. The farming concept developed by SFP centers around the collection of live cod captured in cod traps and holding, feeding and growing these fish in sea cages. The results of this work, although conducted on a small scale, indicated that this concept was feasible and could potentially enhance the value of trap cod by increasing the value of the end product through growth and market opportunity.

The cod trap, developed in the 1860's by Captain William H. Whitely, provides the means whereby the majority of rearing phases are bypassed. Not only is the cod trap one of the most efficient methods for capturing cod, it can also provide undamaged, live fish. The use of the cod trap to provide the initial stock for on-growing gives this type of operation a distinct advantage over cod rearing projects elsewhere in that the supply of cod for farming is relatively dependable and available at low cost compared with hatchery raised juveniles.

The concurrent availability of male capelin as a by-product of the capelin fishery and trap cod for a starting stock coupled with the relatively low acquisition cost of both capelin and cod ($.20/lb.) provided the economic basis for this project. The fact that the cod are acquired during a relatively low-cost part of the yearly pricing cycle (late spring to early summer) and sold during a relatively high-return period of the cycle (fall/winter) could further enhance the economic viability of cod farming in Nfld.

A proposal by SFP to the Fisheries Development Division, Fisheries and Habitat Management Branch of the Department of Fisheries and Oceans for technical and financial support to further evaluate and test the concept under commercial conditions was accepted in part. The Fisheries Development Division funded the procurement of oxygen and aeration systems for collector vessels and some of the feed costs associated with the project. R.F. Services was contracted to provide biological expertise, co-ordination and monitoring of farm operations.

The 1987 project was a follow-up to work carried out in Bay Bulls in 1986 by Sea Forest Plantation Co. Ltd. and was based on research carried out over the past eight years at the Austevoll Aquaculture Station, Norway and and work by Williams and Kiceniuk *1986) at the Marine Sciences Research Laboratory, Nfld. It was felt that on-growing would provide a partial answer to the problem of undersized fish harvested in cod traps as well as providing sufficient increase in weight to support such an undertaking. Part of this financial leverage was expected to result from the fish as top quality fresh fillet on the U.S market. The 1986 project was carried out on a modest scale, comprising only four sea cages and several tons of fish. The target for the 1987 project was to acquire a starting stock of 182,000 kg. in a 12 cage farm.

This report presents an outline of the work carried out by the cod farm operators, the biological and physical parameters of the project, resource allocations within the project and an assessment of project feasibility within the context of the Newfoundland fishery. The scope of this work is essentially biological in nature, addressing growth, feeding and environmental parameters as they relate to the on-growing of cod. However, it would be impossible to separate the biological parameters from handling logistics, equipment operational characteristics (ie. boats), personnel requirements and working relationships with fishermen to name a few. Where it is felt that the inclusion of such factors would enhance a general understanding of the problems inherent in such a project, they were included.

The project centers around the trap-fishing season (usually May to August) and the subsequent on-growing period up to and including December. This is the immediate post-spawning growing period of Atlantic cod. At this time, water temperature starts to rise and fish resume normal feeding rates. Since they have, at this point, recently reached an energy reserve low as a consequence of spawning, they feed well, readily consuming large amounts of food if it is available. This results in re-establishment of good physical condition followed by rapid somatic growth. Harvesting of the farmed fish occurs as this growth is tapering off and metabolic energy resources are starting to be channelled more to gonad growth. With a three week starvation period toward the culmination of the growing phase, rate and efficiency of food conversion to fillet weight should both be optimal.

With the present varying nature of the inshore cod trap fishery, this project offers the possibility of considerably augmenting the earning potential of the fishery while in no way interfering with its traditional conduct. It should be noted that Sea Forest Plantation Company Limited has been granted a Canadian patent which essentially covers the underlying concepts on which the on-growing project is based, and is to some degree indicative of the amount of interest presently being shown in the potential of aquaculture in Newfoundland.

METHODS

FARM OPERATION

Farm Description

The farm (Photo 1 App. 3) consisted of hinged wooden catwalk sections with styrofoam billets providing flotation. These formed 12 rectangular net rings in two parallel rows. Each net was made of 45 mm. netting forming rectangular boxes measuring 13 m. long by 12 m. wide by 5 m. deep. Stocking densities ranged from 1818 kg. to 11818 kg. per cage (2.3 - 15.2 kg./cu.m.). Twelve anchors were deployed around the farm to hold it in position. Corner weights were suspended from bottom corners of the nets to maintain cage shape.

The cage assembly was located 50 m. off the northern shore of Bay Bulls, approximately 100 m. out from the head of the fish plant wharf. The substrate underneath the cages was loose silt and organic detritus at a depth of 13 m. grading to coarser silt and pea gravel at a depth of 16 m. The cage bottoms were normally at least 3 m. above the harbor bottom at low tide. This occasionally results in nets sagging to within 1 m. of the bottom.

Collection

An overall understanding of capture and on-growing logistics and of the problems associated with these two phases of the project were considered to be of primary interest in this study. Daily logs were kept detailing collection trips made, collection areas, times in transit, oxygen levels in the transport holds and at collection sites.

Two vessels were used for fish transport to the farm. These had their holds fiberglassed and a set of flexible air diffuser hoses mounted at the bottom of the holds (App.3, Photos 2, 3, 4, 6). A hybrid aeration system comprising a gasoline-engine powered blower and a compressed oxygen system jointly coupled to the diffusion hose assembly was installed in each (App. 3, Photos 10, 11). A 45 foot gillnet longliner the M/V M.I.6, leased from the Newfoundland and Labrador Institute of Fisheries and Marine Technology, was used to transport fish from fishing grounds off St. John's and Petty Harbour to Bay Bulls. However the majority of collections were carried out using a modified 9 m. trap skiff. This vessel proved most satisfactory and will probably serve as the pattern for future collector boats.

Road transport experiments were carried out using both standard insulated fish containers and purpose-built aluminum containers (App. 3, Photos 10, 11). Fish were transported from St. John's to Bay Bulls and vice-versa as well as along a tertiary road from Bay Bulls for test purposes. Oxygen levels, water temperature, fish behaviour indicative of stress and mortalities were all monitored for these trips.

A brief test of a live fish pumping system (Transvac 2010) potentially suitable for the live transfer of fish was carried out on a sample of 200 fish. No mortalities were encountered, but due to time constraints, rigorous testing could not be undertaken. It would be necessary to perform more extensive testing before arriving at a supportable conclusion as to the suitability of the pumping system in question for live cod transfer for on-growing purposes.

Personnel Allocation

Farm personnel at start-up included a project manager, a biologist, three farm workers and two students. The first month was spent preparing the collection boats and deploying the grow-out cages. Two additional farm workers were hired on, as well as two more students when collection started.

The usual collection complement was three men for the trap skiff and four men for the M/V M.I.6. This arrangement remained relatively constant while trap fish were being caught, but was decreased to four farm workers shortly after the end of the trap season. After the farm stock had been collected, manpower was cut back to one part-time supervisor, one farm worker, who obtained, processed and distributed feed, and a night watchman.

For harvesting, three men handled the removal of fish from the pens and transport to the Bay Bulls fish plant, four men handled the bleeding (and sometimes gutting) in the plant, one truck driver provided transport to the Witless Bay (Cape Pine Fisheries) fish plant, where final processing was carried out using relatively standard techniques, except in the final packaging.

Manpower considerations did not permit direct monitoring of all work carried out. Therefore selected Sea Forest Plantation personnel were briefed on data requirements and were issued log-books to provide a record of culture and transport activities, which included amounts and types of feed used, water temperatures, fish mortalities both on the farm and in transport and any other pertinent data or problems encountered by them. Throughout the course of the project, starting well before the initial introduction of fish into the farm cages, close contact was maintained with S.F.P. personnel.

Feeding

Immediately after capture, fish were "off their feed" and were monitored for resumption of normal feeding by presenting them with small amounts of feed until they showed normal appetite. This had the additional positive effect of acclimatizing them to an unaccustomed mode of feeding (ie. high up in the water column and in relatively warm water). When they showed good appetite, full feeding (App. 3, Photos 14-17) was started at a theoretical feed weight of 6-7% of fish weight in the cages every second day. This was maintained, with some adjustment for appetite displayed, throughout the on-growing season, being cut back only when water temperature dropped below 8-9^{0}C. Feeding was stopped entirely 10 days before the start of harvesting.

Processing

Processing involved the removal and transport of the live fish from the cages to the Bay Bulls fish plant. Bleeding of the live fish was carried out both at the cages and in the fish plant. There was no advantage to the former method. Bleeding was either by "throating" (ie. a ventral, dorsally directed cut in front of the heart) or by the severing of the gill arches (and the associated blood vessels). Fish were bled in both fresh and salt water at ambient temperature (approx. 2-3^{0}C).

Simple throating and bleeding of the fish at the plant, followed by, timely truck transport using insulated containers (X-Actic, Model 335), proved to be the most effective means of maintaining good fish condition while transferring them to the Witless Bay fish plant for final processing where standard machine processing techniques were used.

BIOLOGICAL MONITORING

Parameters Examined

From July 15 until the end of November, a pair of thermographs was deployed alongside the farm. The upper thermograph was placed 2 m. beneath the surface and the lower at 14 m. (approx. 2 m. from the bottom). Random measurements of temperature were made as well throughout the course of the project using a YSI salinometer/thermometer, both as a check on the accuracy of the thermographs and to provide real-time temperature data on an ongoing basis. Temperature profiles generated by these instruments are included in Appendix I.

Samples of the fish (fillets)for lab analysis were taken at the beginning of the project and at roughly monthly intervals until November. Since the feeding regimens of cages differed both in amount and types of feed, a cross sample comprising exclusively capelin-fed, herring-fed and feed-of-opportunity (mackerel, herring, capelin and squid) populations were taken simultaneously for analysis. These samples were brought to the Department of Fisheries and Oceans (DFO) Fish Inspection Laboratory where determinations of protein, lipid, moisture and ash levels were carried out (See Appendix II). All samples of feed fish blended for laboratory analysis were of whole fish. Proteins were analyzed using the Kjeldahl method of determining total nitrogen and multiplying by 6.25 (protein-nitrogen conversion factor for fish and fish by-products) to arrive at protein levels. A modified Bligh and Dyer procedure (1959; HPB) was used to extract lipids which were then treated in a rotary evaporator, redissolved in chloroform, mixed with methanol and the total lipid levels then determined gravimetrically. Blended samples were first dried at 100^{0}C for 24 hours and then ashed in a muffle furnace at 550^{0}C for eight hours. Moisture samples were blended and placed in a drying oven overnight at 103^{0}C. Fork length measurements, total, stomach and liver weights were also determined for all samples taken for laboratory analysis.

Samples of moribund fish for examination were taken from the cages, as time permitted. These samples were examined for any gross signs of parasite infestations, deformities and signs of primary bacterial infections. Since few mortalities were found more than two weeks after initial capture, the causes of mortalities were not considered to be critical factors in the rearing process.

An initial external examination was carried out for the presence of ectoparasites, lesions, exudates or other signs of diminished health. The gills and oral cavity were examined, followed by a mid-ventral incision and examination of the gut cavity and lumen. Innocula taken from fin lesions and the posterior kidney were cultured on TSA medium and Gram-stained.

Growth

Representative fish were tagged to determine growth of the fish in the cages over the course of the project based on the growth of individual fish. The varied stocking densities present in the different cages provided for an estimate of density dependant growth based on the growth achieved in individual fish. The tags used were standard Floy "T-tag" with numbered plastic tubes to provide for individual identification. Insertion was between the second and third dorsal fin rays. Of a total of 555 fish tagged, 83 were recovered during the on-growing season (in September) and 169 were examined during the final processing. Seven tagged fish were recovered outside the cages. This escapement was attributed to breaks in the nets. The discrepancy in the number of tagged fish recovered at harvest time versus the number introduced can only be accounted for through: escapement, mortality (tagged fish died and tags lost), tags dropping out and failure to observe and recover tagged fish during harvesting/processing. Since no initial count or accurate and consistent means of weighing the fish introduced into the pens was carried out, it was not possible to extrapolate to the actual numbers lost. Furthermore, the monitoring of growth performance was hampered when fish from various pens were either grouped together or shunted to additional pens to facilitate operations (ie. net changes, feeding and harvesting).

Mortality Assessment

Surface inspections of the farm were carried out at least three times per week and all floating mortalities noted and removed. Cage conditions were noted and feedings were monitored as frequently as was feasible and records of feeding times and amounts kept by SFP personnel.

Underwater inspections were carried out to determine the amount of unconsumed food present, the state of health of the fish in the cages, the number of mortalities present, the extent of fouling of the substrate and the condition of the cage netting. These inspections were carried out at weekly intervals, making it possible to establish the extent of any malnutrition or disease problems. When there were mortalities present in the bottoms of the cages, diving made possible their removal without disturbing or stressing the fish in the cage or exposing them unnecessarily to pathogens and parasites. This was done by cutting a hole of 10-12 meshes in the bottom of the net, dumping the dead fish and bringing the hole up to the walkway for repair. Due to the advanced state of deterioration of the dead fish thus recovered, only estimated numbers were recorded.

Advice and support on all aspects of the farming operation was freely provided by staff at the Department of Fisheries and Oceans, Marine Sciences Research Laboratory and the Marine Institute.

RESULTS

CHRONOLOGY

The first fish were taken on June 17th using the modified trap skiff. Between the 17th and the 25th of July five successful trips were made carrying from 91 to 409 kg. of fish per trip. Maximum time in transit was 1.5 hours.

A hybrid pressurized oxygen/air pumping system was used to maintain normal oxygen tension in the transport water for the duration of the trip to the cages. Recovery from an initial shocked condition (floating vent up, nearly immobile) was good. Of 1727 lbs. of fish released into cage #2, 93% were alive after 10 days (as determined by hauling the net and removing and weighing mortalities. Tables 1 and 2 provide a breakdown of fish collected and mortalities encountered. A high proportion of the mortalities showed direct physical damage to the gills or pronounced net abrasions on their body surface (greater than 50%) caused by their meshing in the twine of the cod trap. Since the fish at this time of the year are usually glutted with capelin, regurgitation and defecation tended to considerably reduce water quality in the transport water. The insulation around the fish hold appeared to be adequate, as the temperature rise in transit never exceeded 0.3^{0}C. No dissolved oxygen meter was available until June 24th at which time oxygen tensions were measured at five minutes intervals throughout each trip. Levels never fell below 8.2mg./l. water, this being well within fish tolerance limits - even in a stressed condition.

Collection aboard the M/V M.I.6 (see Table 2) proved considerably more difficult than with the trap skiff involving, as it did, longer distances, greater travel times (up to four hours) and larger amounts of fish (2900 kg. maximum per trip to date). Only two trips returned a substantial amount (3670.5 kg. total) of live fish to the cages in Bay Bulls, those on June 25th and July 3rd. Of these, the majority died either immediately or within several days. Several trips involving approximately 5,000 kg. ,et with complete failure (100% mortality). When this occurred, these fish were landed for processing.

The dissolved oxygen meter (YSI Model) was used throughout all trips, registering a minimum of 5.7 mg. oxygen/l. water. This is, theoretically, still within fish tolerance limits (Sundnes, 1956). This only occurred once; at all other times oxygen concentrations were kept above 7.7 mg./l.

TABLE 1. TRAPSKIFF COLLECTION (BAY BULLS)

DATE	WT.(KG.)	MORT	NET	CAGE#	TEMP. AT TRAP °C S[1]	TEMP. AT TRAP °C B[2]	HOLD
June 17	909	45	864	2	-		-
June 19	91	5	86	2	6.2		5.7
June 21	727	45	682	2	-		-
June 24	614	23	591	1	6.8	6.2	6.2
June 25	409	45	364	1	-		-
July 3	909	69	840	4	-		-
July 3	1164	267	897	4	8.8	8.6	8.8
July 4	595	-	595	1	8.2	8.2	8.2
July 4	202	53	149	1	8.7	8.0	8.7
July 4	218	45	173	1	9.9	8.8	9.9
July 6	484	30	454	3	-	-	-
July 7	636	56	580	4	8.3	8.8	8.3
July 8	1064	227	837	3	9.1	8.4	9.1
July 8	150	18	132	3	9.7	8.3	9.7
July 8	141	27	114	3	9.5	8.5	8.5
July 9	700	245	455	3	10.0	9.0	10.0
July 10	1714	206	1508	3	8.6	8.2	-
July 10	418	45	373	3	8.6	8.2	
July 11	682	65	617	3	-	-	-
July 13	1300	0	1300	3	9.8	9.5	-
July 13	545	0	1200	3	9.8	9.5	-
July 13	1373	864	509	3	9.8	9.5	-
July 13	455	91	364	3	-	-	-
July 14	545	0	545	3	10.4	9.2	10.0
July 15	1614	5-3	1111	3	-	7.5	-
July 15	100	18	82	3	10.0	6.0	9.0
July 16	1305	318	987	3	9.7	7.7	9.0
July 16	682	65	617	3	9.7	-	9.7
July 17	-	-	2045	5	-	-	-
July 20	1500	405	1095	6	-	-	12.8
July 22	55	14	41	5	-	-	-
July 24	473	82	391	5	-	-	-
July 24	259	43	216	5	-	-	-
July 25	764	133	631	5	-	-	-
July 25		-	520	5	-	-	-
July 27	618	68	550	5	-	-	-
July 27	500	23	477	5	-	-	-
July 28	277	32	245	5	10.8	5.3	7.3
July 28	1864	173	1691	5	-	-	5.5
July 29	564	18	546	5	-	-	-
July 30	348	68	280	5	12.8	9.0	-
July 31	198	55	143	5	13.9	8.3	-
August 1	318	118	200	7	-	-	-

Continued

TABLE 1. TRAP SKIFF COLLECTION (BAY BULLS) Cont'd.

