The Journal of the Shimonoseki University of Fisheries 27 (1) 1 — 88 (1978)

Catch Pattern of Sablefish along Setline in the Gulf of Alaska - I.*

Frequency Distribution and Outline of Bathymetric Change of Catch by a Skate

By

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The groundfish fishery in the Bering Sea and its adjacent waters developed rather recently, of course Japan is the most experienced country in these areas, but has been one of the most important fisheries in Japan, and its landing occupied about a quarter of Japanese total catch in 1975. This fishery was conducted by the four types of boats —— the factory ships with catcher bull-trawlers and Danish seiners, the stern ramp factory trawlers, the stern ramp freezing trawlers and the freezing Danish seiners, and the setliners. It is a well-known fact that the groundfishes show a well defined bathymetric difference in the relative abundance[1),2)]. Among the commercially important fishes for Japanese fleets, the Alaska pollack (*Theragra chalcogramma*) occupies the shallowest zone. The boats of the former two types aim at this species and process it into the minced product, and a part of freezing Danish seiners also attacks this species but the catch is processed in the factory on their home ports. The catchers of the fleets of the first type fish in the 50-150m zone because of the legal restriction of the deepest limit of fishing, while the boats of the second type from 200 m to about 600 m deep. Those of the third type also fish in the same depth zones. And the catch pattern of this species in relation to the work pattern of the boats of the first type and the daily rhythmic change of catch pattern in relation to the work pattern of the boats of the second type were examined in the previous series of reports[3—37)]. The major objectives in the deeper zone than that occupied mainly by the Alaska pollack are the Pacific ocean perch (*Sebastes alutus*) and the halibut (*Hippoglossus stenolepis*), although the fishing for the latter species was prohibited in the area east of 175°W till the claim to 200 mile limit and in all the areas after claim. They are (or were) fished by the stern ramp trawlers, Dasnish seiners, and the setliners. The sablefish (*Anoplopoma fimbria*) is the species occupying the deepest zone among the exploitable and marketable fishes with the today's level of techniques and on the today's socio-economic backgrounds of Japanese groundfish fisheries. This species was caught mainly by the setliners

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* Contribution from the Shimonoseki University of Fisheries No. 830. Received July 31, 1978.

This series of report was prepared on the bases before claim to 200 miles exclusive fishing zone of related nations and therefore does never concern with the status of fishery after the claim.

but partly by the stern ramp freezing trawlers. The applicable grounds (or the highly profitable grounds without accident) differ according to the fishing method. The recent advance in fishing techniques makes respective fishing methods applicable to deeper and rougher grounds year after year. However, there still exists the following order of the fishing methods in respect of the difficulty in the applicable conditions including the depth barrier : the stern ramp trawling is very high in the fishing efficiency but is suitable for adopting in shallow and smooth grounds when compared with the other fishing methods for catching the groundfishes in this area, although this method is superior to the side-trawling in the fishing on rough and/or deep grounds. The setline, which is the longline for groundfish, is a method applicable to the deepest and roughest grounds. The catch pattern of the halibut and other fishes along setline in the 400 m zone in the western Bering Sea during the season of 1962 was examined in the preceding series of reports[38—41]. In this series, the catch pattern of sablefish along setline was examined through the records collected from the string misshot to deep zone just after a long shift of a fleet, for the purpose of showing an outline of the distribution pattern of groundfishes over wide depth range[39]. During the same cruise, the records on several strings of setlines exclusively aiming at this species were collected. But they were not analysed in detail because of the following difference between those days and the present days in the economic and technical backgrounds of this fishery : on those days it was hard to expect the present importance of this species in Japanese fishing industry. And at first the boats used in setlining were not the properly constructed ones but were the worn-out Danish seiners or the salmon drift-netters remodeled only in the indispensable points, and the radio navigation aids and the echo-sounders were worn-out ones and were insufficiently repaired. These facts made it hard to estimate quickly and exactly the position of turning points during setting and hard to get continuous echogram during hauling work extending over 12 hours, in spite of the fact that the setline was shot from the boat turning very frequently for laying the line within a narrow depth range on a slope and of high possibility of the line drifted either to deep or to shallow grounds.

In these 10 or 15 years, the groundfish fishery in this area got more importance year after year. And the stable market demand of considerable size for sablefish was established. On the present days, the technical and socio-economic backgrounds of the sablefish setlining have been completely changed into the state incomparable with those of the preceding cruise. So-called 499-ton class fully equipped boats of special construction for this fishery were engaged in this fishery throughout the year. These facts raised the necessity of studying the catch pattern of sablefish along a setline. It has became possible to collect not only the continuous echogram throughout the setting and hauling work but also sufficient data for describing the settled course on the chart exactly. The skipper and crew members have accumulated the sufficient experience on this fishery in this area. And with the assistance of the abundant information offered by them, the data obtained from the 39 strings settled mainly off Baranof Island in the Alexander Archipelago in the Gulf of Alaska were analysed and the results were shown in the present series of reports.

Before entering the subject, the author wishes to express his hearty thanks to the staff of the Fishery Agency of Japanese Government for their kindness of giving him the opportunity of participating in the sablefish setlining cruise along the Aleutian Islands (1973) and the Gulf of Alaska (1974). Thanks are also due to master fishermen and crew of the No. 31 Tsune-maru and the No. 88 Matsuei-maru who assisted very much the author in collecting the records used in the present series of work and in giving him much information based on their rich

experience which is indispensable to the present work.

A brief note on the history of Japanese sablefish setlining

In spite of the fact that the Japanese is a fish eating nation, the sablefish is the species very recently introduced into her fish market, although its presence in coastal waters of her northern parts was reported as early as 1939. In the early 1960's, Japanese fishing industry faced the problem of how to find out a good off-season job for the factory ships of Antarctic whaling fleets and on-season job for the factory ships which lost the license of the mother ship of the salmon drift-netting fleets, in spite of extremely poor information concerning the groundfish in the Bering Sea and its adjacent waters. Insufficient information about the eastern Bering Sea was from the experience of fish meal and frozen fish production before World War II, and that about the western Bering Sea was from the Danish seiners exploring their grounds off the Kamchatka Peninsula and from the crab tangle-netting in the same area or a little northward. Based on these information, some of the factory ships engaged in the fish meal production from yellowfin sole (*Limanda aspera*) in the eastern Bering Sea using Danish seiners and bull-trawlers, and others started the fishing trials for frozen fish in the western Bering Sea mainly using Danish seiners and setliners. In the fleets of the latter type, however, most profitable fish —— halibut —— could be caught mainly in spring and early autumn, being interrupted by a slack of catch from late spring to summer. And whether this fishery could get economic success or not depended on how to find the other objectives capable of sustaining the fleet economically during the slack. Some fleets (mainly those having a large capacity for freezing) aimed at herring in the western Bering Sea with drift-net ; but those with limited capacity for freezing could not do so, and had to seek other roundfish, for, though it was possible to catch abundant herring, its unit price was not high enough to sustain the fleet with small freezing capacity. During halibut setlining, a part of line was drifted into deep grounds and caught an unfamiliar roundfish of black color. One of the fleets carried back a few tons of this fish and sold it at fish market by way of a trial. This was the introduction of the sablefish into Japanese fish market. Within a few months, this trial got a success, showing a high possibility of latent market for this fish capable of being a good objective of the fleets in respect of both the probable amount of market demand and unit price. And within a few seasons, the fleets with insufficient capacity for freezing began to fish this species exclusively with setline either in the summer slack of halibut or throughout the season, and the fishing ground of setlining in the Bering Sea was expanded to the area east of the 175°W. This success stimulated the cod setliners working on the continental slope off the Kurile Islands. And they came to fish in the Bering Sea forming small fleets or along the Aleutian Islands and then to the Gulf of Alaska as individual boats.

The invention of the frozen product of minced Alaska pollack caused a basic change in Japanese groundfish fishery in the Bering Sea and its adjacent waters, and some fleets either for frozen fish or for fish meal were changed into aiming at Alaska pollack for this purpose either in the factory ship type or rebuilt into factory trawler. But other fleets were rebuilt into stern ramp trawlers and are working for catching Pacific ocean perch. They sometimes aim at the sablefish, causing trouble with setliners. In consequence, the setliners were driven away into the area difficult to trawl, for example on steep slope, very rough grounds, or deep ones.

On the present days, 22 Japanese boats of special construction are engaging in the sablefish set-lining in the narrow and interrupted belt along the outer edge of the Aleutian Islands, Alaska Peninsula, and the Gulf of Alaska.