DATE	WT.(KG.)	MORT	NET	CAGE#	TEMP. AT TRAP °C S^1	B^2	HOLD
August 3	627	136	491	7	-	-	-
August 5	450		450	7	14.0	4.6	9.5
August 6	1189	319	870	7	13.4	8.5	8.6
August 6	118	18	100	7	-	-	-
August 7	223		223	7	-	-	-
August 8	318	318		7	14.5	6.4	-
August 8	368	73	295	7	-	-	-
August 8	136	68	68	1	-	-	-
August 10	132	132			-	-	-

NOTE: ^{1}S = Surface
^{2}B = Bottom

TABLE 2. M/V M.I.6 COLLECTION

DATE	WT.(KG.)	MORT	NET	CAGE#	AREA	TEMP. AT TRAP °C S^1	B^2	HOLD
June 25	2082	1.5	2080.5	4	St. John's	7.5	6.7	7.5
June 26	909	909	0	-	"	7.5	6.7	7.5
June 30	2773	2773	0	4	"	7.5	6.7	8.4
July 3	2045	455	1590	2	"	8.8	8.6	8.6
July 4	3791	3791	0	-	"	8.5	3.2	8.9
July 9	2832	2423	409	6	"	9.5	5.4	10.0
July 13	986	91	895	6	Petty Hr.	10.0	5.6	9.1
July 14	105	23	82	6	Bay Bulls	10.4	9.2	11.1
July 15	982	159	823	4	Petty Hr.	9.3	-	9.8
July 17	818	148	670	4	Bay Bulls	9.9	-	4.2
July 21	391	73	318	6	"	11.4	-	9.0
July 23	77	16	61	6	"	12.0	11.9	8.5

NOTE: S^1 = Surface
B^2 = Bottom

above 7.7 mg./1. Fouling of the hold water caused by the regurgitation of food by the cod was as a major problem on all trips, but there were no means available to quantify it in terms of accumulation of waste metabolites.

A conversion was carried out to make use of the pumping systems aboard the M/V M.I.6 to provide low volume water exchange in the fish hold. This system avoided damage to the fish which would occur if the two high-volume deck pumps used to fill and drain the hold at the start and end of trips were used for this purpose.

One brief experiment using a standard large insulated container (X-Actic 335) onboard a pickup truck with an oxygen system was carried out in July. The results were encouraging, in that 50% of the fish survived a two hour transport time in the tank truck as opposed to no more than 25% survival rate onboard the M/V M.I.6 throughout the same time interval. It is probable that the improved survival rate was the result of the transferring of fish from the fouled water in the collector boat to the fresh sea water in the transport tank.

By the end of July, three length distribution samples had been carried out on fish in the cages and a sample of 20 fish was tagged, measured and replaced in cage #2. All fish swam away after tagging and appeared to behave normally.

As of July 28, there was a total of 31590 kg. of fish in eight of the 12 cages. This was far short of the desired total of 182,000 kg. By the beginning of August, 320 fish had been tagged and distributed in cages 1 - 6 inclusive as a representative sample for the on-growing population and condition and growth assessment. Tagging of fish in cages 7 - 8 had not yet been carried out at this point as these fish had not yet recovered from initial capture shock (as determined by their willingness to feed). The use of an anaesthetic, with the complications of procedure and the long duration stress for the fish being tagged, was not attempted. It was felt that there would be less total stress if sampling and tagging were carried out in an expeditious manner using an immobilizing measuring board in which the fish were also weighed. The board acted as a partial restraint during tagging, as well as minimized handling.

A second cod farming initiative was started with the Fogo Island Co-operative Society and Sea Forest to evaluate the potential and familiarize interested parties in the area with the methodology of cod rearing. Two cages were set up in Fogo Harbour and stocked with approximately 4550 kg. of cod. Tagging was carried out on this population to provide an indication of growth throughout the on-growing period so that the Co-op could make a decision whether to pursue cod farming operations. The results obtained are not considered in this report.

The M.I.6 ceased collecting at the beginning of August due to the scarcity of fish. Trap landings during the 1987 season were down considerably over previous years, some traps already having been hauled up in the St. John's area in early August. Bi-weekly dives were carried out both to monitor fish condition in the cages and to clear large masses of dead fish and feed accumulation from the cages. One such clearing a week after capture was all that was required for each cage. A continuous photo record of all activities was kept, including underwater photographs of the cage population.

One cage (Cage No. 1) was set aside for a comparative feeding study. Fish in this cage were fed only capelin (ad libidum), while other cages were fed rations of opportunity (ie. mackerel, herring, squid). Concurrent sampling of natural and captive populations was carried out to determine what percentage of fish growth is in the form of liver size increase and what portion goes to flesh weight increase. The length and weight measurements were used to determine not only growth but also whether body proportions remain the same or if there is an increase in "stoutness" of the fish which would lead to an increase in fillet yield.

A theoretical feeding schedule (Table 3) was derived based on a two-fold increase in fish mass over a four month period in the cages and an estimated 34% conversion efficiency for 60 feedings. The feeding schedule called for a feeding of 6% of fish weight present in cages per feeding session (ie. 1000 kg. of fish = 60 kg of feed). This was roughly half the amount fed to experimental fish in the study of Williams and Kiceniuk (1986) and equal to that recommended by Jobling (1988). The optimum feeding point should lie somewhere between these two points, probably tending more toward the lower figure.

A detailed breakdown of the project's energy budget was not possible because of the relatively open nature of the sea-cages used for on-growing. This design permits entrance of food organisms the size of a full-grown capelin. It also permits the loss of a significant proportion of cod biomass (macerated carcasses) through the mesh on sinking as well as to scavenging gulls at the surface. With the structure of the present program, quantification of losses to possible seagull predation and cannibalism was not feasible. It was only possible to note these potential losses and estimate how serious they were.

Alternate feeds became necessary toward the end of August, as the

TABLE 3. FEEDING SUMMARY - BAY BULLS 1987 (WEIGHTS IN KG)

CAGE NO.	1	2	3	4	5	6	7	8	9
July 17	57	45	23	45					
19	34	34	23	34					
21	118	118	118	118					
23	118	118	118	118					
25	118	118	118	118					
27	118	118	118	118					
29	118	118	118	118					
31	118	118	118	118					
Aug. 2	118	118	118	118					
4	118	164	255	164					
6	91	182	500	318					
8	114	182	681	400	11	11			
10	114	182	681	400	11	11			
12	114	182	681	400	364	159			
14	114	182	681	400	364	159	22	45	
16	227	182	681	400	364	114	33	159	
18	227	182	681	300	364	159	45	161	
20	209	364	825	200	418	105	-	250	
22	227	284	718	398	364	55	-	227	
24	227	341	718	398	364	55	-	227	
26	227	284	730	398	364	114	-	227	
29	227	182	682	398	364	159	91	209	
31	227	182	682	398	364	159	91	209	
Sept. 2	227	182	682	398	364	159	91	209	
4	45	36	136	82	73	32	32	45	
5	-	45	144	100	91	41	36	52	
7	240	57	192	123	114	45	45	64	
9	227								
10	-	73	230	155	141	61	59	82	
11	-	109	363	239	218	95	91	125	
12	240		200						
13	227	190	642	398	364	159	148	209	
17	227	190	642	398	364	159	148	209	
19	255	164	613	345	317	236	127	180	16
21	255	164	613	345	317	236	127	180	16
23	255	164	613	345	317	236	127	180	16
26	255	164	613	345	317	236	127	180	16
28	255	164	613	345	317	236	127	180	16
30	255	164	675	261	236	80	64	125	22

Continued.

TABLE 3. FEEDING SUMMARY - BAY BULLS 1987 (WEIGHTS IN KG.) Cont'd.

CAGE NO.		1	2	3	4	5	6	7	8	9	10	11
Oct.	2	255	164	675	261	236	80	64	125	22		
	4	255	164	675	261	236	80	64	125	22		
	6	255	91	659	182	136	80	55	91	16		
	8	255	118	670	200	145	80	55	91	16		
	10	255	118	670	200	145	80	55	91	16		
	12	255	118	670	200	145	80	55	91	16		
	14	250	91	659	182	136	-	55	91	16		
	16	250	91	659	182	136	80	55	91	16		
	18	275	110	659	218	136	80	61	110	18		
	20	275	143	659	240	145	80	-	-	18		
	22	275	143	-	-	-	-	-	-	-		
	24	273	142	720	240	145	158	136	164	65	109	19
	26	300	156	797[1]	-	-	174	150	180	72	120	21
	28	273	143	725[1]	-	-	158	-	307[2]	-	215[3]	18
	30	273	143	725[1]	-	-	158	-	170[2]	-	215[3]	18
	31	273	143	653[4]	-	0	158	0	0	0	124	0
Nov.	1	0	0	0	0	73	0	170	-	91	0	0
	3	275	0	-	0	761[5]	0	164	-	-	236[3]	18
	5	275	0	-	0	770[5]	0	164	-	-	236[3]	18
	7	275	143	-	0	770[5]	0	164	-	-	236[3]	18
	9	275	143	-	0	770[5]	0	164	-	-	236[3]	18
Total		11817	8165	25188	12730	13601	4797	3262	5461	506	1727	148

Total - 87402 KG

1. Amount indicated for cage 3 was distributed to cages 3, 4 and 5.
2. Amount indicated for cage 8 was distributed to cages 7 and 8.
3. Amount indicated for cage 10 was distributed to cages 9 and 10.
4. Amount indicated for cage 3 was distributed to cages 3 and 4.
5. Amount indicated for cage 5 was distributed to cages 3 and 5.

Note: No rations were provided to fish in advance of sorting or harvesting as indicated by 0 feed amounts in the table.

supply of capelin was running low. Alternate feeds included mackerel, herring and squid. No food supplements or artificial feeds were used.

Weekly monitoring dives showed a further accumulation of roughly 450 kg. of mortalities in cage 7 in late August. No cause for this could be determined and all other cages appeared to be in good condition with the fish feeding avidly. Only a small amount of uneaten capelin was seen during inspection dives. It was assumed that essentially all capelin fed to the cod were eaten. The fish seemed healthy with only minor occurrences of "pop-eye" and "fin-rot". Fish exhibiting marked health problems were removed to minimize stress and the risk of infection for the remaining healthy fish.

The last fish were landed on August 11, bringing the total complement in the cages to approximately 34,500 kg. The poor trap season and the late start in collecting both contributed to the shortfall.

The nets in six of the eight cages were cleaned and replaced in late August. Removal of "slub" from the nets was the most time consuming part of the process, as hanging the new nets and moving the fish from the old to the new nets required a maximum of 1.5 hours each for three men.

Several attempts were made to equalize the numbers of fish in the different cages (particularly cage #3), but they proved unsuccessful. A complicating factor was keeping track of the weights involved. Ideally, fish should have been sorted into two groups both to prevent cannibalism and to enhance the growth of smaller fish. A high proportion of smaller fish (30%) appeared to be fairly lean, and this maybe the result of their being out-competed for food by larger fish. A passive sorter, which would permit weighing during sorting was built, but did not function as anticipated. This method of sorting proved to be too complicated and damaging to the fish and was therefore discontinued. It was found that hand sorting on a table was quicker and less stressful to the fish as well as permitting a detailed examination and culling of damaged fish and a recovery of tagged fish. Fish in cages 4-10 (#9 excluded) were sorted in late September through early October using this method.

On August 24-26 the experimental project in Fogo was visited by RF Services and FDD personnel. The layout and location were noted and some advice tendered to personnel involved in the project. A representative sample of fish (60) was tagged and released into the population of roughly 2000 pounds in the cages. It is possible that up to half the fish thought to be in the cages were lost through tears found in the net while tagging and later more carefully examined during an inspection dive done on the site.

A sample of squid (frozen block) was brought back from Fogo to experiment with as fish food and a sub-sample brought to DFO for more detailed examination. A cod sample was also brought back for similar analysis (6 fish). The remainder of the squid was fed to the cod in Bay Bulls to observe the response. It was taken so avidly that fish were jumping out of the water (in bright sunlight, at mid-day) to get it - this despite the fact that they had been adequately fed the evening before.

Two transport experiments were undertaken in mid-October. Full-size, 35 cu. ft. containers were used in both experiments. A flat-bed truck provided transport in the first experiment, and a pickup truck in the second. Fish were not starved prior to transport, but regurgitation did not prove to be a problem. Fish were transferred by dipnet into grey containers aboard the trap-skiff and brought to the wharf. They were then dipnet transferred to containers (X-Actic 335) on the wharf. These tanks were weighed and transferred to the transport vehicle. Oxygenation was maintained throughout by using a medical oxygen flowmeter set to five litres/min. Densities of 33% and 37% fish were used in these experiments. Transportation periods were two hours on both occasions, resulting in total times out of the cage of 3 - 3.5 hours. In the first transport experiment, two mortalities were noted; while in the second, none. Few mortalities were noted in the bottoms of the cages to which the fish were returned when these cages were inspected by diving several days later. A large part of the success of these transport experiments is directly attributable to the advice of Mr. Atle Ahmer, Norwegian live-fish transportation expert, who supervised both experiments.

Truck transport of fish from St. John's to Bay Bulls had been attempted using a flatbed truck and a converted 11.5m^3 cylindrical tank and a purpose built rectangular tank of 10.2m^3 volume in July. Extreme water condition problems (due to regurgitation) resulted in 100% mortalities and, since no useful information was obtained, these trips are not reported in greater detail here.

Harvesting was started at the end of October. The procedure for all the harvests involved loading the fish into the transport trap skiff and delivering them alive to the plant. For the initial slaughters, fish were either 'throated' or had their gills clipped unilaterally for bleeding while being loaded into the fish hold. The water in the hold was oxygenated using the same pressurized oxygen system as provided oxygen during live transport to the farm. Approximately 1800kg. were carried in each transport trip, the amounts processed on a given day ranging from an experimental 1350kg. to a production high of 9000kg. For these first harvests, fish were taken from the cages using dipnets. For later harvests, a purpose-built hydraulic hoist and boom were used to load fish directly into the hold and bleeding was carried out in the fish plant in Bay Bulls.

The first few harvest days involved both bleeding and gutting of the fish in Bay Bulls followed by truck transport and final processing in Witless Bay. This was found to be unnecessarily time consuming, therefore only bleeding was carried out in Bay Bulls from this time onward, with all further processing being done in Witless Bay. The final processing arrangement for the Cape Pine Fisheries Plant started with gutting followed by machine-beheading, filleting and skinning (all using standard Baader machines). The resulting fillets were candled and trimmed and packed in special tins which were in turn packed in ice in a double polyethylene wrap in a styrofoam insulated cardboard shipping carton.

Problems encountered included physical handling difficulties at the bleeding stage. It was found that a 5 - 10 minute exposure to CO_2 anesthetic relaxed fish sufficiently to considerably facilitate handling, making them easier to hold and throat. A brief (1-2 minute) exposure to oxygenated water resulted in a return to normal activity levels and good bleeding. Rigor mortis in the farmed cod was unusually strong and prolonged relative to that observed in wild fish. Some fish taken in the first two harvests (1350 kg. each) were not sufficiently starved before processing. While the quality of the fillets was excellent (color and taste), there was considerable gaping.Bled and gutted farmed fish required up to 72 hours to complete the rigor cycle, based on tests conducted by Cape Pine Fisheries personnel. This time was reduced significantly by starving the fish for 10-15 days prior to harvesting. Tests will have to be conducted to identify optimal starvation periods relative to rigor.

COLLECTION (TRANSPORT)

Boat

The transport tanks on both the trap skiff and the M/V M.I.6 performed as expected. As a result of the incorporation of insulation into the bulkheads of the holds, heating of transport water was not a problem. Fouling of the transport water through fish regurgitation and defecation did prove problematic during the capelin glut period. The regenerative air blower used for aeration at the start of the project proved totally inadequate. The backup system provided the necessary aeration - maintaining required oxygen saturation levels in the hold water without difficulty. If oxygen levels started to drop in the hold, a 5-10 minute purge restored levels to those required as indicated by the dissolved oxygen meter.

The actual collection of the fish at the traps, including maneuvering onto the trap and the transfer of fish to the cages, posed no problem. A portable, light-weight boom and hydraulic winch package installed toward the end of the project should prove advantageous for future collections and transfers. Transport times in the Bay Bulls area were never over 1.5 hours and, outside this immediate area, ranged up to three hours. Assuming adequate water exchange in the transport hold, these times should not pose any problems.

Truck

Truck transport imposed stresses comparable to boat transport. The two transport experiments carried out on October 14 and 16 proved that such transport is a viable option assuming prior acclimation of the fish to surface water temperatures and the absence of feeding induced stress (capelin glut). There were no mortalities as a result of the first experiment and four mortalities as a result of the second, both after three days. Fish remained quiescent throughout both experiments and no regurgitation was noted, even though the fish used had not been starved prior to transport.

FEEDING

Cages #1 and #2 were set aside as controls. Cage #1 was fed only capelin, cage#2 only mackerel and the remaining cages whatever was available (Table 3). Most feedings were carried out by a single farm-worker. For the number of fish in the farm, hand-feeding by a single individual proved adequate, but only marginally. Since the maximum amount of feed on a given day exceeded 2200 kg. and, in the case of mackerel and herring, considerable processing (chopping) was required before the actual feeding. Larger amounts of fish would require either increased manpower or mechanization for feeding.

After the initial post-capture period of appetite loss, feeding proved no problem as the fish took any feed presented as long as light-levels were somewhat subdued. Surface water temperatures did not appear to affect feeding as long as they remained above $8^{0}C$. During periods of rapid temperature drop (eg. to $2^{0}C$ at the beginning of September) fish tended to congregate at the bottom of the cages and showed little inclination to feed.

TEMPERATURE

Temperature, both at the surface and at the bottom, fluctuated greatly throughout the term of the project (Graphs 1-5, Appendix). Bottom temperatures in excess of $8^{0}C$ were reached by the beginning of July and except for occasional brief drops, remained there until the end of October. Surface temperatures remained well above bottom temperatures until the end of September, from which time onward storm driven mixing tended to keep temperatures equal throughout the water column for the rest of the season. Surface temperature throughout August remained above $18^{0}C$ peaking at slightly over $19^{0}C$.

GROWTH

Growth (weight) as shown in Table 4 ranged from 18.1 to 29.8% per month for fish in various cages. These growth rates appear low because growth is pro-rated over the entire period in the cages. This period includes initial stress with concomitant loss of appetite, a period after this during which the fish were fed insufficiently and the pre-starvation period prior to harvesting. Table 5 shows growth in tagged fish captured midway through the on-growing project and at the final harvest. The growth rates shown are highly variable, averaging 30.0% (weight) per month from July to September and 3.8% per month during the period from late September

TABLE 4. COMPARISON OF MEAN GROWTH BY CAGE

CAGE #	# SAMPLED (tagged fish)	MONTHLY INCREASE (%) LENGTH (s.d.)	MONTHLY INCREASE (%) WEIGHT (s.d.)	C.C. (s.d.)	LIVER[1]	FISH[2]	FEED
1	14	3.8(1.4)	20.8(11.2)	1.14(0.16)	8.1	1850	Capelin
2	6	3.8(1.3)	20.5(6.0)	1.08(0.14)	15.2	3012	Mackerel
3	23	4.2(1.6)	19.8(11.7)	1.05(0.16)	10.3	8745	4
4	12	4.5(1.3)	22.5(8.2)	1.16(0.21)	-	5595	4
5	15	4.3(2.1)	18.1(11.0)	1.00(0.11)	8.1	6231	4
6	13	4.9(1.7)	29.8(9.9)	1.15(0.19)	-	1909	4

1) c.c. = condition co-efficient
2) % of whole weight
3) Estimated starting weight in kg.
4) Feed of opportunity

TABLE 5. GROWTH COMPARISON - SUMMER/FALL

INITIAL (JULY) LGT.	INITIAL (JULY) WT.	INTERVAL (SEPT.) LGT.	INTERVAL (SEPT.) WT.	% INCREASE/MONTH LGT.	% INCREASE/MONTH WT.	FINAL (DEC.) LGT.	FINAL (DEC.) WT.	%INCREASE/MONTH LGT.	%INCREASE/MONTH WT.
46	1.05	53	2.15	6.4	44.3	54	2.05	4.8	-11.8
45	0.80	52	1.60	6.6	42.3	55	1.50	3.2	3.5
45	0.80	50	1.55	4.7	39.6	53	1.60	3.3	1.8
39	0.65	47	1.15	7.0	26.2	48	1.00	1.2	- 7.4
60	2.25	68	3.80	5.1	26.2	69	3.95	2.0	5.4
47	1.10	54	2.10	5.0	30.6	56	1.80	5.0	-19.5
59	1.90	67	3.65	4.2	28.2	69	3.45	4.1	7.5
40	0.75	49	1.30	7.6	24.7	53	1.40	4.6	4.5
42	0.65	48	1.30	5.4	38.0	52	1.40	4.7	4.5
48	1.05	51	1.20	2.1	4.8	54	1.30	3.3	4.7
47	0.90	53	1.65	4.9	31.6	56	1.85	3.2	6.9
49	1.40	57	2.40	6.2	27.1	59	2.65	4.8	14.2
54	1.35	58	2.45	2.4	26.6	64	2.65	4.4	3.5
45	0.95	47	1.60	1.4	22.3	52	1.85	4.6	6.7
44	0.80	49	1.45	3.7	26.5	55	1.55	5.2	3.0
45	0.80	49	1.30	4.8	34.0	57	2.00	5.6	18.4
51	1.00	53	1.55	2.6	37.0	59	2.35	4.0	18.4
$\bar{X}$ = 47.3	1.07	53.2	1.89	4.7	30.0	56.8	2.02	4.0	3.8
sd 5.7	0.44	6.2	0.80	1.8	9.2	5.8	0.78	1.2	9.6

through December 14. Essentially, there is very little, if any, growth in the flesh during latter period.

Percentage monthly weight gain, on which the T-test for significant difference in growth between cages was based (Table 6), shows that the only cage with significantly different growth is #6. There is no factor to which this growth anomaly can be attributed. The lack of differences between the other cages shows that there is essentially no difference in growth rates caused by density differences or type of feed used.

Condition coefficients (C.C.) in Williams and Kiceniuk's (1986) study showed a low (.79) at the beginning of the study and a high at the end (.96). In a similar manner, C.C.'s in the present study showed a low of .92 at the beginning of the study and a high of 1.00 - 1.16 at the final harvest (See Table 4). This increase in stoutness was most noticeable across the back, ie. in fillet thickness, although an increase in visceral mass also contributes to this increase.

MORTALITIES

Major losses (mortalities) were correlated with a two week post-capture period, sorting carried out in late October - early November and a problem with feeding levels in mid-September (Tables 7,8). Mortality problems associated with sorting were exacerbated by feeding stress, as the fish were not starved prior to sorting. Past the initial post-capture stress mortality period, mortalities stayed at a level of 15 fish per week total for all cages. Aside from high mortality episodes, all of which had a causative agent directly associated with them, it is speculated that the three most likely mortality inducing factors were parasite infestation

TABLE 6. TEST FOR SIGNIFICANT DIFFERENCE IN GROWTH BETWEEN CAGES USING PRO-RATED MONTHLY GROWTN OF FINAL TAG RECAPTURES AS THE CRITERION

CAGE #	1	2	3	4	5
1					
2	F=3.4578(p=.09) T=0.069549(p=.95)				
3	F=0.9182(p=.45) T=0.2593(p=.80)	F=0.2655(p=.07) T=0.1347(p=.89)			
4	F=1.8539(p=.16) T=0.4198(p=.68)	F=0.5362(p=.26) T=0.5216(p=.61)	F=2.0191(p=.11) T=0.6993(p=.49)		
5	F=1.0348(p=.47) T=0.6659(p=.51)	F=0.2993(p=.10) T=0.5011(p=.62)	F=1.1270(p=.42) T=0.4576(p=.65)	F=2.0191(p=.11) T=1.1471(p=.36)	
6	F=1.2751(p=.34) T=2.2039(p=.04)	F=0.3688(p=.14) T=2.1148(p=.05)	F=1.3888(p=.28) T=2.6007(p=.01)	F=0.6878(p=.27) T=2.0093(p=.06)	F=1.2322(p=.36) T=2.9472(p=.67)

TABLE 7. MORTALITIES NOTED DURING DIVING: ASSUMING AVERAGE STARTING WT. OF 1.4 KG.

	CAGE NO.									
DATE	1	2	3	4	5	6	7	8	9	10
July 25	30.8				44.8					
August 18	4.2	2.8	7.0	2.8		12.6				
September 17					2.8	1.4			1.4	
September 19	2.8				4.2					
September 24	4.2								12.6	
September 29		1.4								
September 30	1.4	4.2	16.8			2.8	1.4			
October 5	5.6	2.8	14.0	1.4	2.8	1.4	1.4	2.8		
October 12	15.4	7.0	8.4	2.8			4.2	4.2		
October 16	5.6					9.8				
October 20	10.5	4.2	19.6	7.0	4.2	8.4		5.6	1.4	
October 21			1.4		4.2					
October 23			15.4		4.2					
October 31	1.4		22.4					11.2		
November 2			8.4	1.4			1.4			
November 10			84.0[1]							
November 12	7.0	5.6	19.6	14.0	16.8	2.8	28.0	7.0	12.6	15.4
November 13						64.4[2]				
	88.9	28.0	217.0	113.1	84.0	103.6	57.4	30.8	28.0	15.4
								TOTAL	766.2	

[1] Mortalities observed post sorting.

[2] Mortalities from cages 6, 7, 8 observed post sorting.

TABLE 8. MORTALITIES NOTED:
SFP Log - those fish removed after August 1 are pro-rated back to their assumed original weight based on a 22%/mo. growth rate. The weights used are thus all initial weights (Kg).

DATE	1	2	3	4	5.	6	7	8
July 8			68					
July 13			864					
July 15			18					
July 16			384					
July 18			909					
July 20					439			
July 22					14			
July 23		182		182	182	182		
July 24					125			
July 25					178			
July 27					91			
July 28					545			145
July 29								20
July 31					909			909
August 1					118			
August 6							323(336)	
August 10							44(47)	
		182	2243	182	2601	182	367	= 6967

+ Diving Total = 766.2 Kg
Season Total = 7733.2 Kg

NOTE: Since feeding commenced in mid-July and had not reached full scale levels by Aug. 10, no correction has been applied to the weights in this table.

(Lernaeocera), meshing and a possible low-level, chronic dietary deficiency (possible resulting from thiaminase action on frozen, unsupplemented and relatively undiversified whole fish feed) as evidenced by the low but noticeable incidence of exophthalmia (pop-eye).

PATHOLOGY

Relatively few signs of debilitating disease were evident in the cage populations. Lernaeocera was quite noticeable at the start of the project and was probably partly responsible for the initial post-capture mortalities. Some fish exhibited vertical spinal scoleosis, possibly the result of a dietary deficiency, and exophthalmia - possibly also diet related. The occasional individual showed signs of septicemia on the fins or body surface. An attempt to isolate the causative organism(s) in the laboratory was not successful, and is not discussed further here.

Other than these occasional signs of poor health, the main population seemed in good health, although Lernaeocera was probably partly responsible for the low-level chronic mortality (Tables 8+9).

PROCESSING

Yields (head-on-gutted=HOG), ranged from 77-80% (Tables 9 and 10). Discussions with the personnel in Cape Pine Fisheries plant, where the final processing was carried out, yielded the following observations:

1) There was no appreciable number of roundworms in the fillets or the viscera of the farm-reared fish, certainly no more than would be expected in freshly caught wild fish taken off the northeast coast of Newfoundland as indicated by Cape Pine Fisheries workers and Inspection

TABLE 9. YIELDS FROM FARMED COD ROUND WEIGHT TO HEAD ON GUTTED (H.O.G.)

	ROUND WEIGHT (kg.)	HOG*	% YIELD $\left(\frac{HOG}{ROUND}\right)$
November 2	2728	1996	73.17
November 13	5664	4438	78.35
November 27	5500	4279	77.80
November 30	5727	4484	78.29
December 8	5255	4041	76.9
December 10	7773	6195	79.7
December 14	9136	7312	80.0
	41783	32747	

+H.O.G. = Head on Gutted

Note: Weights obtained during gutting operations in plant.

TABLE 10. FARMED COD PRODUCTION YIELDS (HAND FILLET)

No. of Fish = 44

H.O.G. Wgt. = 179.39 lbs.

Avg. Wgt per Fish (H.O.G.) = 4.08 lbs.

*All weights expressed in lbs.

	TOTAL WGT. H.O.G.	FILLET SKIN ON	FILLET SKINNED	FILLET TRIMMED	V.CUT	NAPES
	179.39	90.75	83.58	66.60	7.93	7.51
Yield from H.O.G.		50.59%	46.59%	37.13%	4.42%	4.19%

NOTE: All fish were cut by an experienced fish cutter. After filleting the fish were machine skinned and trimmed manually during commercial processing operations.

Officers, Department of Fisheries and Oceans.

2) Starvation for a minimum period of two weeks at the temperatures occurring at the time of harvest is essential as this results in a lowering of stored glycogen levels in the muscle and a complete clearing of the gut (Jobling, 1988). The lowering of digestive enzyme levels materially improves fillet quality as does the less intense rigor which results from lower muscle glycogen levels.

3) A determination of product yields for the farmed cod (Table 10) was undertaken at Cape Pine Fisheries in Witless Bay. A sample of fish was manually filleted to determine a trimmed fillet yield of 37% from head-on gutted fish.

4) Livers were found to be unusually large, averaging in excess of 10% of whole weight (Table 4).

5) The filets were noticeably "stouter" and fuller than in the wild fish of comparable lengths. This resulted in the smaller fish yielding fillets larger than four, eight and 12 ounce filets (arbitrary industry cutoff weights determining desirability of product: largest=highest value).

DISCUSSION

COLLECTION

The basic methodology of collection has been satisfactorily determined. Transportation toward the end of the season in the Bay Bulls area came close to achieving 100% survival of fish brought back to the farm. If fish can be collected before they are satiated on capelin, transport hold water quality should not be a problem. If they are taken when totally satiated, it will be necessary to provide for water changes as there will definitely be problems with regurgitation, particularly on longer trips (greater than two hours).

Fishermen have proven to be uniformly helpful and supportive. Even with the 14 meter aluminum longliner, no problems were experienced coming onto the traps for collecting. Judging by the experiences of the 1987 season, there should be no problem obtaining fish in this manner. As fishermen and farmers become more familiar with procedures and acquire more experience collection efficiency should improve.

For future collections, the key to success will be flexibility of response to local availability of fish. Cages located close to the cod trap sites will provide an opportunity for the fish to evacuate their digestive tracts. If road transport and holding cages which could be readily assembled/disassembled and transported can be utilized and relocated to take advantage of good landings, then even meager trap landings should provide sufficient starting stock to support a successful on-growing effort. If future trap landings are as poor as in 1987 (27000 M.T. in NAFO Divisions 3 KLPs), a 500 M.T. farm should be sustainable. If full advantage is to be taken of widely separated good trap landing sites, such as would be the case with generally poor landings, truck transport will need to be further developed to concentrate the collected fish so that they may be economically farmed. The brief experiments in truck transport carried out in this project proved encouraging and it appears to be a feasible option for supplementing the acquisition of farm stock. However, further work will be required to determine the full potential of this transport method.

FEEDING AND GROWTH

This phase of the project presented few problems. Since only 34000 kg. were collected, feeding was manageable by only one farm worker. Quantification of mortalities was difficult, as they generally tended to sink. The only way to determine mortalities in this case was by diving below the various cages. As long as capelin was the only feed, feeding at an assumed 3% body weight/day was possible with no wastage. When the feed was changed to mackerel, some accumulation of waste was noted at the bottoms of the cages. Good growth was achieved (Tables 2,3) and could be improved in future by size sorting, careful monitoring of feed and acceptance, scaling of feeding levels according to temperature, shading of cages to reduce activity levels during the day and stimulation of feeding as soon after capture as possible. The recapture of seven tagged fish outside the cages casts doubt on the exact number of fish remaining in the cages at harvest time. If one assumes a 20% growth rate per month in all the cages over a 4.5 month growth period, the final yield figure of 43640 kg. is low. This indicates a loss (both to escapement and mortality) of up to 33% of the starting stock. No definite cause for this loss could be determined. Food conversion ratios could not be accurately determined for the farm stock due to problems encountered with the weighing scales on a number of occasions and as pointed out that only estimates of mortalities after collection were possible.

Mortalities remained at low levels throughout the on-growing phase. While these losses were not alarming in themselves, what they indicated of fish condition vis-a-vis stress, nutritional status and parasite burdens is very important. Stress and its manifestations are critically important for any such venture as are the means of obviating and alleviating them. Therefore, a separate section on stress and its implications is included in this discussion.

HARVEST

Yields at final harvest were 80% H.O.G. (Table 9). This was considered quite acceptable by Cape Pine Fisheries personnel. Fillet yields, as well, were quite acceptable (Table 10). These two results tend to lay to rest concerns expressed as to whether growth in cod fed to repletion would be of viscera to the detriment of flesh weight gain. The increase in relative weight of liver can be dealt with by an adequate starvation period (greater than two weeks) prior to harvesting. This will permit the liver to be used as the primary energy source for physiological maintenance. Since cod will selectively use up glycogen and lipid energy stores (both centered primarily in the liver) before metabolizing protein, flesh weight should not decrease appreciably over a one month starvation period if the fish have first built up sufficient energy stores (Jobling, 1988).

STRESS AND OTHER OBSERVATIONS

Normal conditions in a fish's environment are demanding and, for the most part, have no direct terrestrial equivalent. While fish may be said to be physiologically adapted to these conditions, this adaptation is based on a certain energy cost. They must expend a significant amount of energy to overcome frictional drag while swimming and in the ventilation of respiratory exchange surfaces. Since the amount of oxygen available for respiration is quite limited (less than 13mg./l normally), this can amount to a sizeable energy debt. The respiratory medium also acts as a dialyzing medium for the blood. Thus, when additional oxygen is needed, the increased gill circulation results in an increased water influx (salt uptake in marine species). This shift of blood electrolyte balance has serious implications for fish physiological processes. Thus fish are continually challenged by the normal physio-chemical demands of the aquatic environment itself. Added to this may be stress from habitat alterations and inter-and intra- specific interactions such as social heirarchies (Jobling, 1988).

The term used to describe these responses collectively is - General Adaptation Syndrome (G.A.S.). The G.A.S. is composed of both general (ie. responses evoked by any type of stress) and specific responses. These responses to stress are classified as primary (neural and neuro-endocrine), secondary (physiological consequences of primary responses) and tertiary (behavioural modification, decline in growth and susceptibility to disease). To reduce stress to this simple three-tiered classification system, while convenient, may prove misleading since that which is evoked by stress is an interdependent pattern of responses. This underlying pattern should always be borne in mind when assessing stress effects.

Fish culture, whether intensive, semi-intensive or extensive, is a prime example of multiple stress impact on individual and population health and growth. Since stress, in such a situation, has immediate economic implications, it is important that its effects be recognized and to as great a degree as possible, compensated for in the rearing environment (ie. feeding schedules and amounts, medication, food additives and a minimization of handling stress; Jobling, 1988).