Fishing method and gear construction

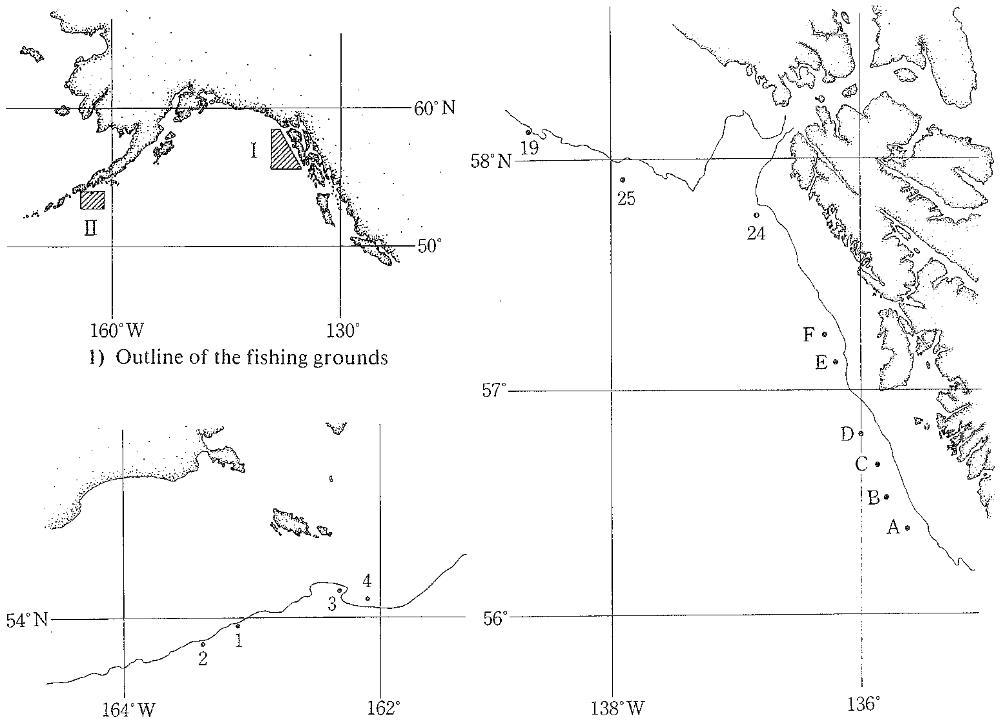
1. Fishing ground

The sablefish setline is the method capable of being the all-year-round job, although some of the setliners engage in herring set-netting (or gill-netting) early in spring. It passed more than 10 years since the expansion of this fishery into the Gulf of Alaska. The master fishermen are familiar not only with the bottom topography of respective favorable spots for fishing but also with the seasonal and geographical bathymetric migration of the objective fish. Generally speaking, the fishing grounds are in a narrow belt between the 500-m isobath and the 1000-m one extending from south of Adak Island in the Aleutian Islands to near Vancouver Island. Actually the favorable grounds are, however, rather restricted, because some areas within this belt are too steep or too rough to fish without fastening the gear with bottom objects, some other areas are too smooth to fish without trouble against trawlers, and the favorable depth zones in the other areas are included in the 12-mile range from the U.S. or Canadian coast and are unable to fish with Japanese boats. It is natural that the relative abundance of sablefish within the fishable zone differs spot to spot depending mainly on the bottom character and local topography.

The line is set along a zigzag course, but a string extends over about 10 miles in the Aleutian area and about 5 miles in the Gulf of Alaska, and the spots narrower than this are practically of low value. According to the recognition common to the master fishermen, once a spot is fished, it is necessary to wait for the accumulation of the slowly migrating fish without fishing at least for five days, for the purpose of yielding a good catch through the consecutive shootings. Accordingly, the ground wide enough to shoot more than five strings without overlapping is desirable.

The master fishermen, consequently the boats, could be classified into the two types according to their preference to the fishing grounds : one prefers to fish along the Aleutian Islands, and the other along the Gulf of Alaska, although few master fishermen incline to fish covering both the areas shifting frequently to and fro.

Several days after the departure from the home port, the setliner enters into the radio communication system with the fellow boats, usually twice a day. And the master fisherman chooses the spot to the first shooting, paying attention not only to the difference of catch according to the spots but also to the distribution of the fellow boats and the trawlers and their daily shifts. The setliners sailing to the Gulf of Alaska pass a few days for fishing at several isolated spots favorable to fish near the course to their final destination.



1) Outline of the fishing grounds

2) Off Baranof Island

3) South of Kodiak Island

Fig. 1. Sketch chart of the fishing grounds for sablefish setlining.

I.....enlarged into sub-figure 2) II.....enlarged into sub-figure 3)
Thin line shows the 200 m isobath. Number shows the location of the isolated string.
A—F show the locations of the major fishing spots of the present cruise, and the following strings were settled in respective areas :

A .... Nos. 5, 8, 14, 28, and 35.
B......... Nos. 6, 9, 15, 22, 27, 34, and 36.
C......... Nos. 7, 16, 23, 29, and 37.
D .... Nos. 11, 17, 26, 30, 32, and 38.
E......... Nos. 12, 18, 20, 21, 31, and 39.
F......... Nos. 10, 13, and 33.

2. Gear construction

The setline, i.e. the longline for groundfish, is one of the gears of the simplest construction covering very wide range, and a string consists of about 400 skates (unit sections) of main lines of equal construction connected in a series with several markers attached at intervals, although the number of skates in a string differs according to the capacity of the boat to process the catch (on the days of good catch just after exploitation into new grounds of rich population) or according to the capacity of the boat to haul up the gear (on the present days of poor catch). Accordingly, the catch along this is one of the best materials of examining the distribution pattern of groundfish, because no differentiation of the structure and function can be found within a string.

The setline consists of the main line, the hook droppers, the markers, the marker lines, and the sinkers. A skate of main line is about 72 m long, constructed of the 43g 4-strand s-twisted twine woven with mixture of the long fibers of vinylon, polyethylene, and polyvinyl alcohol (a coil of raw materials is 200 m long. This is cut into three pieces ; in consequence, the main line of a skate is 75 m long, but both ends are eyed for quick connection with each other into a string. And the actual length in a string was 72 m on the average). From 35 to 45 hook droppers (or gangions) are attached to a skate, the number depending on the master fishermen's preference. The dropper is constructed of No. 18 × 45 plain laid cremona (polyvinyl alcohol) cut into the piece of about 1 m long, although its length varies also according to the master fishermen's preference. The other reason of making the large variation of the length of dropper of the used (or using) skate is as follows : the droppers twisted around the main line after being hauled up have to pass the gurdy receiving high shealing stress with the steel disc idler and center wheel, or are rubbed strongly with the bottom objects during hauling. And the droppers especially at the parts of knots around the main line or around the front of hook are seriously damaged. And it is necessary to cut off the damaged part and tie again. Accordingly, the actual length of the droppers varies dropper by dropper within a skate. The cod hook No.18 (long shanked round hook of about 6 cm long with barb and plated front) is common in use. Sliced pieces of frozen squids are used in common as the bait.

The markers are attached at every 70 to 80 skates, depending also on the master fishermen's preference. The string is shot along a zigzag course, accordingly, the marker does not play the role of marker in the exact meaning, but is for hauling up the main line from intermediate point, when the main line is cut off during hauling or fastened with bottom object and unable to be hauled up. The marker and buoy system supporting the marker line vary according to the case. A 30 × 40 cm red flag attached at a 3-m bamboo pole is used in common as the marker. Radio buoy is added both ends of the string and at intervals. The marker in the parts expected to be hauled up at night is substituted by the flash lamp. Three to five plastic baloons (Bakelittfabrikkenais) of 30 to 50 cm in diameter are connected in a series and used as the buoy system, and the number of the baloons depends on the arrangement of marker system. The marker line is constructed of a 50 g 4-strand s-twisted twine woven with the same materials as the main line, and is usually about 1.5times of the depth of water, adjusting the number of coils connected in a line (a coil being 200 m long).

A bag containing about 15 kg of natural stones is attached at every junction of marker line with the main line. The ends of a string are anchored with large stone bag or with the long shanked grapnel. In addition to these weights, cement block of 4 kg or iron block of 4.5 kg is used every junction of the main line.

A boat is equipped with two hydraulic gurdies of the same model (usually, NT type .... diameter of the hauling drum, or center wheel, being about 50 cm ; the shaft of the drum being in the direction of bow-to-stern ; the capacity being 1 ton × 75 m per min.). One is for hauling up the initial marker line and the main line, and the other is mainly for hauling up the intermediate marker line and partly for exchanging the parts to the former when some parts of the former are broken.

3. Fishing work

3.1 Shooting work

In most of the fishing methods in the off-shore except the groundfish trawling, the hour of fishing work depends mainly on the daily rhythmic change of the behavior pattern of the objective fish. And in most of those in the on-shore, it depends mainly on the hour of auction at fish market on the base port and the hours needed to sail back there, and partly on the behavior pattern of the objective fish and on the activities of the other fishing methods working in the same grounds. The sablefish setlining is, however, rather exception in this respect, and the gear is shot regardless of the hour. A little before the arrival of the boat at the intended spot to shoot the gear, the echo-sounder and loran are switched on, for seaking the exact point to start shooting the gear. Usually, the initial marker is shot a little shoreward the initial anchor, and the marker line is paid with sufficient slack from the boat sailing to off-shore at full speed. When most of the initial marker line is paid out, the engine is stopped, and the boat sails using the way. When the boat passes over the isobath of the intended depth, the initial anchor is shot, and the boat sails again at full speed, and the main lines are paid out manually from the working quarter at stern with a slight slack. There are the two types of boats in respect of the general pattern of the course of shooting the line. In one of the types, the string is shot about along the meandering isobath, while in the other type, along the several parallel courses nearly perpendicular to the isobath repeating turnings to nearly the counter direction. In this way of shooting, the echo-sounded depth varies from 500 m to 900 m. In some grounds with ridge or trench, it is inconvenient to shoot the string clear of it, and the string is shot across it, in spite of presumable decline of daily catch due to the drop of efficiency of the parts laid on the bottom of unprofitable depth. In this case, the depth ranges from 200 m to 1100 m, although this is rare. The master fishermen inclined to shoot the line in the former type prefer to fish along the Aleutian Islands and off Kodiak Island. And those inclined to shoot the line along the latter way prefer to fish along the Gulf of Alaska. According to the master fishermen's opinion, this difference is mainly due to their preference but partly due to the presumable simplicity of current in the Aleutian area and the complexity in the Gulf of Alaska. The records of the cruise in 1973 were collected from the boat of the former type and those in 1974 were from the latter one. In spite of the basic difference in the master fishermen's intention, however, the string is shot along a zigzag course in either of the cases, and it was difficult to find any basic difference in the covering depth range. The difference could be found only in the turning angle of shooting course —— either about 45° to 90° in the former type or 135° to 180° in the latter one —— and in the distance between the initial marker and the final one of the string —— about 8 miles to 11 miles in the former type and about 5 miles in the latter one.

The line is shot usually following the current. According to the master fishermen's opinion, this is because of the following two reasons: One is that the current may assist sinking (or settling) of the line, and this is effective to prevent the line from drifted over out of the profitable depth and to prevent the hooks not only from hanging over small grooves but also from being occupied by the fish of low commercial value swimming in the mid-water (for example Alaska pollack). The other reason is for the purpose of preventing the parts shot latter from being settled over the parts shot earlier ; if the accident of this type happens, the hauling work becomes very hard and most of the hooked individuals are slipped off.