The most thoroughly studied stress responses in fish are the typical increases in blood glucose and lactate and the depletion of glycogen in the liver and muscle. These responses are secondary effects caused by the increased release of hormones from the pituitary, the inter-renals and the chromaffin tissues and the increased activities of the sympathetic nervous system.

In a study by Barton et al (1986), plasma glucose concentrations observed after handling were much greater in diseased than in healthy fish, suggesting a higher metabolic response in this group. Alternatively, the higher concentrations of plasma glucose evoked by the stresses in the diseased fish could indicate that these fish were preconditioned to respond in this manner by the chronic stress of continued infection.

Fish response to hypoxia is a good measure of the level of complexity and synergistic nature of stress/response interactions. Most responses to hypoxia are reflexive responses of the ventilatory system. Initiation is by exteroceptors, probably on the surface of the gills or associated regions such as the pseudobranchs. Interoceptors, which respond to changes in blood oxygen and carbon dioxide levels, may also be involved in this feedback cycle. On the blood side of the gill/water interface, there are cardiovascular adaptations which improve the effectiveness of oxygen uptake by the blood. Many of these changes are responses to stimulation of sense organs and are effected via reflex pathways from the CNS. These responses mainly alter the cardiac output and its distribution to the tissues as well as to the gills in a way which improves the effectiveness of oxygen uptake (ie. increased blood flow to the secondary gill lamellae).

The hypothalamic-pituitary-interrenal (HPI) axis is sensitive and responsive to stresses. The response of the HPI axis to culture procedures, disease and xenobiotics can in many cases be used to quantify and compare the relative significance of different stresses. The use of the HPI axis may be particularly appropriate where fish are exposed to two or more sublethal stresses simultaneously as the response reflects the integrated effect of the several components.

The defense system, both controlled and mediated by the HPI, is responsible for such responses as tissue repair, phagocytosis and inflammation as well as for a number of lymphoid system mediated responses, both specific and non-specific. Defense mechanisms act to localize irritants, present a hostile barrier and finally to eliminate or destroy them. The first points of contact with an environmental stressor are the skin, gills and, to some extent, the lumen of the gut. Their response will determine whether the stress remains localized. The initial response is localized inflammation accompanied by fluid and blood cell accumulation. This response is non-specific and can be elicited by any surface perturbation. Stress modulates many of the defense mechanisms, suppressing some and exaggerating others.

Stress pheromones have been found to mediate immune suppression in fish. This may account for the ability of dominant members of a dominance heirarchy to produce antibodies to experimental infection while subordinate individuals failed to produce an antibody response. It is possible that elevated corticosteroid levels in subordinate individuals are responsible for this stress induced suppression of the immune system. To further complicate matters, this suppression or enhancement of immune system function is not a constant, given a particular stress input; system response will vary based on temperature, time of annual cycle, state of sexual maturity and previous stress history of the individual being examined. This aspect of stress is only poorly understood but has wide-ranging implications for disease management within an aquacultural context.

Mazeaud et al (1977) found that capture, transportation, freshwater-saltwater transfer and vaccination resulted in several types of stress which induced struggling, hypoxia, temperature and osmotic shock. The lethal consequences of stress are quite often not immediate. Death can be delayed (in the case of the cod farm for up to two weeks after capture) and the stressed condition remain unnoticed for a considerable period after its application. As a rough scale of degree of stress, they found that five minutes of struggling out of water imposes more severe stress than five minutes at elevated temperature, which in turn imposes more severe stress than 20 minutes in a seine.

Fish in an aquacultural setting are almost invariably additionally stressed as a result of normal operating conditions (ie. handling, crowding, net handling) as well as by unfavorable or fluctuating temperatures and water chemistry. This stress is conjoint with the previously mentioned "normal" conditions in the aquatic environment. Additionally, operating practices and population densities are often dictated by economic rather than by biological considerations. All of these conditions, together with any fright response that accompanies them, can impose a considerable load on the normal metabolism of fish. Although individual stress factors in aquacultural systems are usually sublethal in themselves, stresses are more commonly multiple and the resulting physiological load can reduce growth, impair fish health and quality and result in decreased survival and increased costs.

A fish's survival in the face of environmental stress depends on its ability to regulate physiological processes in order to achieve compensation (homeostasis). Any stress requiring an adjustment in excess of the fish's ability to respond appropriately will eventually be lethal - either directly or indirectly as a result of diseases. An understanding of the mechanism of response to environmental changes and the degree of stress to which fish can adapt through these mechanisms is important to a definition of the environmental quality required for optimum fish health in an aquaculture setting. Although fish can usually survive unfavorable environmental conditions for limited periods because of their homeostatic capabilities, this should not be used as an excuse for operating aquacultural systems under marginal conditions.

One of the most insidious effects of stress in aquaculture is increased susceptibility to disease. Attention is now being paid to the use of this effect as a method of biological monitoring of environmental quality (Esch and Hazen, 1980; Ellis, 1981).

The presence of fish pathogens, unless in overwhelming numbers, will not result in epizootics unless unfavorable environmental conditions have already weakened the fish's defence system. Thus, infectious fish diseases are not single-cause events. They are the outcome of the continuing interactions between the environment, the fish and the pathogen reservoir (Nillson and Holmgren, 1986). If the host - environment - pathogen interrelationship is balanced, good fish health, survival and growth will result. If the balance is disturbed, disease problems will crop up and reduced fish condition, survival and growth will ensue.

Certain stress-mediated diseases have been identified as promising indicators of unfavorable conditions in the marine environment. These include chromosomal and morphological abnormalities of eggs and larvae, skeletal anomalies, neoplasms, fin erosion and epidermal ulcerations. Viral erythrocytic necrosis may be a potentially useful indicator disease in the estuarine environment (MacMillan et al, 1980). Fish disease incidence can be most easily used as an index of unfavourable conditions in aquaculture facilities having relatively controlled environmental conditions - a situation not obtaining in the present cod on-growing project.

The number of fish which can successfully live and grow in a given water supply depends on its pathogen load, the dissolved oxygen level, metabolic rate of the fish, feeding rate and how fast the water is being exchanged, which in turn governs the rate at which metabolic wastes accumulate. The fish pathogen is a usually neglected, but very important factor affecting both the carrying capacity and the health of the fish being reared. In recirculating systems, pathogens can be controlled by water sterilization devices using ozone or U/V light. In the Bay Bulls situation, these pathogen loads are only indirectly under control (ie. by exclusion or removal of intermediate hosts; net changeouts).

Practical handling is a problem, as sorting must be carried out at least once (preferably twice) in a given on-growing period. This is necessitated both by the need to forestall the establishment of a size-based social dominance heirarchy in which smaller individuals would only achieve modest growth as a result of being continually out-competed for food by larger fish and to eliminate direct mortalities due to cannibalism. Even without the direct disadvantage of being out-competed for food, submissive individuals will often fare poorly as a consequence of the stress associated with low ranking in the dominance heirarchy. The extent of the cannibalism problem has been well documented in an aquaculture context for fry in Norwegian rearing work on cod (Kvenseth, 1985), but has not been clearly shown under similar conditions for adults. Within the constraints of oral aperture size, cod in the wild are known to cannibalize smaller cod but it is assumed that in the case of larger individuals (greater than 35 cm) in a well fed state, the effects of cannibalism would be minimal.

Conditions of fish transport are directly influenced by the over-exertion and fatigue of the fish being transported. The first hour after loading is a particularly critical time with respect to fish oxygen requirements since the fish are excited and require a large amount of oxygen within a short time for adjustment. Additionally, since activity levels are so high at this time, normal supplies of oxygen will fall short of physiological requirements, even in cold water oxygenated to saturation (greater than 13 mg./1.). Anaerobic energy resources are then called upon to make up the shortfall, resulting in lactic acid accumulation in the muscles and blood. This in turn, causes blood pH to drop, thereby reducing oxygen utilization - an effect further compounded by elevated CO_2 levels. Although this acidification of fish body fluids and transport water reduces the percentage of un-ionized ammonia in the water, it also reduces the O_2 carrying capacity of fish blood. Fish may succumb if CO_2 levels are high, even though O_2 levels are seemingly adequate.

Ammonia builds up in transport water due to protein metabolism of the fish and bacterial action on the waste. Decreasing the metabolic rate of the fish by lowering the water temperature, and thus lessening fish activity, reduces the production of NH_3. The production of NH_3 by bacterial action can be decreased by shipping fish only after food has been withheld long enough to void the stomach and intestine. Temperature and time of last feeding are important factors regulating ammonia excretion. Critical concentrations of toxic ammonia are rarely obtained under standard fish transport conditions. However, the effect of ammonia as part of the "stress complex" should not be underestimated (Berka, 1985). Transport conditions also influence the composition of fish blood and the parameters of blood serum chemistry. Fish transported at high densities showed increases in glucose and corticosteroid levels in the plasma, both of which continued well after the termination of transport. Although mortality as a direct consequence of transport (ie. short-term) can be low, the secondary effects of stress were responsible, in the present cod on-growing trials, for delayed mortality caused by the consequences of osmoregulatory and immune system dysfunction.

It should be noted that release of fish at the destination can be the most critical stage of the transport process. The fish are under some degree of stress in the transport unit and sudden exposure to water of difference characteristics or low quality will further stress the fish, often beyond what they can endure. Different water characteristics would include pH, temperature, gas saturation as well as a number of other factors. Quite often, when the CO_2 of a fish is determined following its initial recovery from hypoxia, some species show a marked increase which is usually taken to indicate the paying off of an oxygen debt.

The foregoing has been a brief outline of aspects of stress of interest with regard to cod on-growing. The stresses associated with various stages of the on-growing process are now detailed and briefly discussed.

Stress for the "farm" cod begins with the initial discovery, on its exploration of the cod trap in which it finds itself trapped, that movement is confined and the population density is higher than normal. This stress may last several days, depending on weather conditions for hauling of the trap. The precipitous ascent when the trap is hauled causes net abrasions (possibly inflicting direct physical trauma by "meshing"), crowds the fish closely, exposes them to high light intensities and temperatures and, as well causes distress through the distension of the swimbladder. The crowding is not only directly stressful, it also offers the opportunity for the transfer of parasites and pathogens between individuals. Since much of the trap catch is obtained during the capelin "glut", the fish are in a heavily loaded digestive state. Considerable regurgitation is induced by the hauling and subsequent brailer transfer from the trap to the transport tank aboard the boat. During transport, the fish may experience low O_2 levels as well as elevated CO_2 levels. If cooling is used, there will be an additional thermal shock as a result of transferring the fish from relatively warm surface water to the cooled tank. Some cooling is beneficial, but the temperature in the ongrowing cages should determine the degree of transport cooling. An attempt should be made to let the temperature in the transport tank gradually rise until it roughly matches the temperature in the cages to which the transfer is to take place. This temperature ranged as high as 15^{0}C this past summer - quite stressful to fish taken from traps at 6 - 7^{0}C. There is crowding and noise stress associated with both boat and truck transport as well as elevated ammonia levels from the products of regurgitation and defecation as well as "Schreckstoffe" (fright inducing substances) in the transport water.

Stress also results from restricted movement and moderate crowding occurring in the ongrowing cages. Dominance heirarchies, largely based on size differences, will cause stunting in smaller individuals. These may also fall prey to the larger fish, even if they do succeed in obtaining adequate feed. If a single, natural feed such as capelin is used, the fish may develop nutritional deficiencies even if they are feeding well. The nets surrounding the captive populations are subject to fouling, restricting water circulation and causing a deterioration in water quality. This mat of fouling organisms, consisting of such diverse organisms as algae, amphipods, bivalves and gastropods as well as a thriving bacterial flora and a variety of parasites searching for potential hosts. There was a population of benthic scavengers (flatfish, sculpins, eelpouts, sea urchins, amphipods, Lunatia sp. and juvenile cod) associated with waste feed and the dumping of mortalities from the cages. These organisms include species known to be intermediate hosts and disease reservoirs for a number of organisms known to be pathogenic to cod or parasitic on them. Predators, particularly marine mammals, will have relatively unimpeded access to the cod which will have no refuge. The amount of farm stock consumed by predators will probably be minimal; the stress induced in impounded fish by their presence however should not be underestimated. These predators will provide an additional reservoir of disease, as will other scavengers such as herring gulls. Herring gulls may also cause incidental direct damage to fish while competing for food with them; on the other hand, by removing floating moribund or dead fish they may be providing a useful service.

The excitement induced during feeding is itself a stress. The physiological energy required to support digestion is a burden. While feeding, there is considerable crowding around the feeding site with the concommitent opportunity for parasite and pathogen transfer; there is also direct physical damage as a result of collisions between individuals competing for food. The feed may be a vector for parasite and pathogen transmission, since the fish used may act as either reservoir or intermediate host. The mackerel (chopped) used as part of the feed, as well as frozen parts of other feeds used may directly damage the cod, since it is flung up to four metres before impacting the water. Net changeouts and sorting are the final stressors here identified - both having obvious consequences.

Even in the final processing, stress may still play a role. Stress during the removal from the cages and the subsequent handling of the fish will determine the level of lactic acid in the flesh, and thereby the time to onset and the duration of rigor. In the case of bleeding, secondary responses such as elevated heart rate and blood volume moved may facilitate the operation. A shift in blood pH associated with CO_2 anaesthetic treatment may also positively affect flesh quality.

This ends a brief review of stress implications for cod ongrowing. Its shortness and, therefore, incompleteness are the inevitable consequence of limiting the length of such a discussion. An attempt has been made, hopefully with some measure of success, to give an indication of the complexity of the stress complex as well as some indication of the multiple nature of its impacts, both physiological and economic, on cod ongrowing. As has previously been stated, it should be recognized as an integral part of aquaculture - to be carefully studied and planned for and dealt with more by elimination or minimization rather than by treatment after the fact.

RECOMMENDATIONS

Based on the experiences of the 1987 cod farming project and in consultation with SFP, Cape Pine Fisheries and DFO personnel the following recommendations were arrived at. Their adoption is strongly urged as, collectively, they will provide for minimum mortalities, close to optimum growth (at reduced cost) and rigorous and detailed monitoring of project success while it is in progress:

1. Continued tagging of representative fish. This yields an accurate estimate of growth regardless of farm conditions or losses to mortality or escapement.
2. Selection of only good condition fish from the catches for ongrowing. This should include discarding of *Lernaeocera* infested and any other fish in visibly poor condition during initial sorting. It is unlikely that these fish would survive initial capture stress. Even if they do, they will not be capable of as good growth as uninfested fish.

3. Replacement of the weighing scales used on the boat for initial weighing. A digital reading load cell with a remote readout/control panel will eliminate the safety hazard posed by the analog unit as well as being more easily readable, thereby speeding up the loading process. The use of an accelerometer based, microcomputer controlled, motion control unit would provide accurate weighing.
4. On site (fishing ground) collection cages would provide an opportunity for fish to acclimatize to surface water temperatures as well as letting them evacuate their stomachs. This would considerably reduce transport mortalities and improve the efficiency of collection.
5. Sorting based on size immediately prior to impoundment. Feeding should be rendered more effective (smaller fish no longer being outcompeted for food) by this, and final processing should be facilitated by increased uniformity of fish size in a given slaughter lot. Length and weight measurements, culling of sick fish and counting of individuals placed in the cages would be most easily carried out at this point.
6. Automated feeding should be investigated if 200 M.T. or more of fish are to be ongrown to reduce manpower requirements.
7. An onboard cooling plant for the collection boats would minimize thermal stress in transport during the warmest part of the collection season and would eliminate the need for cooling ice.
8. Provisions should be made for preliminary health assessment and a check of feed quality on site; although the facilities to provide these services exist, the turn-around time on samples is too long and undependable for timely remedial measures to be taken.

9. Cooperation with existing research facilities should continue; at this point the main thrust of cod ongrowing research should be directed at feed optimization.
10. If an intermediate sorting by size is undertaken, an attempt should be made to partition the fish into cage lots which will yield the required amount of fish for one day's slaughter. This will minimize stress effects on the population as a whole.