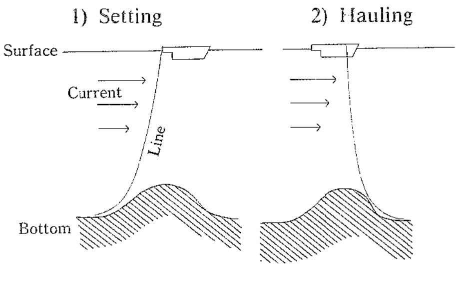


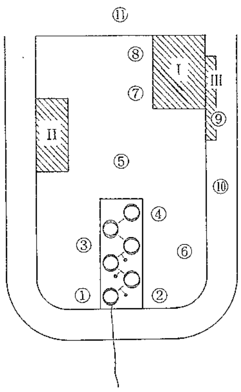
Fig. 2. Preferable direction of current during setting and hauling.

As shown in this figure, the current from the stern during setting assists the sinking of line, and that from the same direction during hauling lessens the load of hauling the line.

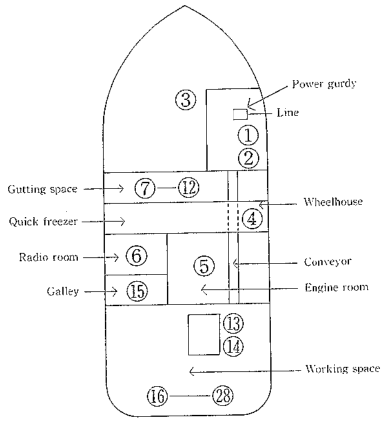
It takes about two hours to shoot a string of setline. The arrangement of the hands on deck during shooting work is shown in Fig. 3 1). Regardless of the way of shooting the line, the master fisherman is exposed to extremely high psychological strain throughout the shooting work, for the day's catch depends on whether the line is settled on the profitable grounds (or within the profitable depth range) or not. And regardless of whether the line is shot successfully or not, the line should be hauled up, and the unsuccessful shooting results not only in the poor catch but also in heavy fastening with bottom objects and needs additional labor to haul it up. Careless handling of the line during shooting sometimes makes some of the skates of line ineffective to fish. A skate of line should be shot at a speed of 3 to 4 skates per minute. When the speed of paying out the main line is too slow, the main line is stretched too tight. This results in the main line hanging over rock to rock, and many hooks can not touch the sea bed. When some parts of main line are shot together, they are tangled with one another ; this results also in loss of the efficiency of the hooks in the tangled parts but also needs much additional labor to haul up the parts. The hanging-over of the other type is due to the shooting miss of marker line. When several hooks are caught with the marker line, the marker line is not stretched and each 10 or more skates shot before and after the marker line are hung and these skates lose their fishing efficiency completely. To prevent the line from the accident of this type, most of the master fishermen add one or two skates of main lines without hook before and after the sinker for marker line.

3.2 Hauling work

After the shooting work, the boat sails back to the initial marker. This is because of the following two reasons : one is to wait the feeding of the objective fish. The other is to haul up the line receiving the current from the stern. This is, according to the master fishermen's opinion, for lessening the load to haul up the main line due to good use of blowing-up by current, as shown in Fig. 2 2). Whether the boat is drifted for a while near the initial marker or not depends on the working system of the hands in relation to the labor contract. According to the labor contract, it is necessary to make the hands taking the rest no less than six hours without interruption. In most of the boats, the shooting work is conducted by a half of the crew members. This group takes rest six consecutive hours without interruption after shooting work. The other group takes rest for the same hours even during shooting work. It takes a half hour or a little longer to clear the hauling work of the preceding string and to prepare the next shooting, two hours to shoot the string, and another half hour or longer to sail back the initial marker. Accordingly, the boat has to be drifted near the initial marker about a little shorter than three hours. The hauling work during the first three hours is conducted only by the latter group. During this step, the work hands are not sufficient to process the catch and



1) Arrangement during shooting the line



2) Arrangement during hauling up the line

Fig. 3. Arrangement of work hands during fishing work.

1) Arrangement during shooting the line

- Men Nos. 1 and 2 .... Pay out the main line alternately skate by skate.
- Man No. 3 .... Ties sinker block to the junction of main lines, and shoves skate along table.
- Man No.4............... Ties head of one skate to tail of another, and shoves skate along table.
- Man No. 5 .... Passes one by one the skates stacked behind.
- Man No. 6 .... Carries and stacks empty skates.
- Men Nos. 7 and 8......... Carry stacked skates behind Man No. 5.
- Men Nos. 9 and 10........ Prepare, tie, and shoot the marker system and marker line.
- Man No. 11 .... Maneuvers the boat.

I........ Place to stack the prepared skates
II .... Stocker for sinker
III....... Stocker for baloon and other marker system

2) Arramgement during hauling up the line

- Man No.1 .... Takes inboard the catch by gaffing it and passing over the roller or tearing off the hook dropper with catch.
- Man No.2 .... Assists Man No. 1, and recaptures the dropped fish with long-shank gaff.
- Man No.3 .... Handles clutch of power gurdy according to hand signals from Man No. 1, unties the main line, and carries it to conveyor.
- Man No.4............... Maneuvers the boat according to hand signals or transiver communication from Man No.1, and commands the hauling work.
- Man No.5 .... Checks engine, freezer system, and power gurdy ; when not occupied, assists distangling and repairing work for used line.
- Man No.6 .... Engages in wireless communication and checks electronic devices ; when not occupied, assists distangling and repairing work for used line.
- Men Nos. 7—12 .... Head down, gut, clearn, and freeze the catch.
- Men Nos.13 and 14 ...... Disfreeze, chop up, and hang baits.
- Man No. 15 .... Cooks ; when not occupied, assists distangling and repairing work for used line.
- Men Nos. 16—28 .... Engage in distangling and repairing work for used line.

rearrange the used line. In a few of the boats, the crew members are divided into three teams, and each team works 16 consecutive hours with the 8-hour phase lag one another. On the boat of this type, there is no need to make her drift, in an attempt to make the crew taking the rest over six consecutive hours. And the boat can continue the fishing work throughout the stay in the fishing grounds always with the two thirds of the crew members without interruption.

The hauling work continues over from 10 to 16 hours, depending on the load of hauling up the line, the amount of catch, and the accident (mainly fastening of the line with bottom objects), especially the last is of most influential. As mentioned in the section of gear construction and shooting work, the markers are attached at very long intervals, in spite of the fact that the main line is shot along a zigzag course. Accordingly, there is no guide on the sea surface telling the presence of the setline underneath. In spite of this fact, it is necessary to haul up the line locating the boat exactly above the part of the line just leaving from sea bed. Otherwise, the line is dragged over the sea bed. This increases the load to haul up the line and results in severe reduction of hauling speed, which causes not only the elongation of the work but also decline of freshness of catch or sometimes severe nibbling of catch by scavengers into complete loss of commercial value. In addition this causes the slip-off of catch and increases the possibility of the main line fastened with the bottom objects. The master fishermen should maneuver the boat, accordingly, with great care, in order to haul up the line vertically. To assist this work, most of the boats are equipped with changeable pitch propeller and wide rudder plate, and some of them have even the bow thruster.

The arrangement of the work hands during hauling work is illustrated in Fig. 3 2). As shown in this figure, the work pattern of the hands during sablefish setlining is very curious : the men engaging directly in the hauling work are only three or four, and most of the labor are spent for rearranging work, because of the following reasons : all the hook droppers on the line once hauled up are heavily twisted around the main line. This is not due to the dislaying (or dis-twisting) of the main line but is due to the following reason : the baited hooks or the hooks with catch are more or less asymmetric. During hauling, they are towed flapping in water over the same distance to the settled depth at the speed equal to the hauling speed. Accordingly, they are easily twisted around the main line. And the most labor consuming step of work is to distwist the hook droppers. Some of the master fishermen prefer to use long droppers, for long dropper has a possibility of settling the baited hook not close to the main line. However, the other master fishermen prefer to use short one, for it takes short time and less labor to distwist the short dropper and that the short dropper has less risk of entangling within itself or with the adjacent one. The labor consuming step next to distwisting is the checking the hook droppers. The droppers twisted around the main line have to pass between the steel disk idler and center wheel receiving high stress. This gives serious damage on the droppers or hooks. The damage is especially serious in the skates settled on rough grounds or in the part fastened with bottom objects and rubbed against their edge. It is necessary to cut off the damaged part and tie the hook or dropper again. Even in the skates hauled up without accident, about the one tenth of the droppers is worn out and is changed with the new ones. And it is necessary to repair the deformed hooks haul by haul, and a hook can be used only three hauls on the average (including the case of exchanging the whole dropper). It is not rare that all the droppers in a skate are cut off or all the hooks are deformed, when the skate is heavily fastened. The main line is shot at high speed, being 3 to 4 skates a minute. For smooth shooting, the main line and droppers should be carefully looped on the skate (flat basket) of ca. 1 m in diameter. It takes about 15 minutes to check and rearrange a skate of main line by a skillful hand. It takes a little more than a minute to haul a skate up. This means that at least 15 hands are needed to conduct this work smooth.

It is said that dirty bait (or slightly deteriorating one) is better than the clean one. The room temperature is low, for the fishing ground is in high latitudinal waters. These facts make it possible to bait the hook just after rearranging work. The next shooting begins a little after the finish of the hauling work ; in consequence, the hour starting the shooting work differs according to the string.

The records used in the present series of reports

The records used in the present series of reports were collected from the earlier half of the third trip of the No.88 Matsuei-maru (499 gross tons ; launched in 1973) in July to August of 1974. Among the records of the 39 strings, those of the four strings were in the waters south of Kodiak Island (around the Albatross Bank) during the trip to the Gulf of Alaska, and those of the 35 strings were mainly in the five spots off Baranof Island in the Gulf of Alaska, as shown in Fig. 1.