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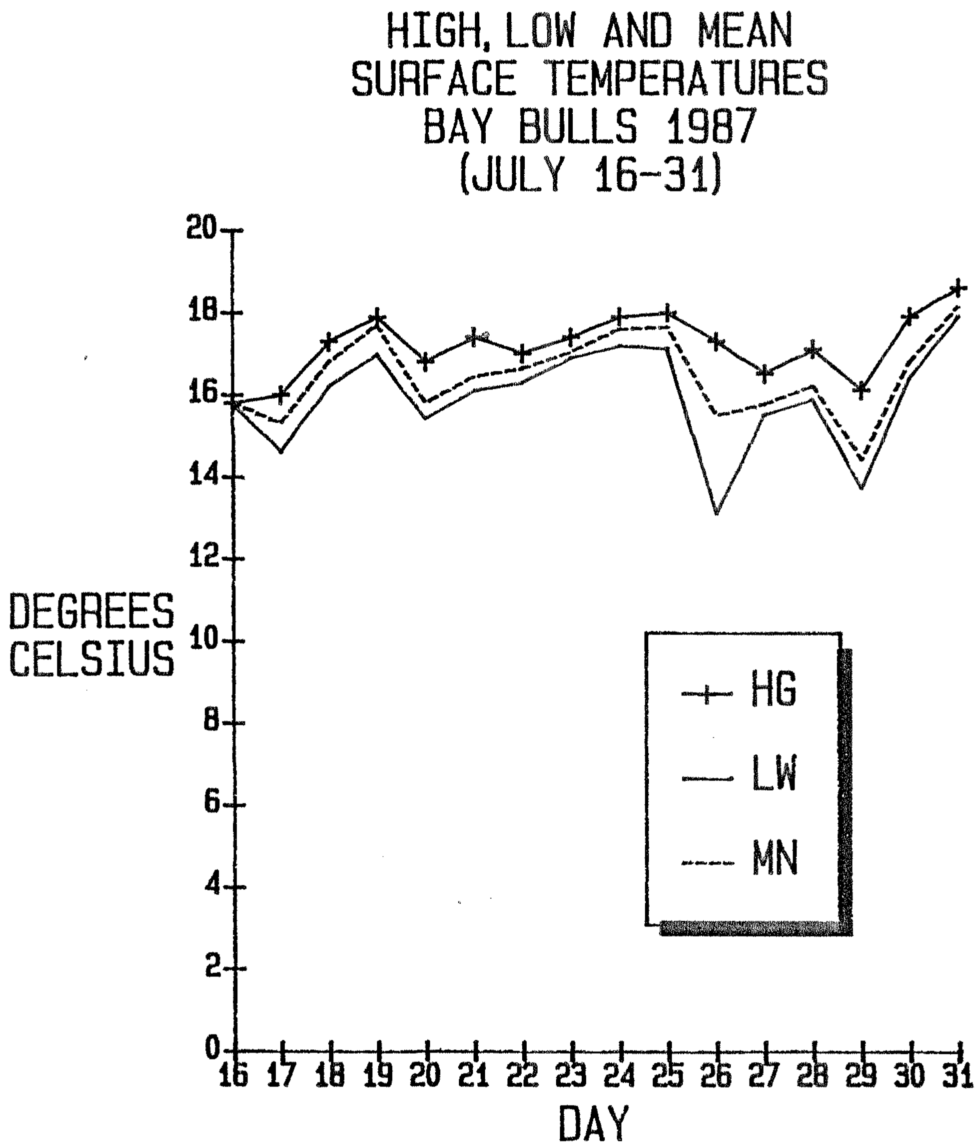
APPENDIX I

TEMPERATURE PROFILES



HIGH, LOW AND MEAN
SURFACE TEMPERATURES
BAY BULLS 1987
(JULY 16-31)
DEGREES CELSIUS
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16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DAY
HG
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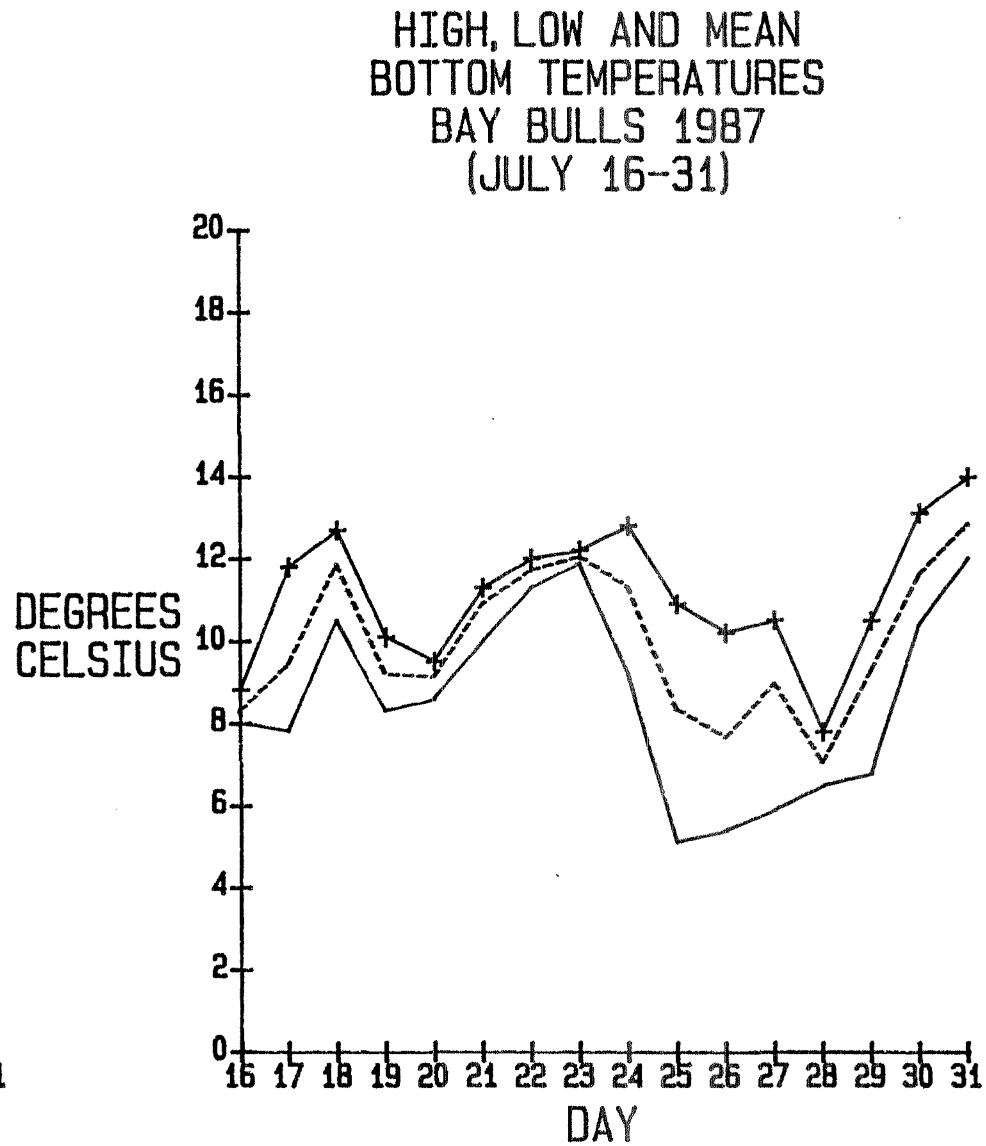

HIGH, LOW AND MEAN
BOTTOM TEMPERATURES
BAY BULLS 1987
(JULY 16-31)
DEGREES CELSIUS
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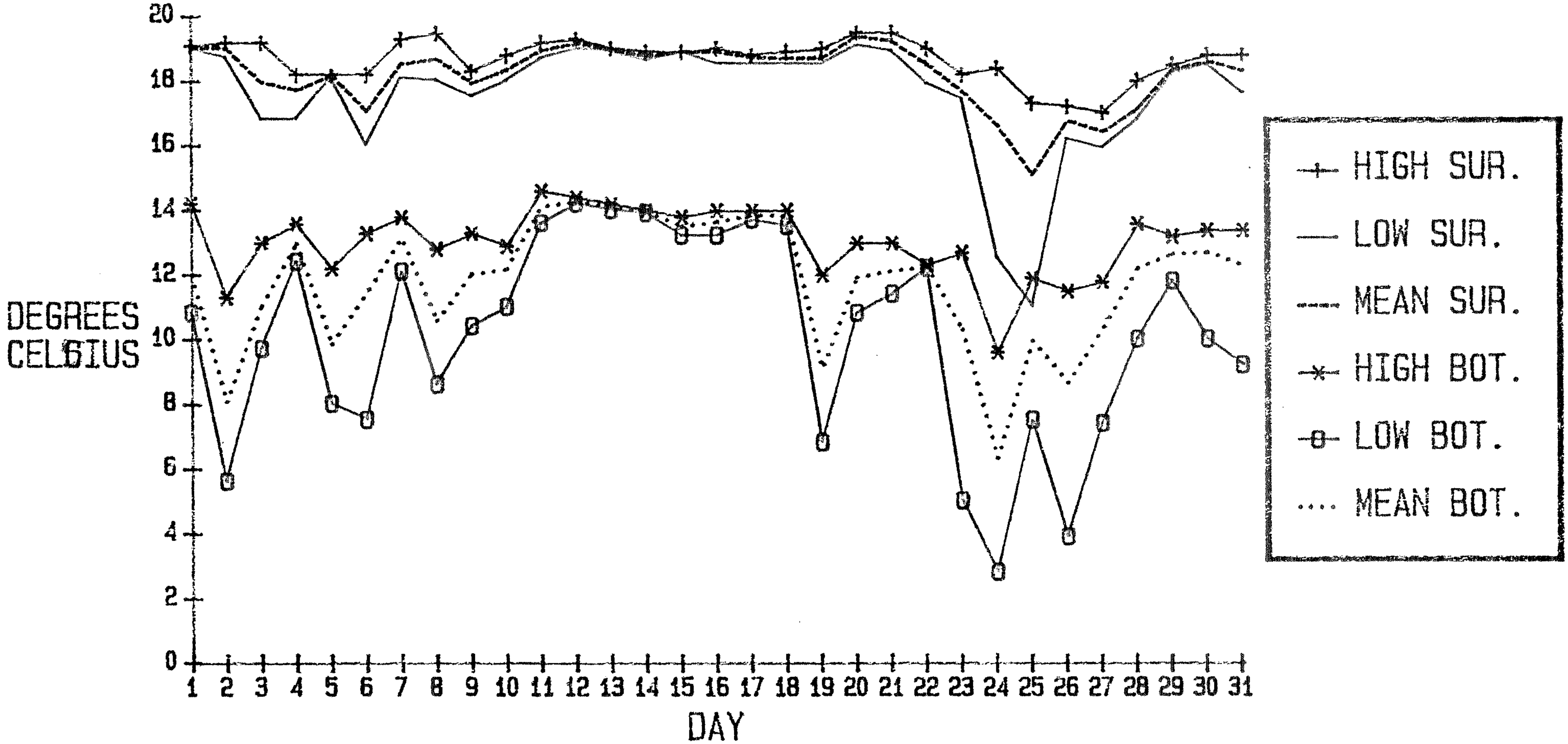
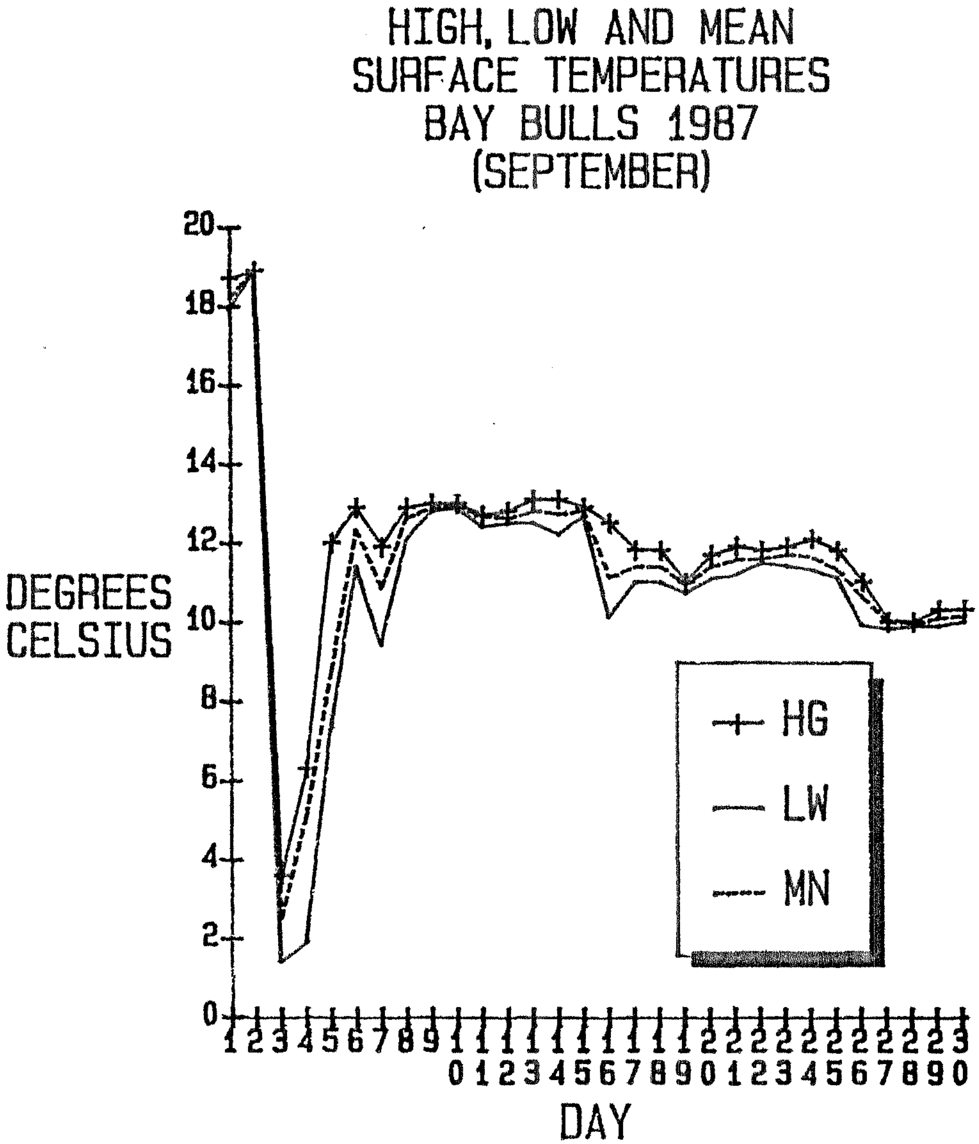
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
DAY

HIGH, LOW AND MEAN
SURFACE AND BOTTOM TEMPERATURES
BAY BULLS 1987
(AUGUST)




HIGH, LOW AND MEAN
SURFACE TEMPERATURES
BAY BULLS 1987
(SEPTEMBER)
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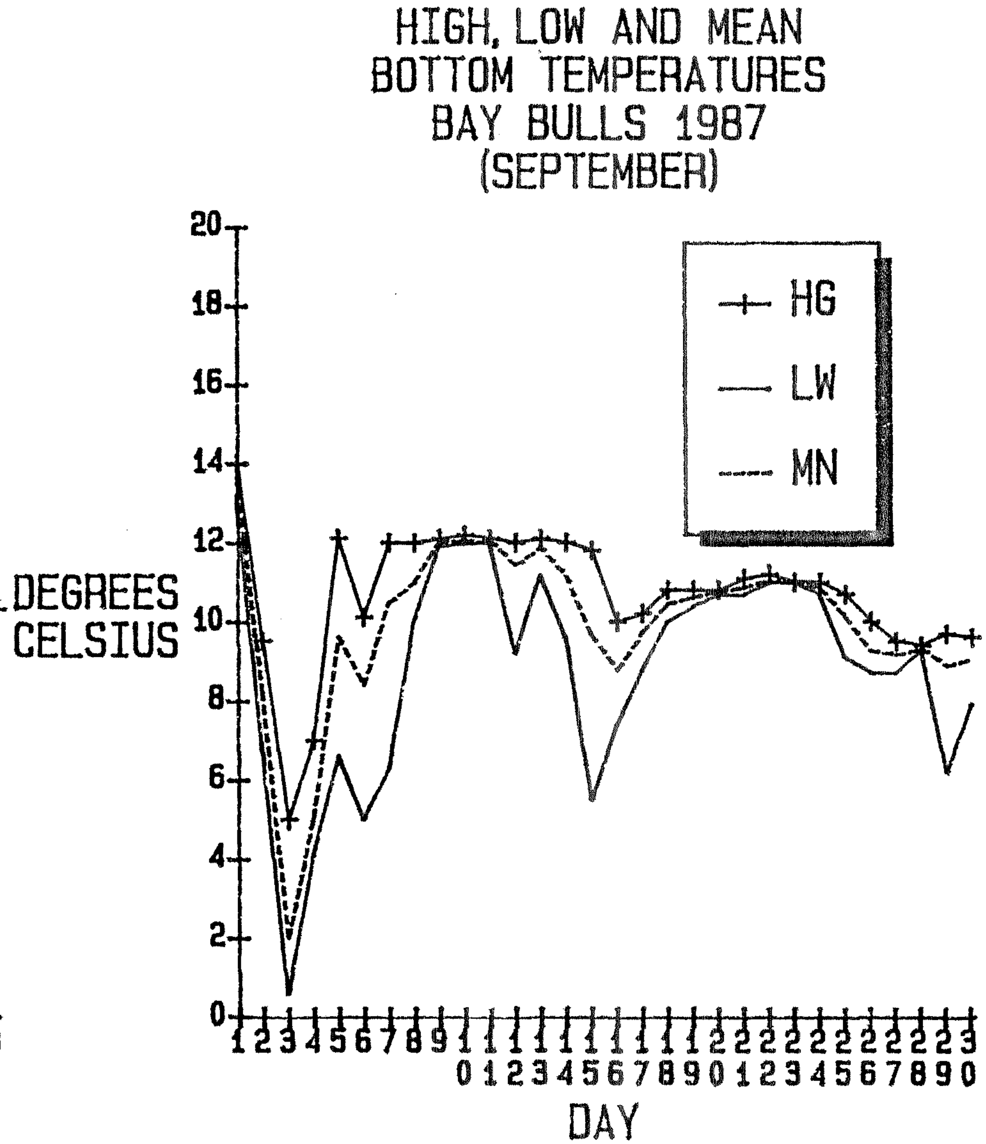
HIGH, LOW AND MEAN
BOTTOM TEMPERATURES
BAY BULLS 1987
(SEPTEMBER)
DEGREES CELSIUS
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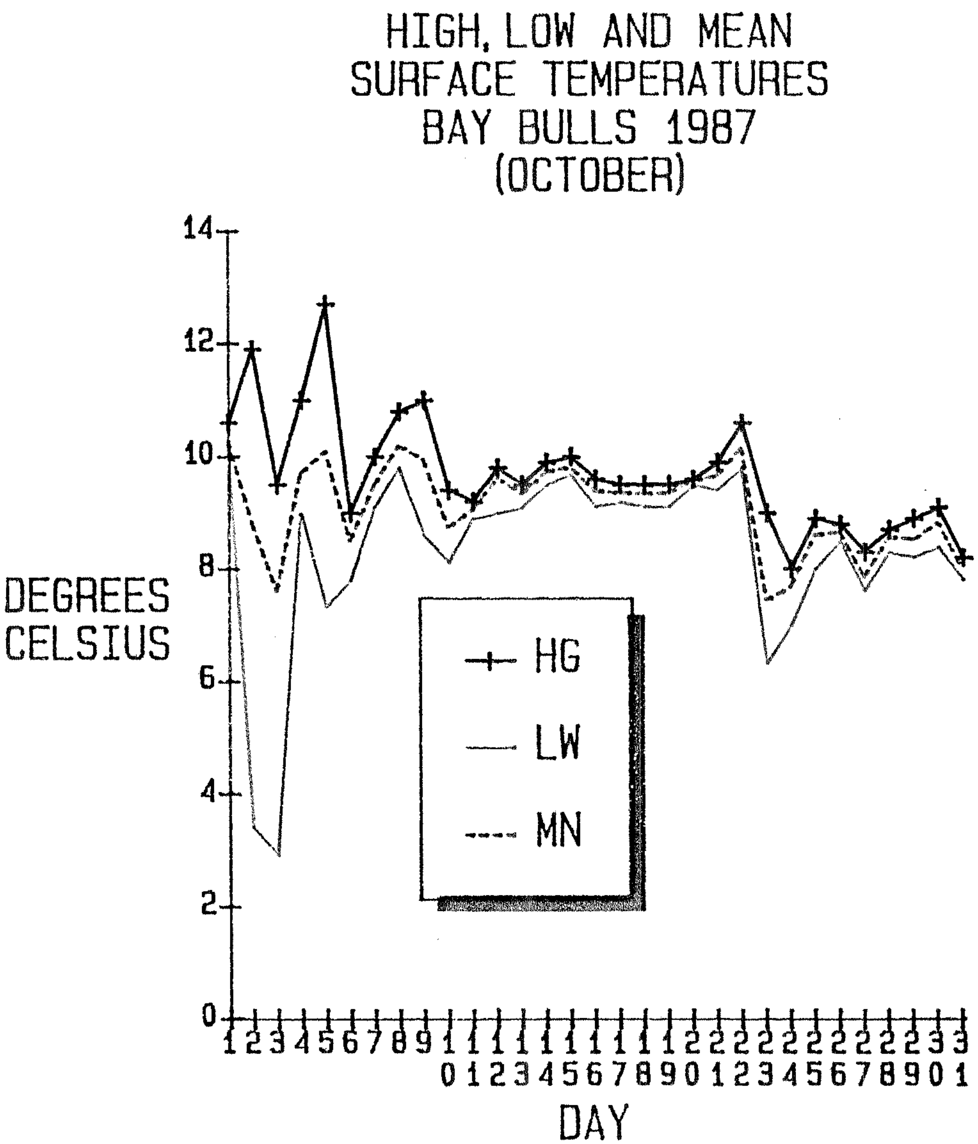

HIGH, LOW AND MEAN
SURFACE TEMPERATURES
BAY BULLS 1987
(OCTOBER)
DEGREES CELSIUS
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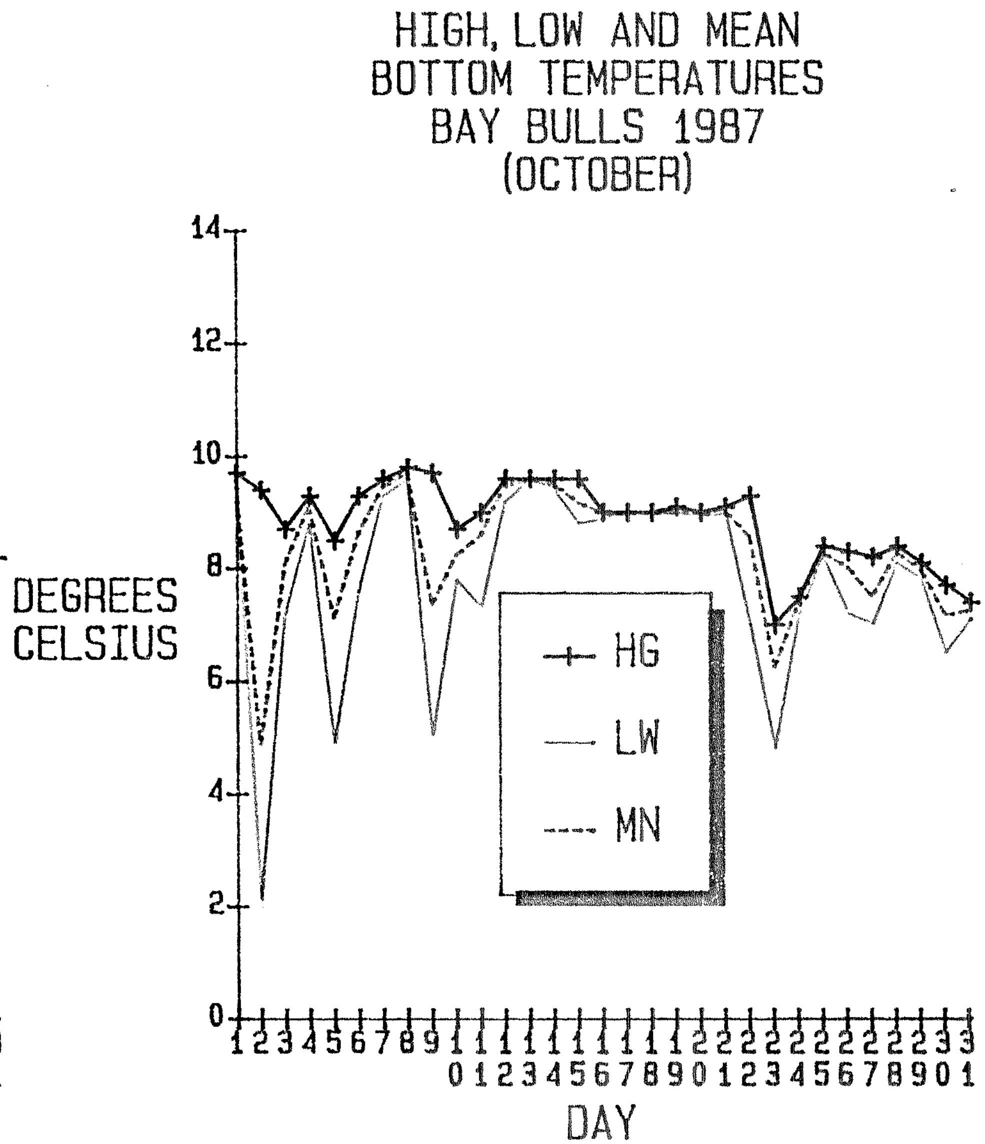

HIGH, LOW AND MEAN
BOTTOM TEMPERATURES
BAY BULLS 1987
(OCTOBER)
DEGREES CELSIUS
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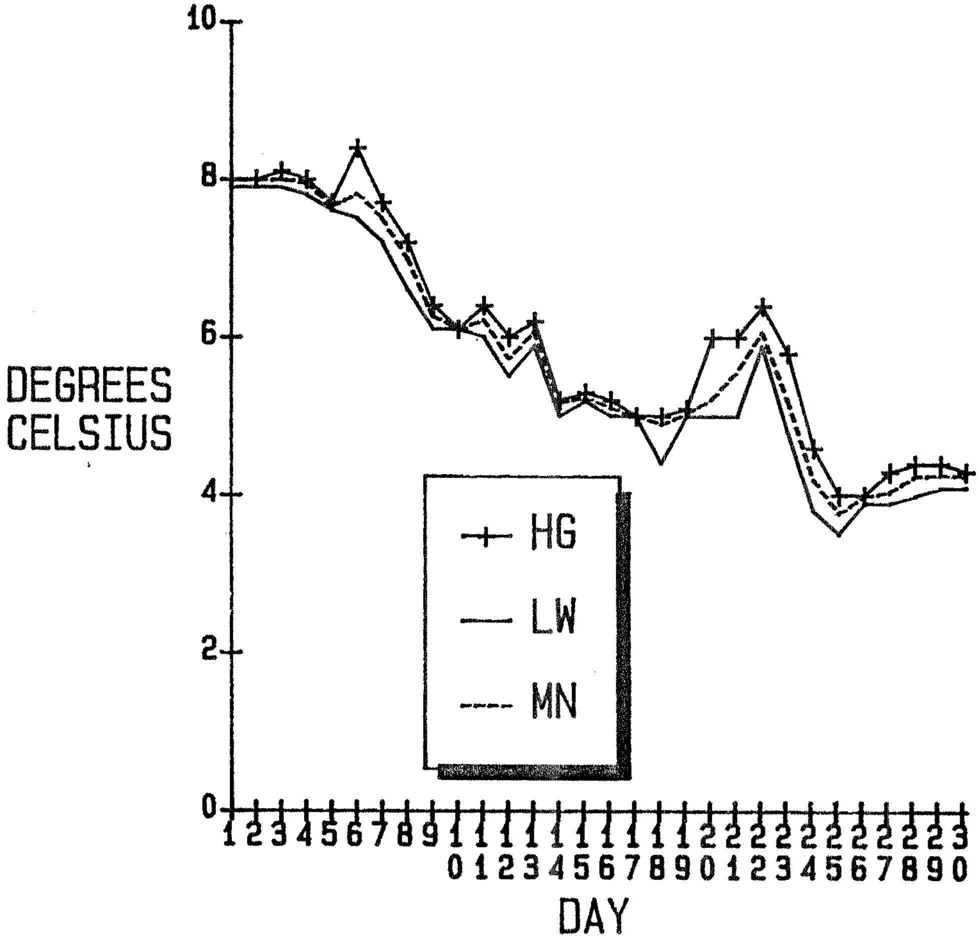
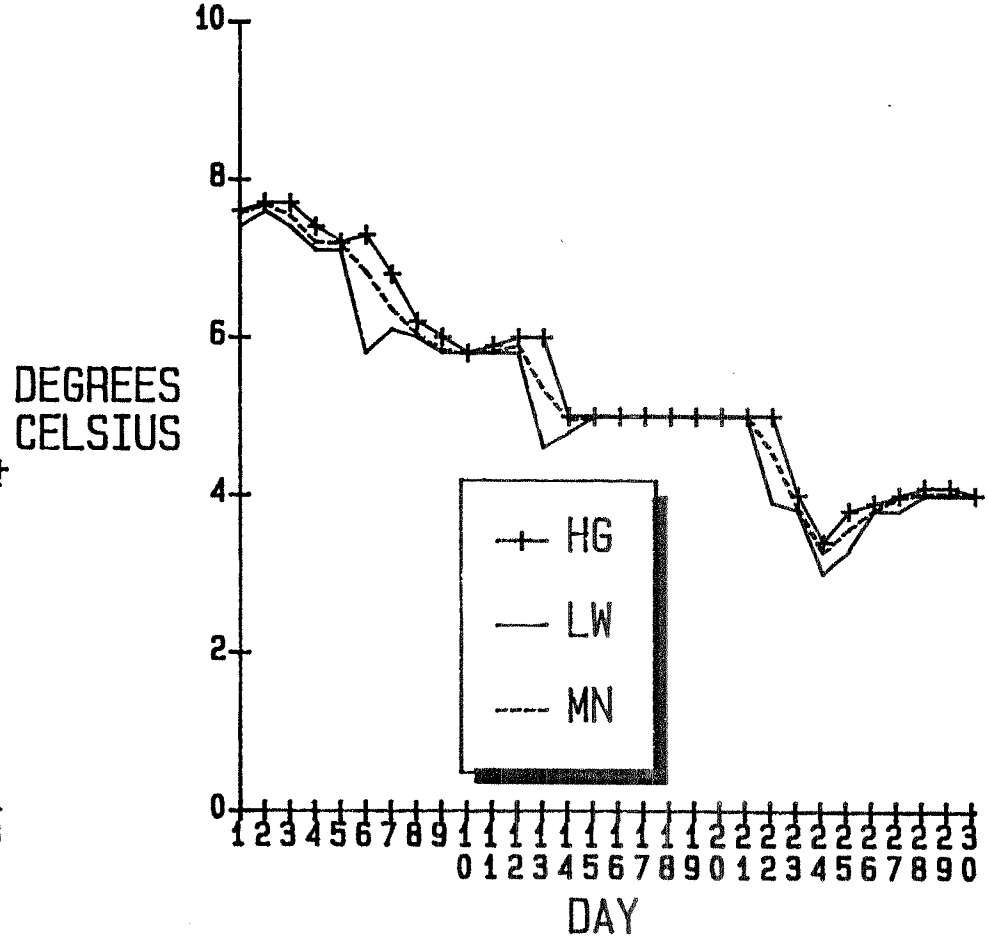
DAY

HIGH, LOW AND MEAN
SURFACE TEMPERATURES
BAY BULLS 1987
(NOVEMBER)



HIGH, LOW AND MEAN
BOTTOM TEMPERATURES
BAY BULLS 1987
(NOVEMBER)



APPENDIX II

FLESH SAMPLE ANALYSIS DATA

DEPT. OF FISHERIES & OCEANS
INSPECTION SERVICES BRANCH
ST. JOHN'S, NF
A1C 5X1

Submitted by: Larry Yetman, Development
Nature of Sample: Cod
Date Received: July 6, 1987
Date Reported: July 27, 1987

		% WET						
Log No.	Moisture	Protein (N X 6.25)	Fat (Bligh-dyer)	Ash	Stomach Wt (g)	Liver Wt (g)	Length (cm)	Fish Wt (g)
AM-51,621	81.0	16.6	0.9	1.2	48.9	150.5	53	1680.5
AM-51,622	81.8	16.4	0.8	1.2	24.9	67.1	40	781.5
AM-51,623	85.2	13.1	1.0	1.0	16.2	50.5	39	585.6
AM-51,624	81.4	15.7	0.8	1.3	34.6	135.0	48.5	1583.3

Regional Chemist
Fish Inspection Laboratory

DEPT. OF FISHERIES & OCEANS
INSPECTION SERVICES BRANCH
ST. JOHN'S, NF
A1C 5X1

Submitted by: Larry Yetman, Development Br., DFO
Nature of Sample: Cod
Date Received: August 18, 1987
Date Reported: September 2, 1987
Log No.: AM-52,341 (12 subs)

Sub/Tag #	Moisture	% Fat (Bligh-dyer)	% Protein (N X 6.25)	% Ash	Length (cm)	Weight (g)	Stomach Wt (g)	Liver Wt (g)
1/ A004589	81.9	0.8	16.1	1.2	48.0	1354.0	31.2	99.0
2/ A004591	80.5	0.7	17.5	1.3	51.0	1835.2	53.9	128.5
3/ A004594	81.7	0.6	16.9	1.2	57.0	2534.6	245.6	117.0
4/ A004598	79.9	0.7	18.2	1.3	53.0	2245.4	108.0	197.3
5/ A004593	83.3	0.5	15.4	1.2	45.0	976.4	54.7	13.0
6/ A004596	81.0	0.6	17.5	1.3	56.0	2085.4	133.2	98.5
7/ A004595	80.3	0.7	17.3	1.3	45.0	1195.1	74.0	77.3
8/ A004587	80.2	0.7	17.9	1.4	41.0	1069.1	18.1	95.6
9/ A004600	81.7	0.7	16.8	1.3	57.0	2359.8	186.8	132.0
10/A004598	81.2	0.7	17.2	1.3	49.0	1519.4	67.9	97.7
11/A004599	81.3	0.7	17.1	1.3	50.0	1617.8	166.9	109.8
12/A004597	82.1	0.7	16.3	1.3	40.0	706.7	73.8	34.9

Regional Chemist
Fish Inspection Laboratory

DEPARTMENT OF FISHERIES AND OCEANS
FISH INSPECTION LABORATORY
P.O. Box 5667
St. John's, NF A1C 5X1

Submitted by: Larry Yetman, Development Br., DFO
Sample: 4 Fresh Cod Fish
Date Received: August 26, 1987 Date Reported: September 15, 1987
Log No.: AM-52,552

Sub	% Moisture	% (NX6.25) Protein	% (Bligh Dyer) Fat	% Ash	(cm) Length	(g) weight	(g) Stomach wt.	(g) Liver wt.
1.	81.1	16.8	0.7	1.2	41	936.2	52.2	67.7
2.	80.2	17.5	0.7	1.3	41	1045.1	100.6	74.1
3.	80.4	17.3	0.7	1.3	47	1215.2	54.8	87.8
4.	80.5	16.8	0.6	1.3	51	2015.8	146.5	215.3

Karen Kennedy
Karen Kennedy
Regional Chemist
Fish Inspection Laboratory

Fisheries and Oceans / Pêches et Océans

FISH INSPECTION LABORATORY
P.O. BOX 5667
ST. JOHN'S, NEWFOUNDLAND
A1C 5X1

SUBMITTED BY: L. Yetman, Fisheries Development Branch, DFO
NATURE OF SAMPLE: Squid
DATE RECEIVED: August 28, 1987 DATE REPORTED: September 28, 1987
LABELLED:

RESULTS OF CHEMICAL ANALYSES

ANALYSIS	SAMPLE LOG NO. AM-52,603			
Moisture	76.7%			
Protein (n x 6.25)	15.4% wet			
Fat (~~Ethyl Ether~~ Bligh-Dyer Extract)	1.6% wet			
Iodine Number (Wij's Method)				
Free Fatty Acid (as Oleic Acid)				
Salt (Cl as NaCl)				
pH				
Ash	1.7% wet			

These analyses refer to samples only and are not necessarily representative of any lot, bulk or shipment. In making enquiries concerning these samples, please quote sample number.