Each string consisted of about 400 skates of main line with the markers at 80-skate intervals. Each skate has 35 hook droppers. The records for respective strings comprised of the following items : the position of the initial and the final markers, the shooting course, the echograms during shooting and hauling, and the catch of respective species by respective skates. The position of shooting the anchor either for the initial or for the final marker was fixed with loran and radar, for in this area the shore line is steep and the sets of the lines of position fixing through loran cross at very acute angle one another nearly perpendicular to the shore line, which means that the position fixing only with loran is easy to cause the error in the direction perpendicular to the coast and the assistance of radar is needed to estimate the distance from coast.

During setting, the boat is maneuvered with gyro-autopilot. The line is set along a zigzag course, repeating turnings to nearly the counter direction about at 40 skates. During this work, the following items were recorded : the times shooting respective marker anchors and the time and direction of ship's head at start and finish of respective turnings. These records were used to draw a rough chart for the purpose of assisting to get a general idea of the settled course of main line in relation to the bottom topography around it. The boat is equipped with two echo-sounders : better one is used by the master fisherman during shooting, and the other is for collecting the echograms used in the present study. The master fisherman is familiar with the bottom topography of all the profitable spots in this area, and he uses the echo-sounded depth during setting as the most powerful (or an exclusive) indicator to choose the course (or depth zone) of setting the line, although it is natural that the probable current drift and the results of preceding shootings are taken into account. The echo-sounder used in the present study (manufactured by Koden Electronics, SRM-873 Z-15K) have two transducers ; one being 200 KHz (Type TDT) and the other being 28 KHz (Type F). The former is with narrow beam and used in the zone shallower than 600 m. The latter is with wide beam and powerful and used in the zone deeper than this depth, for it is desirable to use the echo-sounder of narrow beam to get the echogram showing exactly the bottom topography but this is insufficiently powerful to get the echogram from deep grounds. The echo-sounder was switched on throughout the setting and hauling works.

During hauling work, the number of skates between the adjacent markers was counted, and the catch of respective species by respective skates were recorded, but the course was not recorded, because of very complicated maneuvering of the boat by short and frequent dead-slow-ahead and -astern propulsion and sudden helming of very large rudder angle under probably large influence of wind and current drift of the boat. And most of the propulsions and helmings are mainly for adjusting the position of boat compensating the wind and current drift and partly for sailing along the setline, as indicated by the fact that it takes 12 to 16 hours to sail 72 m × 400, i.e. 28.8 km. The line is hauled up nearly vertically, as supported by the fact that when the ground was shallow it was possible to get the echo traces of fish (especially the rockfish) just on the sea bed to surface. If the above-mentioned fact is true to throughout the hauling work, it is possible to estimate the depth of respective skates actually settled. The echogram throughout the hauling work was recorded for the purpose of estimating the probable depth of respective parts of main line settled actually.

Methods of data analysis

The master fisherman uses the echo-sounded depth during setting as the most powerful indicator of determining the course to shoot the line. It is, however, highly doubtful that the line would be settled on the sea bed without being drifted. And it is very hard to estimate the depth of respective skates of main line settled actually without any special device and it is unable to do so before the main line being settled down, but it is easy to estimate the depth along the shooting course. If it is possible to verify the presence of a clear relation between the catch by a skate and the echo-sounded depth during setting, accordingly, it is possible to regard that the master fishermen's way of determining the fishing depth is rational, in spite of high possibility of the current drift of main line.

If the groundfish shows a well-defined bathymetric difference in their density with the maximum at an intermediate depth and if the line covers very wide depth range centering the probable depth of maximum fish density, the catch by a skate has to show significantly negative quadratic regression with positive linear coefficient on the depth settled. If the groundfish is distributed along the above-mentioned pattern but the echo-sounded depth during shooting shows a phase lag to the actually settled depth, the relation should be either cubic or linear. If the probable depth of maximum fish density is out of the depth range covered by the string, the simplest representation of the catch-depth relation should be linear. Accordingly, the cubic, quadratic, and linear regressions of catch of respective species by respective skates on the echo-sounded depth during setting were examined.

The line is hauled up vertically, for the purpose of preventing it from being fastened with the bottom objects or from drop-off of the hooked fish by being dragged over the bottom. This fact means that the echo-sounded depth during hauling shows the change of the settled depth of meandering main line. To examine the relation between the catch and the depth, however, it is necessary to pay attention to the following two points : one is that the horizontal axis of the echogram shows not the distance but the passing of time, in spite of a large between-skate variation in the hauling speed. The other is the phase lag of catch from the sounded depth :

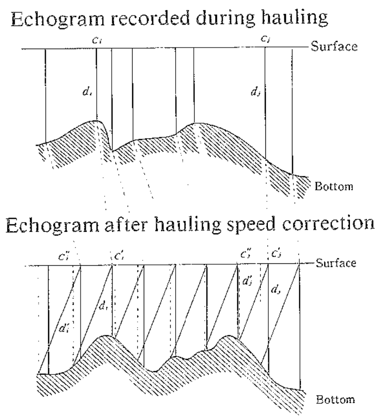


Fig. 4. The method of estimating the settled depth of respective skates from the echogram during hauling.

The hauling speed varied skate by skate. The depths (d_i and d_j) at the centers (c_i and c_j) of respective skates of main line passing the power gurdy were measured from the echogram recorded during hauling. These depths were plotted at equal intervals (d_i..... d_j in the lower half of this figure). Connecting the points on graph showing respective depths, the probable echogram after correction of irregularity of hauling speed was obtained. Through this step, the horizontal axis in the figure was converted from passing of time to distance. In this figure, the depth and horizontal distance were drawn in different scales, for convenience. $c_i''c_i' = d_i'$ and $c_j''c_j' = d_j'$. The part of main line just beneath c_i'' apprears to the surface, when the main line of the same length to d_i' was hauled up, i.e. at c_i'. It is, accordingly, possible to estimate the settled depths (d_i' and d_j') of the centers of respective skates of main lines by 1) drawing parallel lines with the dip equivalent to the horizontal-vertical scale ratio from the centers (c_i' and c_j') of respective skates on the corrected ecogram and 2) estimating the depths at cross points of these parallel lines with the bottom line of the corrected echogram.

namely, the part of main line just beneath the boat, i.e. that settled on the bottom of the echo-sounded position, is hauled up to surface, when the same length of a main line to the depth is taken inboard. For the purpose of estimating the settled depth of respective skates of main line correcting the lag due to these reasons, the echo-sounded depths at the center of respective skates were plotted at equal intervals ; from the centers of respective skates on the surface line, then, parallel lines with the dip equivalent to the horizontal-vertical scale ratio were drawn on this figure. And the settled depths of respective skates were estimated to be those at the cross points of these parallel lines with the curve showing the change of the echo-sounded depth after the horizontal axis correction (cf. Fig. 4). And as in the estimation of the relation to the depth at shooting, the cubic, quadratic, and the linear regressions of catch of respective species by respective skates on the depth estimated along the above-mentioned way (hereafter called the depth during hauling) were examined.

Results

1. Frequency distribution of catch of respective species by respective skates

This fishery aims mainly at sablefish (*Anoplopoma fimbria*). Idiot (*Sebastolobus macrocir*), rockfishes (*Sebastes* spp.), Greenland halibut (*Reinhardius hippoglossoides*), and rarely Pacific cod (*Gadus macrocephalus*) were caught as the marketable fish. And rays, arrowtooth flounder (*Atheresthes stomias*), and rattails (*Nematonurus* spp.) were caught as unmarketable fish. Besides these fish, many invertebrates were hooked, although whether they were caught because of taking the bait or only incidentally caught with the hooks dragged on the sea bed during hauling was highly doubtful, especially in some of the species. They were effective to conjecture the character of bottom where respective skates of main lines were settled. Of these fish, the frequency distributions of each species of fish by each skate were counted ; however, those of the following three species were compared with the theoretical series, for the other species were found only in a few of the skates in a few of the strings.

1.1 Sablefish

In spite of the fact that this is the main objective, the catch varied greatly skate by skate from 0 to 23. The average of catch also showed a large between-string variation from 0.0810 per hook (No. 21) to 0.2399 per hook (No. 7). As the first step of the examination of the distribution pattern of fish caught at low density with the gear consisted of a series of units of the equal construction, the observed series of frequency distribution of individuals caught by a skate were compared with the binomial series. And it was found out that all the examples showed contagious pattern of catch. As the second step, accordingly, the observed series were compared with the negative binomial series. And as shown in Table 1, it was found out that the observed distribution in the 10 strings out of the 39 ones was agreeable to the negative binomial series, but that in the rest showed more strongly contagious pattern than this theoretical distribution. And whether the observed distribution was agreeable to the negative binomial series or not seems to have a relation to the area and to the progress of consecutive shootings. The observed distributions agreeable to this series were found mainly in the ealier half of Area B, the latter half of Area C, and the last part of Area D. Those not agreeable to this series were found mainly in Area E, the latter half of Area B, and the earlier half of Area C. The distributions in Area A were included in this group, but differed from the others in the level of fitness. To find the clue to explaining the reason why the distributions in some of the strings were agreeable to while those in the others were not agreeable to this series, the relation between the level of fitness and some probable factors were shown in Fig.5. This figure revealed the following trends : the strings in the lowest level of fitness (<0.005) to the negative binomial series were scattered over wide range in respect to either of the factors. If the strings in this level were put aside the consideration, the frequency distribution showed better fitness to the negative binomial series 1) with deepening trend of the shallowest limit of the settled depth echo-sounded during setting, 2) as well as that estimated from the echogram during hauling, 3) with the shallowing trend of the deepest limit of the depth sounded during setting, 4) that of the depth estimated from the echogram during hauling, in consequence, 5) with the narrowing trend of the depth difference within a string sounded during setting, and 6) that estimated from the echogram during hauling.

It is a well-known fact that the depth is one of the leading factors controlling the distribution density of the groundfish. And the above-mentioned seeming contagiousness of catch should be derived from the variation of the settled depth within a string, or at least the influence of the settled depth should be excluded from the results before giving further consideration.