Karen Kennedy
Regional Chemist
Fish Inspection Laboratory

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Canada

Fisheries and Oceans
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FISH INSPECTION LABORATORY
P.O. BOX 5667
ST. JOHN'S, NEWFOUNDLAND
A1C 5X1

SUBMITTED BY: L. Yetman, Fisheries Development Branch, DFo
NATURE OF SAMPLE: Capelin
DATE RECEIVED: August 28, 1987 DATE REPORTED: September 28, 1987
LABELLED:

RESULTS OF CHEMICAL ANALYSES

ANALYSIS	SAMPLE LOG NO. AM-52,604			
Moisture	83.6%			
Protein (n x 6.25)	12.8% wet			
Fat (~~Ethyl Ether~~ Extract) Bligh-Dyer	1.1% wet			
Iodine Number (Wij's Method)				
Free Fatty Acid (as Oleic Acid)				
Salt (Cl as NaCl)				
pH				
Ash	2.8% wet			

These analyses refer to samples only and are not necessarily representative of any lot, bulk or shipment. In making enquiries concerning these samples, please quote sample number.

Karen Kennedy
Regional Chemist
Fish Inspection Laboratory

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Canada

DEPT. OF FISHERIES & OCEANS
INSPECTION SERVICES BRANCH
ST. JOHN'S, NF
A1C 5X1

Submitted by: Larry Yetman, Development Br., DFO
Nature of Sample: 4 Cod
Date Received: September 18, Bay Bulls, Cage #3
Date Reported: January 28, 1988
Log No.: AM-53,07 (4 Subs)

Sub No.	Moisture	% Fat (Bligh-dyer)	% Protein (N X 6.25)	% Ash	Length (cm)	Weight (g)	Stomach Wt (g)	Liver Wt (g)
1	80.4%	0.5%	17.3% wet	1.2%	48cm	1033.1	23.5	65.6g
2	80.1%	0.6%	17.7% wet	1.2%	43cm	907.9	30.8	34.1g
3	80.9%	0.3%	17.0% wet	1.3%	42.5cm	696.6	24.2	26.6g
4	80.9%	0.5%	17.0% wet	1.2%	47.0cm	790.7	14.5	38.3g

Karen Kennedy
Regional Chemist
Fish Inspection Laboratory

DEPT. OF FISHERIES & OCEANS
INSPECTION SERVICES BRANCH
ST. JOHN'S, NF
A1C 5X1

Submitted by: Larry Yetman, Development Br., DFO
Nature of Sample: 4 Cod - Wild Fish taken
Date Received: September 26, 1987
Date Reported: January 28, 1988
Log No.: AM-54,025 (4 Subs)

Sub No.	Moisture	% Fat (Bligh-dyer)	% Protein (N X 6.25)	% Ash	Length (cm)	Weight (g)	Stomach Wt (g)	Liver Wt (g)
1	81.1%	0.6%	17.2%	1.2%	42cm	638.6	25.1	4.0
2	80.8%	0.4%	17.2%	1.2%	53cm	1661.6	48.3	57.3
3	80.7%	0.5%	17.0%	1.2%	51cm	1425.4	22.6	112.0
4	80.7%	0.6%	17.1%	1.3%	37cm	460.5	9.0	14.8

Karen Kennedy

Regional Chemist
Fish Inspection Laboratory

DEPT. OF FISHERIES & OCEANS
INSPECTION SERVICES BRANCH
ST. JOHN'S, NF
A1C 5X1

Submitted by: Larry Yetman, Development Br., DFO
Nature of Sample: 2 Mackerel
Date Received: October 9, 1987
Date Reported: January 28, 1988
Log No.: AM-54,026 (2 Subs)

Sub No.	Moisture	% Fat (Bligh-dyer)	% Protein (N X 6.25)	% Ash
1	63.5%	11.9%	17.2%	1.4%
2	63.9%	13.0%	17.0%	1.7%

Karen Kennedy
Regional Chemist
Fish Inspection Laboratory

DEPT. OF FISHERIES & OCEANS
INSPECTION SERVICES BRANCH
ST. JOHN'S, NF
A1C 5X1

Submitted by: Larry Yetman, Development Br., DFO
Nature of Sample: Round Cod Fish, Cage #3, Caught Nov. 9/87
Date Received: November 9, 1987
Date Reported: February 16, 1988
Log No.: AN-50-673 (2 subs)

Sub	Moisture	% Fat (Bligh-dyer)	% Protein (N X 6.25)	% Ash	Length (cm)	Weight (g)	Stomach Wt (g)	Liver Wt (g)
1.	82.4	.6%	15.9%	1.2%	41.0	891.8	69.8	40.3
2.	81.7	.6%	16.1%	1.2%	39.0	661.7	15.8	8.2

for Paul D. Whelan
Regional Chemist
Fish Inspection Laboratory

DEPT. OF FISHERIES & OCEANS
INSPECTION SERVICES BRANCH
ST. JOHN'S, NF
A1C 5X1

Submitted by: Larry Yetman, Development Br., DFO
Nature of Sample: Round Cod Fish, Cage #1, Caught Nov. 9/87
Date Received: November 9, 1987
Date Reported: February 16, 1988
Log No.: AN-50-672 (2 subs)

Sub	Moisture	% Fat (Bligh-dyer)	% Protein (N X 6.25)	% Ash	Length (cm)	Weight (g)	Stomach Wt (g)	Liver Wt (g)
1.	81.1	.64	16.8	1.2	40	948.5	52.0	47.1
2.	83.2	.40	15.2	1.1	46	1237	197.4	41.4

for Paul D. Wheeler
Regional Chemist
Fish Inspection Laboratory

DEPT. OF FISHERIES & OCEANS
INSPECTION SERVICES BRANCH
ST. JOHN'S, NF
A1C 5X1

Submitted by: Larry Yetman, Development Br., DFO
Nature of Sample: Cod Fish
Date Received: December 1, 1987
Date Reported: February 16, 1988
Log No.: AN-50-674 (3 subs)

Sub	Moisture	% Fat (Bligh-dyer)	% Protein (N X 6.25)	% Ash	Length (cm)	Weight (g)	Stomach Wt (g)	Liver Wt (g)
1.	80.0%	0.7%	18.1%	1.1%	53.0	2559.8	53.1	324.9
2.	80.5%	0.7%	17.5%	1.2%	50.0	1580.4	21.3	150.5
3.	79.8%	0.7%	18.0%	1.2%	48.0	1495.8	16.9	158.8

for Paul D. Whelan
Regional Chemist
Fish Inspection Laboratory

APPENDIX III

PHOTOGRAPHS

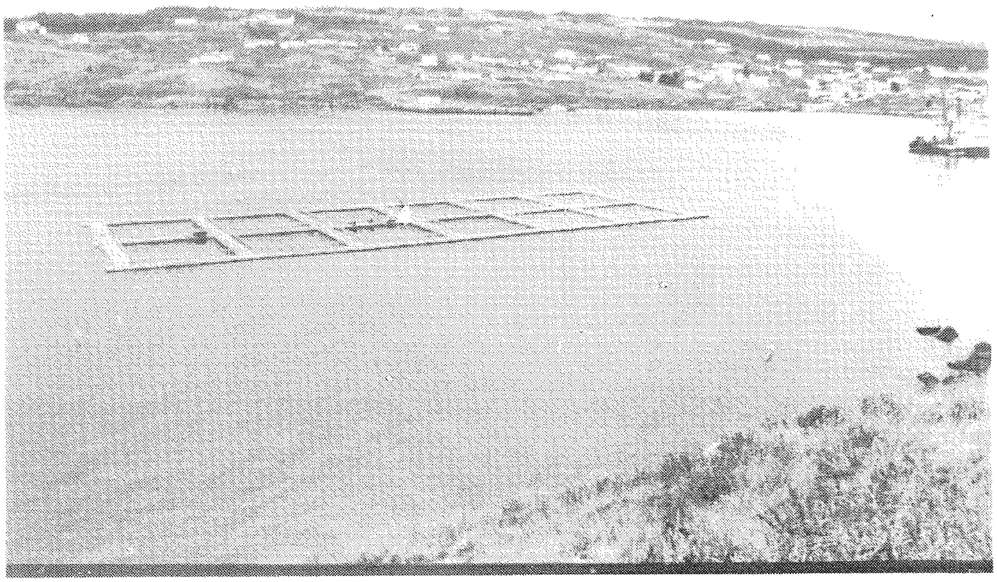


PHOTO 1: The cod farm at Bay Bulls.
8 of the 12 cages were used in 1987.

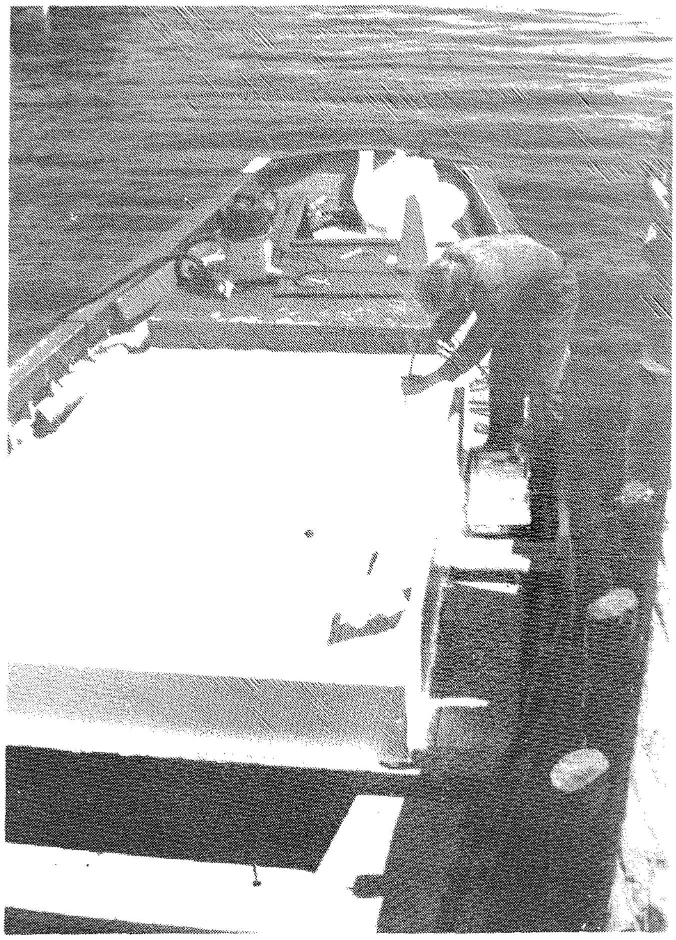
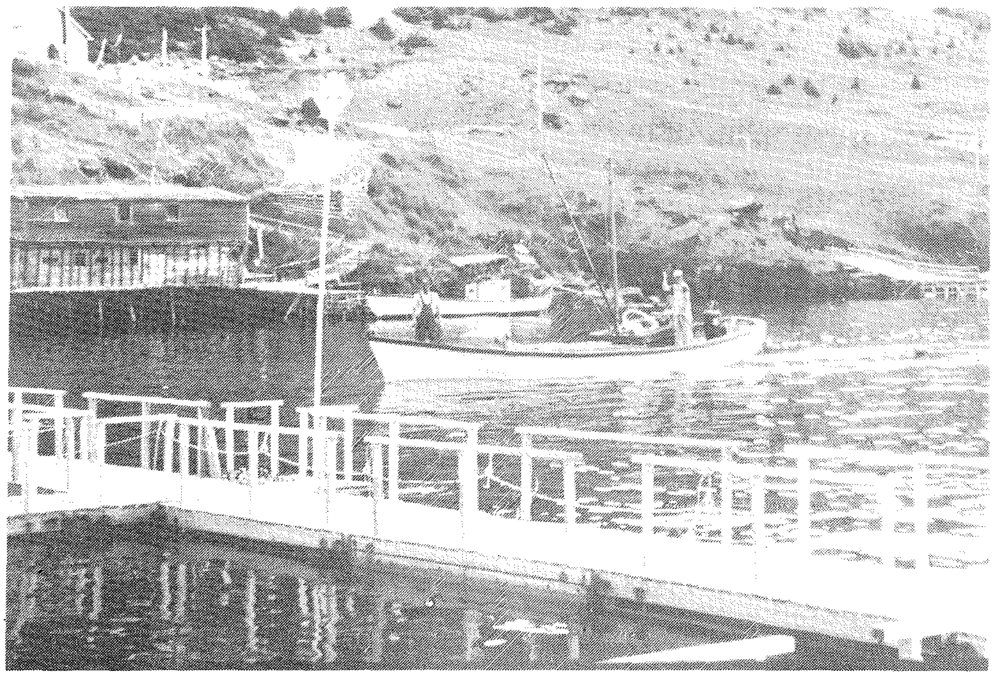


PHOTO 2: This 33' Trap Skiff was modified to transport the live fish.

PHOTO 3: (below) The collector boat returning with live fish.



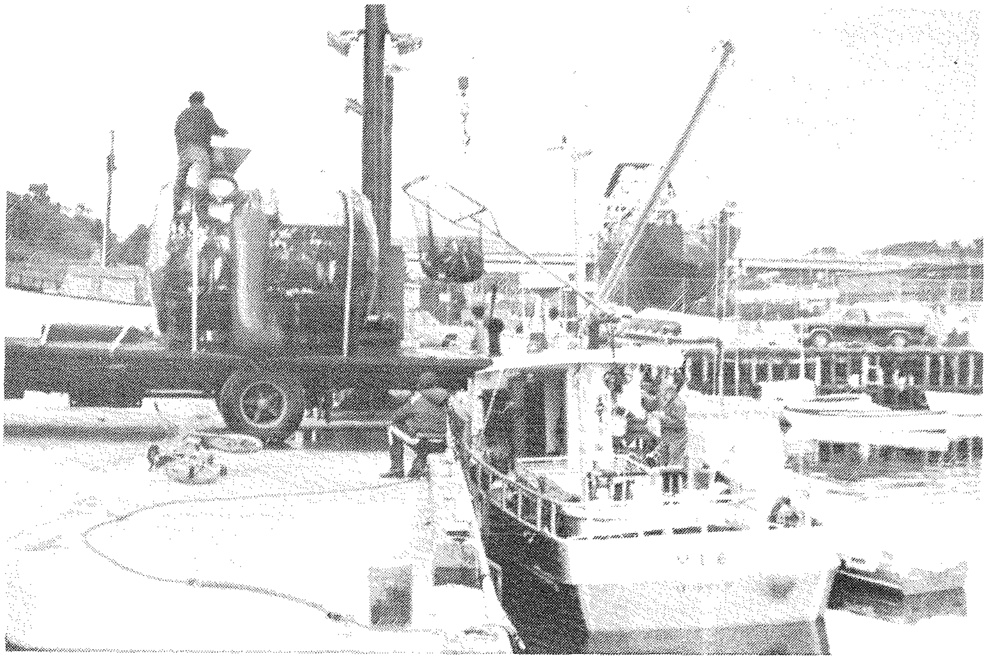


PHOTO 4: The M/V M.I.6 a 45' gillnetter was modified to transport live fish. As shown, the fish are being transferred to a tank for trucking to the farm.

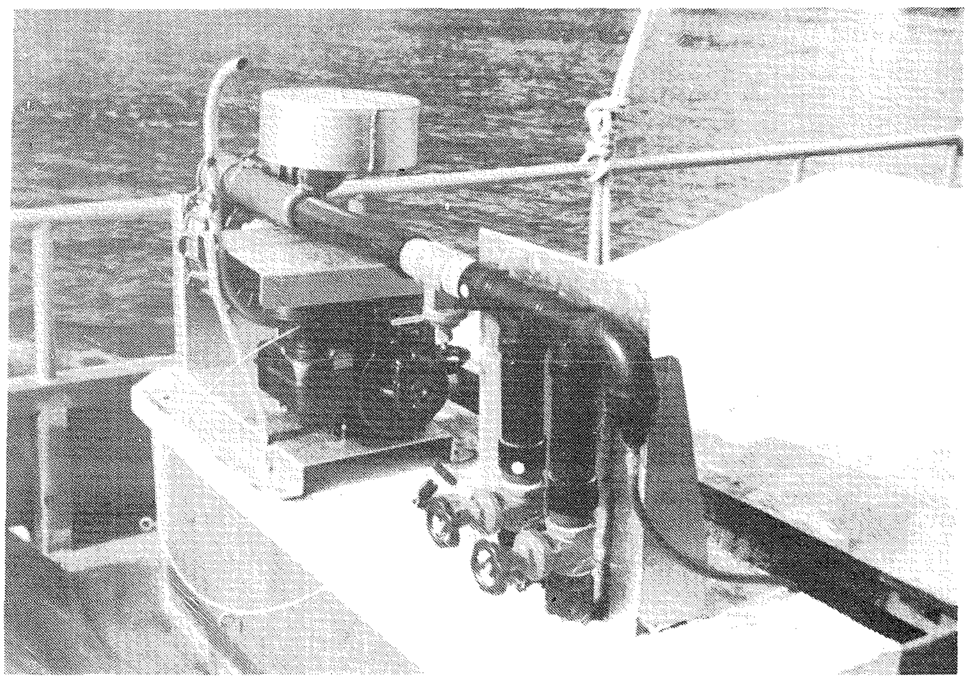


PHOTO 5: These gas powered air pumps used onboard the M/V M.I.6 and the Trap Skiff could not provide sufficient aeration to keep the fish alive.

PHOTO 6: Collector boats must be able to operate alongside the traps when they are being hauled.