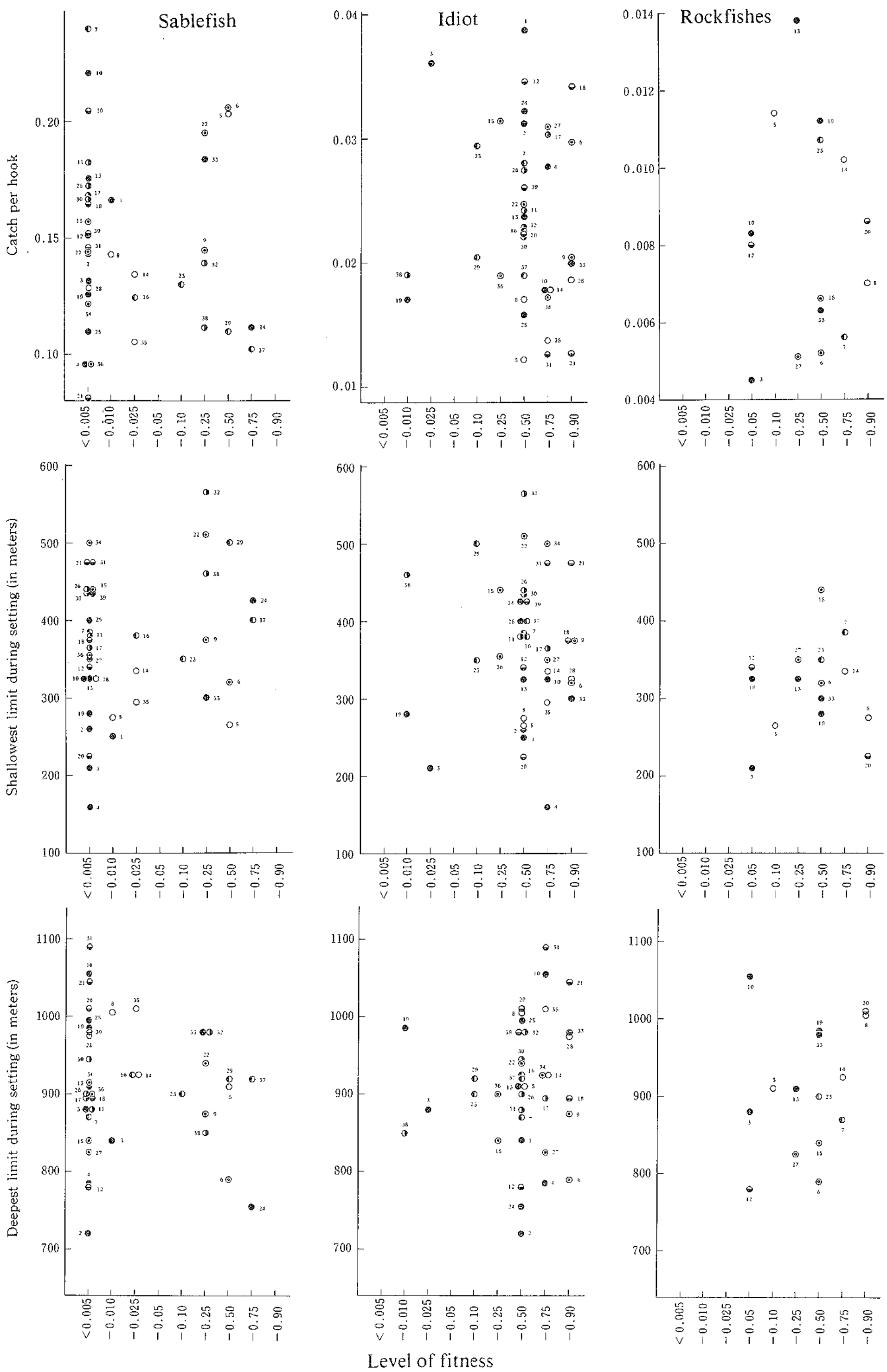
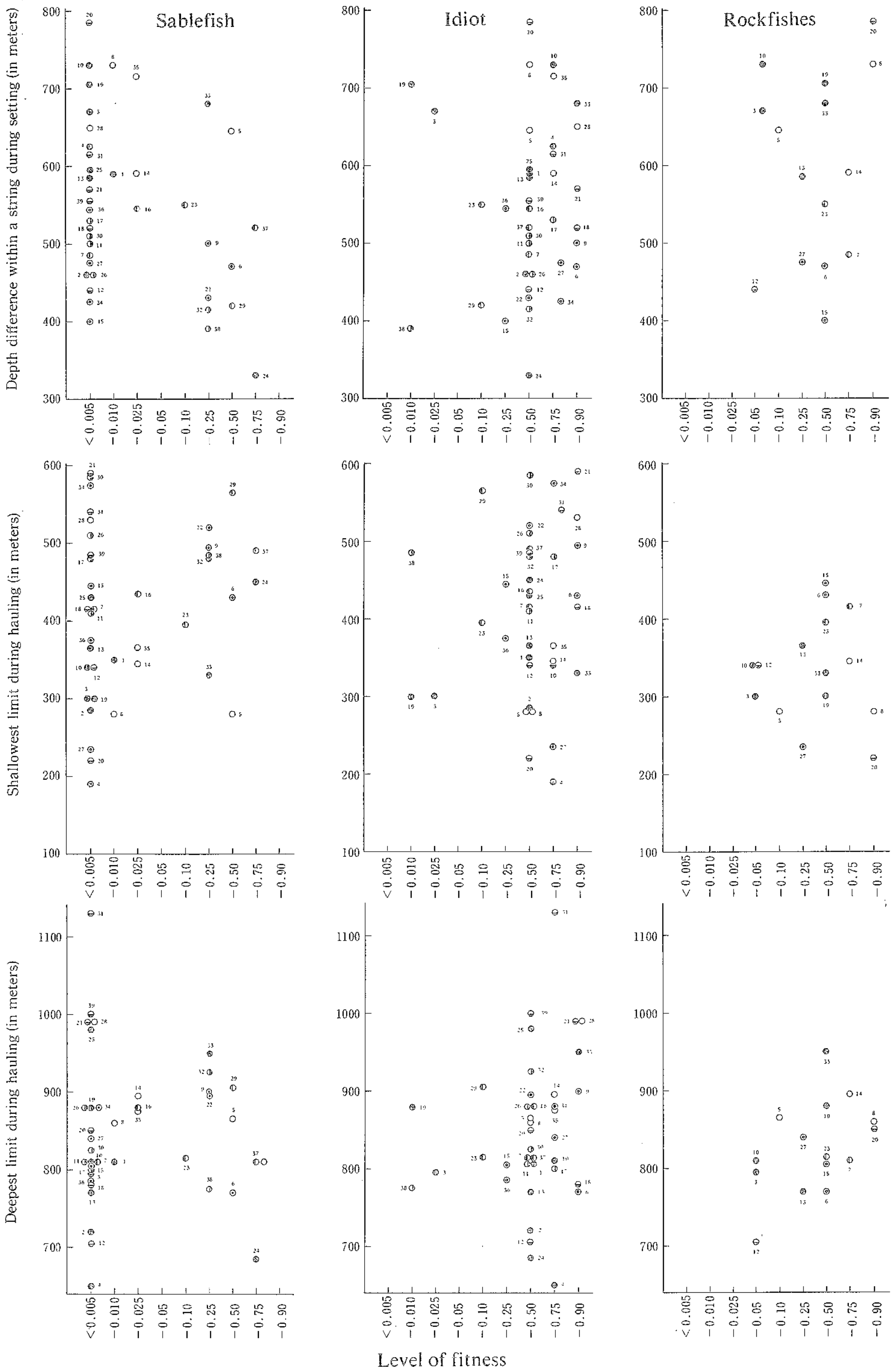

Sablefish
Idiot
Rockfishes
Catch per hook
Shallowest limit during setting (in meters)
Deepest limit during setting (in meters)
Level of fitness

Fig. 5—1.



Sablefish
Idiot
Rockfishes
Depth difference within a string during setting (in meters)
Shallowest limit during hauling (in meters)
Deepest limit during hauling (in meters)
<0.005
−0.010
−0.025
−0.05
−0.10
−0.25
−0.50
−0.75
−0.90
Level of fitness

Fig. 5—2.

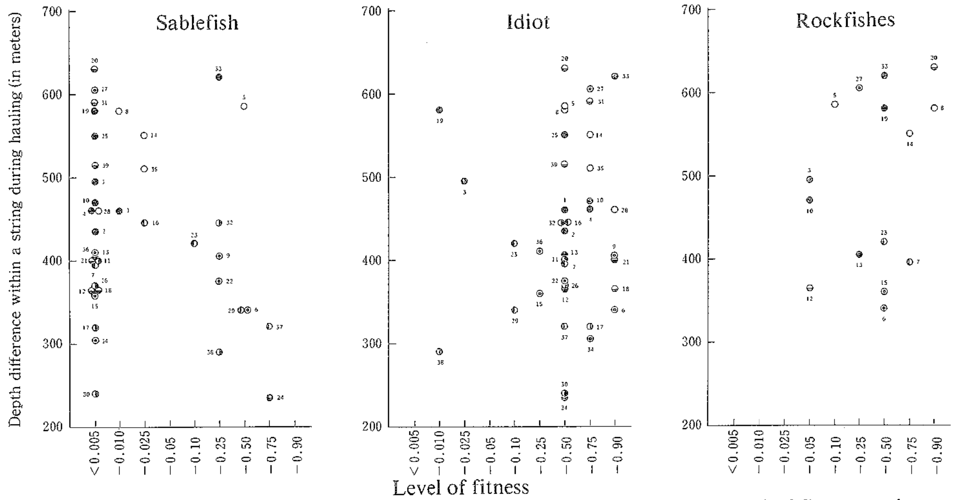


Fig. 5. The distribution of the strings in respect of the relation between the level of fitness to the negative binomial series and some factors probable to have relation to the level.

Note : ○ Area A ◉ Area B ◉ Area C ◉ Area D ◉ Area E ◉ Area F and others

Level of fitness $= \Pr\{\chi^2 > \chi_0^2\}$

Table 1. The frequency distribution of sablefish caught by a skate

Area A

	No. 5			No. 8			No. 14		
Catch by a skate	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
0	14	0.14	4.78	25	1.85	11.88	27	2.60	13.09
1	14	1.25	13.97	28	10.77	30.71	26	14.11	33.69
2	21	5.41	24.52	37	30.48	47.09	45	37.14	50.99
3	30	15.15	33.51	48	55.82	55.72	51	63.28	59.11
4	36	30.86	39.27	59	74.34	56.18	53	78.42	58.06
5	39	48.70	41.44	52	76.73	50.72	60	75.30	50.87
6	35	61.99	40.51	33	63.87	42.25	40	58.32	40.97
7	38	65.37	37.34	40	44.05	33.08	32	37.40	30.92
8	39	58.24	32.87	25	25.66	24.65	27	20.29	22.17
9	29	44.48	27.87	21	12.82	17.65	17	9.43	15.24
10	21	29.44	22.90	15	5.55	12.23	9	3.80	10.12
11	16	17.03	18.34	11	2.10	8.24	6	1.34	6.52
12	13	8.67	14.36	5	0.70	5.42	5	0.41	4.10
13	14	3.91	11.03	3	0.21	3.49	1	0.11	2.52
14	8	1.56	8.33	1	0.05	2.21	2	0.03	1.52
15	10	0.56	6.20	2	0.01	1.38	0	0.01	0.90
16	7	0.18	4.55		0.00	0.84	1	0.00	0.53
17	5	0.05	3.30		0.00	0.51		0.00	0.30
18	3	0.01	2.37		0.00	0.31		0.00	0.17
19	0	0.00	1.69		0.00	0.18		0.00	0.10
20	1	0.00	1.19		0.00	0.11		0.00	0.05
21		0.00	0.83		0.00	0.06		0.00	0.03
22		0.00	0.58		0.00	0.04		0.00	0.02
23		0.00	0.40		0.00	0.02		0.00	0.01
24		0.00	0.27		0.00	0.01		0.00	0.00
≧ 25		0.00	0.58		0.00	0.02		0.00	0.00
M	393			405			402		
N	2791			2023			1887		
p		0.20291			0.14272			0.13412	
p'			2.43038			1.93260			1.82296
n			4.96496			5.35608			5.70385
χ_0^2		596.56519	15.65593		256.79495	24.93353		167.79652	22.06674
df.		9	14		7	11		7	10
Pr.		0.005 >	0.50−0.25		0.005 >	0.010−0.005		0.005 >	0.025−0.010

Note : Ob .... Observed series B..... Binomial series $(p+q)^{35}$ $p+q=1$

Nb .... Negative binomial series $(q'-p')^{-n}$ $p'+q'=1$

M.......... Number of skates in a string N...... Number of sablefish caught by a string

p .... Occupied rate of hook dropper, i.e. $N/35M$

p' and n .... Estimated parameters of the negative binomial series, i.e.

$$p' = \frac{s^2}{\bar{x}} - 1 \quad \text{and} \quad n = \frac{\bar{x}}{p'}$$

	Area A						Area B		
	No. 28			No. 35			No. 6		
Catch by a skate	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
0	38	3.25	17.41	60	7.98	41.01	5	0.13	2.19
1	32	16.72	39.41	45	32.86	60.66	7	1.13	8.50
2	42	41.85	54.38	53	65.69	63.00	18	5.00	18.46
3	48	67.77	59.00	54	84.97	56.19	35	14.26	29.56
4	57	79.81	55.34	52	79.94	46.00	42	29.58	38.91
5	42	72.84	47.01	37	58.29	35.63	39	47.54	44.56
6	37	53.61	37.17	19	34.27	26.55	45	61.62	45.95
7	32	32.70	27.82	23	16.70	19.23	31	66.18	43.65
8	28	16.85	19.95	20	6.87	13.62	41	60.05	38.80
9	14	7.44	13.81	10	2.42	9.48	28	46.70	32.64
10	15	2.85	9.29	7	0.74	6.51	31	31.48	26.22
11	7	0.95	6.10	4	0.20	4.42	20	18.55	20.25
12	3	0.28	3.93	1	0.05	2.97	22	9.62	15.12
13	2	0.07	2.48	2	0.01	1.98	10	4.41	10.95
14		0.02	1.54	3	0.00	1.31	12	1.80	7.73
15		0.00	0.95	1	0.00	0.86	5	0.65	5.33
16		0.00	0.57		0.00	0.56	6	0.21	3.60
17		0.00	0.34		0.00	0.37	2	0.06	2.38
18		0.00	0.20		0.00	0.24		0.02	1.55
19		0.00	0.12		0.00	0.15		0.00	1.00
20		0.00	0.07		0.00	0.10		0.00	0.63
21		0.00	0.04		0.00	0.06		0.00	0.39
22		0.00	0.02		0.00	0.04		0.00	0.24
23		0.00	0.01		0.00	0.03		0.00	0.15
24		0.00	0.01		0.00	0.02		0.00	0.09
≧ 25		0.00	0.03		0.01	0.01		0.01	0.15
M	397			391			399		
N	1783			1440			2875		
p		0.12832			0.10522			0.20587	
p′			1.98437			2.49017			1.85688
n			4.56250			2.47144			8.40902
χ_0^2		237.62101	41.45396		522.04369	22.06994		287.96055	13.51579
df.		6	10		6	10		9	13
Pr.		0.005 >	0.005 >		0.005 >	0.025−0.010		0.005 >	0.50−0.25

	Area B								
	No. 9			No. 15			No. 22		
Catch by a skate	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
0	8	1.69	6.61	16	1.02	5.07	2	0.20	2.04
1	22	9.98	22.26	25	6.67	17.92	13	1.73	8.52
2	44	28.69	41.22	25	21.08	34.89	14	7.11	19.45
3	45	53.33	55.48	33	43.12	49.41	25	18.93	32.12
4	63	72.11	60.64	58	64.16	56.87	47	36.68	42.89
5	60	75.56	57.07	51	73.99	56.41	55	55.07	49.14
6	52	63.85	47.94	42	68.80	49.97	52	66.69	50.09
7	35	44.71	36.81	47	53.01	40.48	51	66.91	46.55
8	27	26.45	26.26	40	34.51	30.49	30	56.71	40.10
9	15	13.41	17.63	30	19.26	21.62	39	41.21	32.44
10	10	5.89	11.24	19	9.31	14.57	21	25.95	24.87
11	14	2.26	6.86	8	3.94	9.39	15	14.28	18.21
12	0	0.77	4.03	2	1.46	5.83	8	6.92	12.81
13	1	0.23	2.29	4	0.48	3.50	14	2.96	8.70
14	0	0.06	1.26	0	0.14	2.04	6	1.13	5.73
15	1	0.01	0.68	1	0.04	1.16	5	0.38	3.67
16	2	0.00	0.35		0.01	0.64	5	0.12	2.29
17		0.00	0.18		0.00	0.35	0	0.03	1.40
18		0.00	0.09		0.00	0.19	0	0.01	0.84
19		0.00	0.05		0.00	0.10	1	0.00	0.49
20		0.00	0.02		0.00	0.05		0.00	0.28
21		0.00	0.01		0.00	0.03		0.00	0.16
22		0.00	0.00		0.00	0.01		0.00	0.09
23		0.00	0.00		0.00	0.01		0.00	0.05
24		0.00	0.00		0.00	0.00		0.00	0.03
≧ 25		0.00	0.02		0.00	0.00		0.00	0.04
M	399			401			403		
N	2019			2201			2750		
p		0.14458			0.15682			0.19497	
p′			1.50181			1.55144			1.63332
n			10.08378			9.95357			10.77464
χ_0^2		85.37762	13.88073		196.33078	48.93369		134.85748	16.94421
df.		7	10		8	11		8	12
Pr.		0.005 >	0.25−0.10		0.005 >	0.005 >		0.005 >	0.25−0.10

Area B

Catch by a skate	No. 27 Ob.	No. 27 B.	No. 27 Nb.	No. 34 Ob.	No. 34 B.	No. 34 Nb.	No. 36 Ob.	No. 36 B.	No. 36 Nb.
0	19	1.73	6.55	36	4.26	21.18	49	11.73	30.82
1	16	10.20	22.25	43	20.66	44.72	48	43.55	61.67
2	31	29.17	41.45	46	48.67	58.49	61	78.55	74.16
3	57	53.98	55.96	48	74.19	60.83	67	91.69	69.44
4	53	72.64	61.22	58	82.25	55.12	59	77.83	55.78
5	59	75.77	57.56	43	70.67	45.52	37	51.20	40.35
6	56	63.73	48.23	42	48.97	35.15	40	27.16	27.04
7	39	44.41	36.88	22	28.11	25.80	20	11.94	17.10
8	32	26.15	26.17	28	13.64	18.19	10	4.43	10.32
9	13	13.20	17.46	15	5.67	12.42	3	1.41	6.00
10	10	5.77	11.05	9	2.04	8.26	4	0.39	3.38
11	8	2.21	6.68	3	0.64	5.37	1	0.09	1.86
12	4	0.74	3.89	4	0.18	3.43	0	0.02	1.00
13	2	0.22	2.18	1	0.04	2.15	1	0.00	0.53
14	0	0.06	1.19	1	0.01	1.33		0.00	0.27
15	0	0.01	0.63	1	0.00	0.82		0.00	0.14
16	1	0.00	0.33		0.00	0.49		0.00	0.07
17		0.00	0.17		0.00	0.30		0.00	0.03
18		0.00	0.08		0.00	0.18		0.00	0.02
19		0.00	0.04		0.00	0.10		0.00	0.01
20		0.00	0.02		0.00	0.06		0.00	0.00
21		0.00	0.01		0.00	0.04		0.00	0.00
22		0.00	0.00		0.00	0.02		0.00	0.00
23		0.00	0.00		0.00	0.01		0.00	0.00
24		0.00	0.00		0.00	0.01		0.00	0.00
≧ 25		0.01	0.00		0.00	0.01		0.01	0.01
M	400			400			400		
N	2016			1704			1343		
p		0.14400			0.12171			0.09593	
p'			1.48256			2.01734			1.67797
n			10.44439			4.18737			4.95230
χ_0^2		85.13673	33.66373		237.48691	25.35741		174.64845	25.09051
df.		7	10		6	10		6	8
Pr.		0.005 >	0.005 >		0.005 >	0.005 >		0.005 >	0.005 >