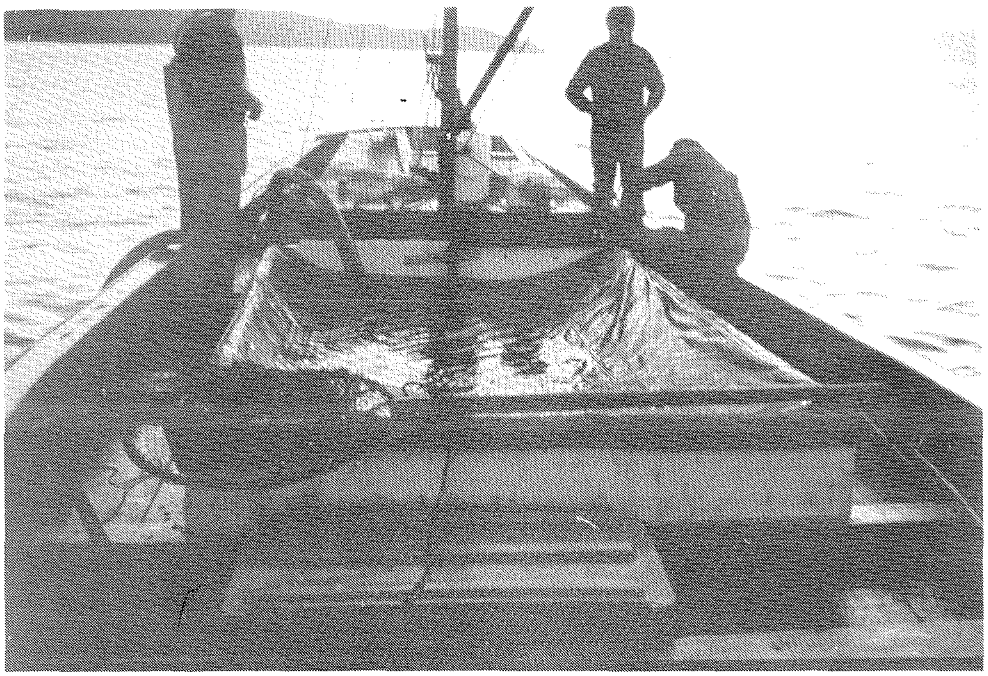
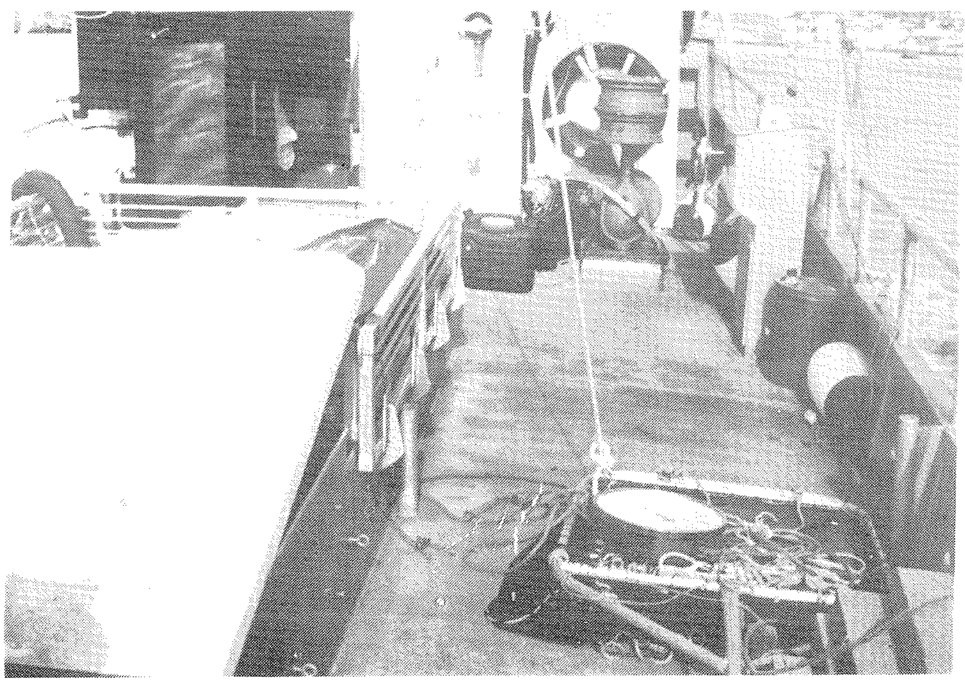


PHOTO 7: The Trap Skiff was well suited for collection of fish wihtin 3 - 4 miles of the farm.

PHOTO 8: Gas powered pumps were used to fill fish holds with sea water.

PHOTO 9: (Below) A weighing balance attached to the fish brailler was used to determine the weight of fish purchased from fishermen.



PHOTOS 10 plus 11:

Insulated fish containers and steel transport tanks were tested during truck transport experiments. Both methods appear feasible.

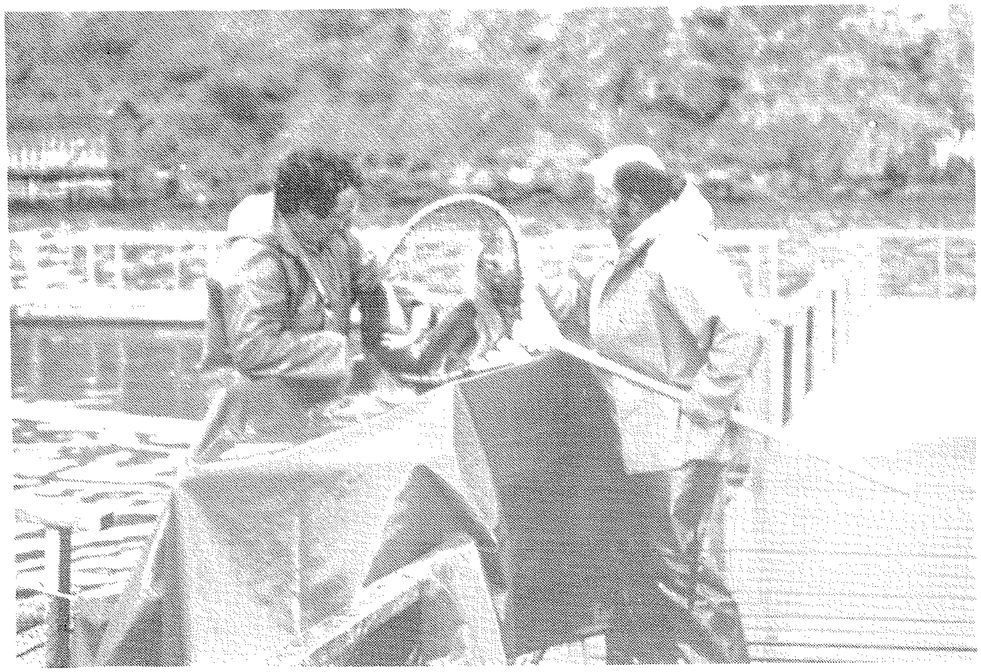


PHOTO 12: Fish should be sorted, counted and weighed into the various pens.

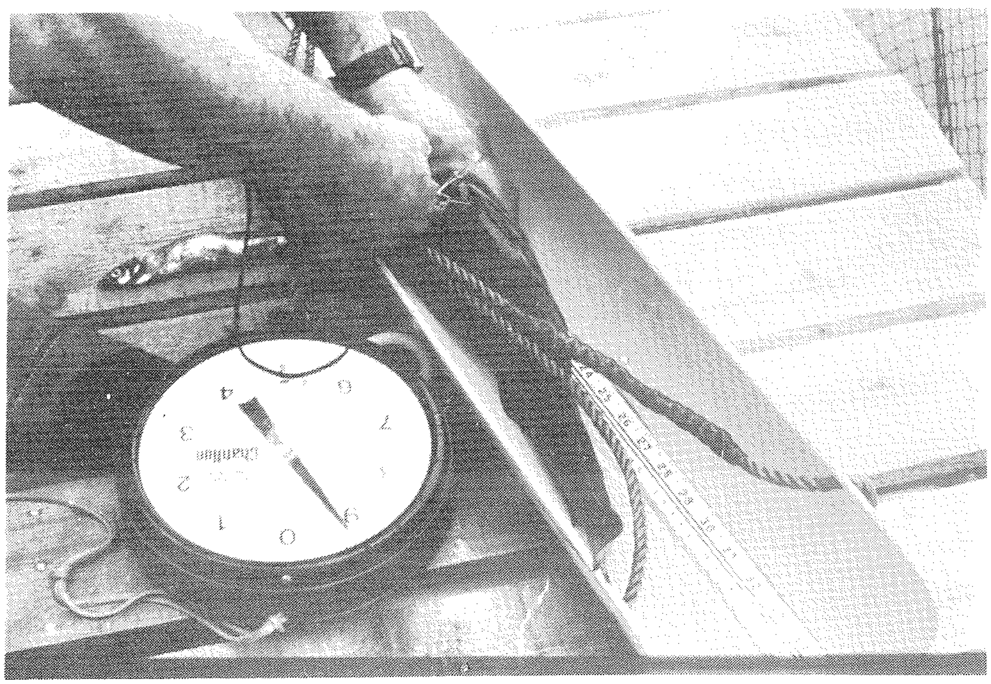


PHOTO 13: A sample of fish were tagged to determine growth rates.

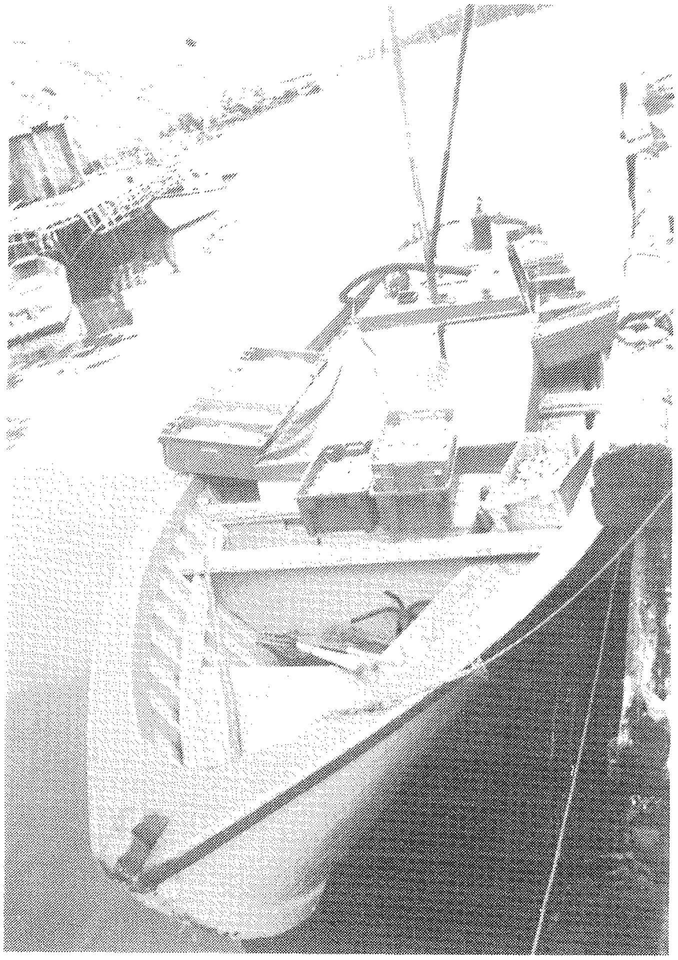
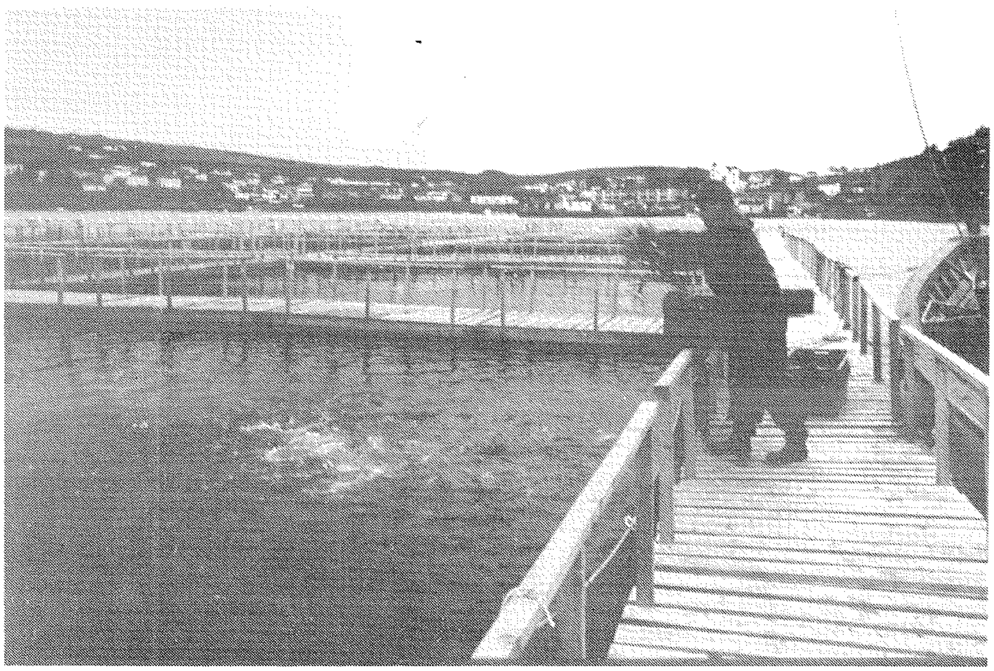


PHOTO 14: Boxes of defrosted capelin ready for the farm.

PHOTO 15: (Below) Feeding the fish by hand.



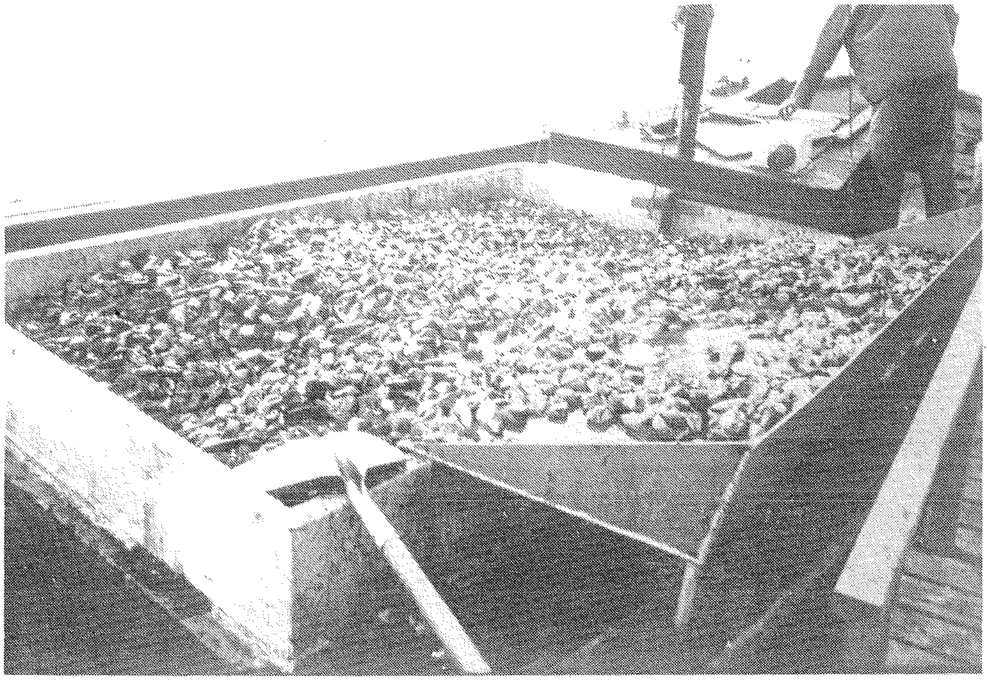


PHOTO 16: Herring and Mackerel were cut into portions and transported in bulk.

PHOTO 17: Broadcasting the feed.

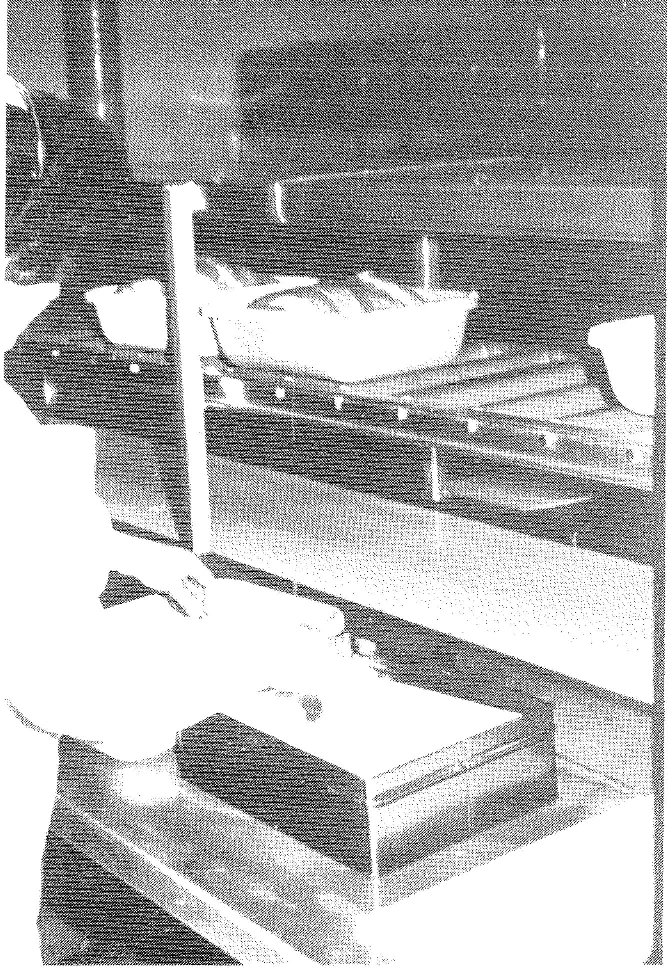


PHOTO 18: The fillet product was sold fresh on the U.S. market.