Area C

Catch by a skate	No. 7 Ob.	No. 7 B.	No. 7 Nb.	No. 16 Ob.	No. 16 B.	No. 16 Nb.	No. 23 Ob.	No. 23 B.	No. 23 Nb.
0	3	0.03	2.04	27	3.81	16.26	22	3.07	11.55
1	8	0.30	7.24	30	18.93	39.23	27	16.03	32.50
2	21	1.62	14.92	49	45.65	56.06	45	40.67	51.94
3	20	5.64	23.37	71	71.24	61.72	59	66.74	61.91
4	32	14.23	30.84	52	80.85	57.83	61	79.65	61.23
5	32	27.85	36.12	38	71.11	48.50	52	73.68	53.11
6	42	43.96	38.73	41	50.44	37.50	50	54.96	41.76
7	35	57.49	38.79	35	29.65	27.23	22	33.97	30.41
8	38	63.52	36.80	26	14.72	18.82	26	17.74	20.83
9	25	60.15	33.40	11	6.27	12.49	14	7.94	13.56
10	23	49.37	29.21	7	2.31	8.02	9	3.08	8.46
11	28	35.42	24.76	2	0.75	5.00	7	1.04	5.09
12	23	22.36	20.43	3	0.21	3.05	5	0.31	2.97
13	21	12.49	16.47	1	0.05	1.82		0.08	1.69
14	4	6.19	13.01	2	0.01	1.07		0.02	0.93
15	7	2.74	10.09	0	0.00	0.61		0.00	0.51
16	20	1.08	7.70	1	0.00	0.35		0.00	0.27
17	14	0.38	5.80		0.00	0.20		0.00	0.14
18	4	0.12	4.30		0.00	0.11		0.00	0.07
19	1	0.03	3.16		0.00	0.06		0.00	0.04
20	4	0.01	2.30		0.00	0.03		0.00	0.02
21		0.00	1.65		0.00	0.02		0.00	0.01
22		0.00	1.18		0.00	0.01		0.00	0.00
23		0.00	0.83		0.00	0.00		0.00	0.00
24		0.00	0.58		0.00	0.00		0.00	0.00
≧ 25		0.02	1.28		0.00	0.01		0.02	0.00
M	405			396			399		
N	3401			1722			1813		
p		0.23993			0.12424			0.12982	
p'			2.36957			1.80241			1.61407
n			6.13152			5.41929			7.39953
χ_0^2		522.23749	51.01204		120.48734	21.81720		107.99149	17.88344
df.		9	16		6	10		6	10
Pr.		0.005 >	0.005 >		0.005 >	0.025−0.010		0.005 >	0.10−0.05

Area C / Area D

Catch by a skate	No. 29 Ob.	No. 29 B.	No. 29 Nb.	No. 37 Ob.	No. 37 B.	No. 37 Nb.	No. 11 Ob.	No. 11 B.	No. 11 Nb.
0	27	6.93	21.31	26	9.30	32.65	19	0.35	3.93
1	41	29.78	48.89	60	36.91	59.57	16	2.72	13.59
2	60	62.22	65.90	77	71.14	68.89	22	10.32	26.60
3	64	84.09	68.02	70	88.71	64.32	29	25.32	38.79
4	71	82.66	59.47	52	80.46	52.88	34	45.19	46.87
5	55	62.97	46.37	35	56.56	39.94	52	62.50	49.60
6	33	38.69	33.22	30	32.06	28.39	38	69.72	47.53
7	22	19.70	22.30	14	15.06	19.28	35	64.44	42.15
8	9	8.47	14.22	14	5.97	12.63	37	50.31	35.12
9	5	3.12	8.69	7	2.03	8.04	39	33.67	27.81
10	5	1.00	5.13	3	0.60	5.00	33	19.53	21.09
11	4	0.28	2.94	6	0.15	3.05	25	9.90	15.41
12	0	0.07	1.64	2	0.03	1.83	9	4.42	10.92
13	2	0.01	0.90	1	0.01	1.08	4	1.74	7.52
14	0	0.00	0.48	1	0.00	0.63	5	0.61	5.06
15	1	0.00	0.25	1	0.00	0.36	2	0.19	3.33
16	1	0.00	0.13		0.00	0.21	2	0.05	2.15
17		0.00	0.07		0.00	0.12		0.01	1.37
18		0.00	0.03		0.00	0.07		0.00	0.85
19		0.00	0.02		0.00	0.04		0.00	0.53
20		0.00	0.01		0.00	0.02		0.00	0.32
21		0.00	0.00		0.00	0.01		0.00	0.19
22		0.00	0.00		0.00	0.01		0.00	0.11
23		0.00	0.00		0.00	0.00		0.00	0.07
24		0.00	0.00		0.00	0.00		0.00	0.04
≧ 25		0.01	0.01		0.01	0.00		0.01	0.05
M	400			399			401		
N	1532			1422			2560		
p		0.10943			0.10183			0.18240	
p'			1.66895			1.95294			1.84635
n			5.72539			3.73991			7.54306
χ_0^2		86.19985	11.24838		145.35828	7.77527		243.54936	49.54908
df.		6	9		6	9		8	12
Pr.		0.005 >	0.50−0.25		0.005 >	0.75−0.50		0.005 >	0.005 >

Area D

Catch by a skate	No. 17 Ob.	No. 17 B.	No. 17 Nb.	No. 26 Ob.	No. 26 B.	No. 26 Nb.	No. 30 Ob.	No. 30 B.	No. 30 Nb.
0	24	0.63	6.88	16	0.53	5.55	27	0.69	8.59
1	17	4.48	20.08	20	3.86	17.42	20	4.79	22.90
2	28	15.41	34.38	23	13.69	31.54	27	16.26	36.72
3	33	34.30	45.02	37	31.40	43.11	44	35.68	45.89
4	39	55.52	49.89	47	52.36	49.37	35	56.96	49.24
5	58	69.65	49.26	54	67.68	49.96	39	70.48	47.61
6	33	70.46	44.67	35	70.54	46.13	46	70.32	42.66
7	44	59.06	37.94	37	60.92	39.67	31	58.14	36.07
8	39	41.83	30.59	36	44.45	32.22	40	40.61	29.13
9	21	25.39	23.64	29	27.80	24.99	33	24.31	22.67
10	27	13.36	17.63	18	15.07	18.64	20	12.61	17.11
11	18	6.14	12.76	22	7.14	13.45	15	5.72	12.58
12	4	2.49	9.00	9	2.98	9.44	9	2.28	9.05
13	6	0.89	6.21	10	1.10	6.46	4	0.81	6.38
14	5	0.28	4.21	4	0.36	4.33	5	0.25	4.43
15	1	0.08	2.80	2	0.10	2.84	2	0.07	3.03
16	1	0.02	1.83	1	0.03	1.84	2	0.02	2.04
17	0	0.00	1.19		0.01	1.17	0	0.00	1.36
18	2	0.00	0.76		0.00	0.73	0	0.00	0.90
19		0.00	0.48		0.00	0.45	0	0.00	0.59
20		0.00	0.30		0.00	0.28	0	0.00	0.38
21		0.00	0.18		0.00	0.17	1	0.00	0.25
22		0.00	0.11		0.00	0.10		0.00	0.16
23		0.00	0.07		0.00	0.06		0.00	0.10
24		0.00	0.04		0.00	0.04		0.00	0.06
≧ 25		0.01	0.08		0.00	0.04		0.00	0.10
M	400			400			400		
N	2356			2415			2329		
p		0.16829			0.17250			0.16636	
p'			2.01742			1.92217			2.18511
n			5.78915			6.54705			4.91305
χ_0^2		381.95778	68.90595		238.75869	37.16293		465.63383	61.21206
df.		8	13		7	12		8	13
Pr.		0.005 >	0.005 >		0.005 >	0.005 >		0.005 >	0.005 >

Catch by a skate	Area D No. 32 Ob.	No. 32 B.	No. 32 Nb.	Area D No. 38 Ob.	No. 38 B.	No. 38 Nb.	Area E No. 12 Ob.	No. 12 B.	No. 12 Nb.
0	14	2.08	16.28	32	5.11	22.91	19	1.25	5.68
1	34	11.71	35.53	35	22.41	42.58	12	7.86	19.67
2	48	32.10	48.56	46	47.72	50.70	30	23.94	37.49
3	53	56.91	53.16	48	65.75	49.08	51	47.22	51.99
4	69	73.38	50.97	35	65.89	42.06	59	67.73	58.62
5	44	73.33	44.70	40	51.17	33.23	48	75.28	56.97
6	29	59.10	36.78	34	32.05	24.78	51	67.48	49.46
7	23	39.46	28.83	14	16.63	17.69	51	50.12	39.27
8	18	22.26	21.76	15	7.29	12.20	27	31.45	29.00
9	16	10.76	15.93	8	2.74	8.19	17	16.92	20.16
10	13	4.51	11.37	5	0.89	5.38	14	7.88	13.32
11	5	1.65	7.95	0	0.25	3.47	12	3.21	8.42
12	8	0.53	5.46	1	0.06	2.20	9	1.15	5.13
13	6	0.15	3.69	2	0.01	1.38	2	0.37	3.02
14	4	0.04	2.46	0	0.00	0.85		0.10	1.73
15	2	0.01	1.63	2	0.00	0.52		0.03	0.96
16	2	0.00	1.06	1	0.00	0.32		0.01	0.52
17		0.00	0.69		0.00	0.19		0.00	0.28
18		0.00	0.44		0.00	0.11		0.00	0.15
19		0.00	0.28		0.00	0.07		0.00	0.07
20		0.00	0.18		0.00	0.04		0.00	0.04
21		0.00	0.11		0.00	0.02		0.00	0.02
22		0.00	0.07		0.00	0.01		0.00	0.01
23		0.00	0.04		0.00	0.01		0.00	0.00
24		0.00	0.03		0.00	0.00		0.00	0.00
≧ 25		0.02	0.04		0.03	0.01		0.00	0.02
M	388			318			402		
N	1885			1239			2139		
p		0.13881			0.11132			0.15203	
p'			2.22600			2.09665			1.53707
n			3.96267			3.55286			9.90735
χ_0^2		289.02623	13.76915		216.72599	13.96695		116.23882	49.22499
df.		7	11		6	9		7	11
Pr.		0.005 >	≒ 0.250		0.005 >	0.250−0.10		0.005 >	0.005 >

Catch by a skate	Area E No. 18 Ob.	No. 18 B.	No. 18 Nb.	Area E No. 20 Ob.	No. 20 B.	No. 20 Nb.	Area E No. 21 Ob.	No. 21 B.	No. 21 Nb.
0	15	0.75	6.30	33	0.13	5.12	66	17.05	45.60
1	28	5.19	19.62	23	1.20	14.62	42	52.61	65.11
2	22	17.38	35.07	18	5.25	25.25	56	78.84	62.64
3	31	37.69	47.16	14	14.85	34.14	54	76.44	50.54
4	54	59.42	52.98	27	30.58	39.76	31	53.91	36.86
5	54	72.60	52.48	25	48.79	41.83	34	29.46	25.16
6	48	71.54	47.34	32	62.78	40.86	21	12.99	16.40
7	48	58.41	39.71	31	66.94	37.73	13	4.74	10.32
8	32	40.29	31.42	32	60.29	33.32	5	1.46	6.33
9	24	23.82	23.71	36	46.55	28.39	1	0.39	3.80
10	18	12.21	17.19	37	31.15	23.47	2	0.09	2.24
11	13	5.47	12.04	30	18.22	18.93	2	0.02	1.30
12	11	2.16	8.20	32	9.38	14.94	1	0.00	0.75
13	3	0.75	5.44	10	4.27	11.58		0.00	0.42
14	1	0.23	3.53	9	1.73	8.83		0.00	0.24
15	3	0.06	2.25	7	0.62	6.64		0.00	0.13
16	1	0.02	1.41	4	0.20	4.93		0.00	0.07
17	1	0.00	0.87	0	0.06	3.62		0.00	0.04
18	1	0.00	0.53	2	0.01	2.63		0.00	0.02
19		0.00	0.31	1	0.00	1.89		0.00	0.01
20		0.00	0.19		0.00	1.35		0.00	0.01
21		0.00	0.11		0.00	0.96		0.00	0.00
22		0.00	0.06		0.00	0.68		0.00	0.00
23		0.00	0.04		0.00	0.47		0.00	0.00
24		0.00	0.02		0.00	0.33		0.00	0.00
≧ 25		0.01	0.02		0.00	0.73		0.00	0.01
M	408			403			328		
N	2351			2887			930		
p		0.16464			0.20468			0.08101	
p'			1.84968			2.51097			1.98574
n			6.78168			4.74116			2.87638
χ_0^2		326.52206	30.57116		915.12778	227.11110		215.92294	25.59519
df.		8	12		9	15		5	7
Pr.		0.005 >	0.005 >		0.005 >	0.005 >		0.005 >	0.005 >

Area E / Area F

Catch by a skate	No. 31 Ob.	No. 31 B.	No. 31 Nb.	No. 39 Ob.	No. 39 B.	No. 39 Nb.	No. 10 Ob.	No. 10 B.	No. 10 Nb.
0	55	1.59	18.89	31	1.28	10.62	21	0.06	4.61
1	26	9.51	36.93	19	8.01	27.55	22	0.64	12.93
2	28	27.58	47.49	35	24.28	42.76	23	3.06	22.23
3	33	51.77	50.48	40	47.61	51.51	19	9.56	30.20
4	29	70.66	48.02	42	67.90	53.11	21	21.68	35.59
5	48	74.74	42.47	50	75.04	49.23	26	38.11	38.10
6	42	63.76	35.67	50	66.88	42.21	31	54.03	38.03
7	47	45.07	28.82	40	49.39	34.10	34	63.47	36.01
8	14	26.91	22.59	25	30.81	26.28	29	62.99	32.70
9	25	13.78	17.29	31	16.48	19.49	33	53.58	28.71
10	17	6.11	12.98	14	7.64	14.00	24	39.50	24.52
11	12	2.37	9.58	11	3.09	9.80	28	25.46	20.46
12	6	0.81	6.98	2	1.10	6.70	23	14.44	16.74
13	3	0.24	5.02	4	0.35	4.49	16	7.24	13.46
14	4	0.07	3.58	1	0.10	2.96	16	3.23	10.66
15	5	0.02	2.53	3	0.02	1.92	15	1.28	8.34
16	1	0.00	1.77	0	0.01	1.23	8	0.45	6.44
17		0.00	1.23	1	0.00	0.78	3	0.14	4.93
18		0.00	0.85	0	0.00	0.49	3	0.04	3.74
19		0.00	0.58	1	0.00	0.30	2	0.01	2.81
20		0.00	0.40		0.00	0.19	1	0.00	2.09
21		0.00	0.27		0.00	0.11	1	0.00	1.55
22		0.00	0.18		0.00	0.07		0.00	1.14
23		0.00	0.12		0.00	0.04		0.00	0.84
24		0.00	0.08		0.00	0.02		0.00	0.61
≧ 25		0.01	0.20		0.01	0.04		0.03	1.56
M	395			400			399		
N	2015			2118			3085		
p		0.14575			0.15129			0.22091	
p'			2.60906			2.04155			2.76034
n			3.17034			5.08378			4.39224
χ_0^2		656.84212	121.89350		271.95541	61.65420		832.05535	72.34478
df.		7	13		7	12		9	15
Pr.		0.005 >	0.005 >		0.005 >	0.005 >		0.005 >	0.005 >

Area F / Albatross Bank

Catch by a skate	No. 13 Ob.	No. 13 B.	No. 13 Nb.	No. 33 Ob.	No. 33 B.	No. 33 Nb.	No. 1 Ob.	No. 1 B.	No. 1 Nb.
0	17	0.47	8.18	11	0.33	3.70	25	0.63	11.45
1	38	3.51	21.48	16	2.58	13.00	24	4.38	25.40
2	22	12.70	34.36	20	9.89	25.79	26	14.83	36.03
3	34	29.72	43.19	35	24.47	37.98	33	32.52	41.50
4	39	50.58	46.89	41	44.05	46.27	36	51.83	42.27
5	31	66.70	46.09	39	61.45	49.30	37	65.04	39.67
6	34	70.94	42.15	50	69.13	47.49	39	63.80	35.11
7	47	62.51	36.49	45	64.44	42.29	35	52.67	29.74
8	31	46.54	30.25	41	50.75	35.36	30	36.73	24.34
9	33	29.70	24.21	29	34.25	28.06	23	21.96	19.39
10	27	16.42	18.83	28	20.04	21.31	20	11.38	15.09
11	19	7.94	14.29	17	10.25	15.59	11	5.15	11.53
12	15	3.38	10.62	9	4.61	11.05	5	2.05	8.67
13	5	1.27	7.76	6	1.84	7.61	6	0.72	6.43
14	3	0.42	5.58	3	0.65	5.12	4	0.23	4.71
15	5	0.13	3.95	4	0.20	3.36	1	0.06	3.42
16	1	0.03	2.77	3	0.06	2.17	1	0.02	2.45
17	0	0.01	1.92	1	0.01	1.37	2	0.00	1.75
18	0	0.00	1.32	0	0.00	0.86	1	0.00	1.24
19	0	0.00	0.90	0	0.00	0.53	2	0.00	0.87
20	0	0.00	0.60	0	0.00	0.32	0	0.00	0.61
21	0	0.00	0.41	1	0.00	0.19	0	0.00	0.42
22	2	0.00	0.27		0.00	0.11	1	0.00	0.29
23		0.00	0.18		0.00	0.07	1	0.00	0.20
24		0.00	0.12		0.00	0.04		0.00	0.14
≧ 25		0.03	0.19		0.00	0.06		0.00	0.28
M	403			399			363		
N	2474			2565			2111		
p		0.17540			0.18367			0.16616	
p'			2.33734			1.83060			2.62145
n			4.59044			7.73970			3.58656
χ_0^2		416.99636	54.44033		178.05006	15.70318		521.37957	29.52161
df.		8	14		8	12		8	13
Pr.		0.005 >	0.005 >		0.005 >	0.25−0.10		0.005 >	0.010−0.005

Albatross Bank

Catch by a skate	No. 2 Ob.	No. 2 B.	No. 2 Nb.	No. 3 Ob.	No. 3 B.	No. 3 Nb.	No. 4 Ob.	No. 4 B.	No. 4 Nb.
0	36	1.74	16.94	78	2.82	38.43	86	11.73	58.70
1	27	10.21	35.49	36	14.95	51.12	57	43.55	70.29
2	35	29.04	47.52	30	38.48	52.18	38	78.55	64.70
3	49	53.45	51.64	33	64.07	47.87	52	91.69	53.58
4	39	71.57	49.60	38	77.60	41.45	44	77.83	41.89
5	53	74.26	43.90	34	72.84	34.60	35	51.20	31.59
6	37	62.14	36.64	31	55.14	28.17	25	27.16	23.24
7	23	43.09	29.26	24	34.58	22.52	21	11.94	16.79
8	34	25.24	22.57	17	18.32	17.75	18	4.43	11.97
9	17	12.67	16.94	15	8.32	13.84	7	1.41	8.43
10	16	5.51	12.43	14	3.28	10.70	3	0.39	5.89
11	10	2.10	8.95	18	1.13	8.21	6	0.09	4.09
12	5	0.70	6.34	8	0.34	6.26	4	0.02	2.82
13	2	0.21	4.43	8	0.09	4.75	2	0.00	1.93
14	3	0.05	3.06	3	0.02	3.59	1	0.00	1.32
15	3	0.01	2.09	1	0.00	2.70	1	0.00	0.90
16	1	0.00	1.42	2	0.00	2.02		0.00	0.61
17	1	0.00	0.95	1	0.00	1.51		0.00	0.41
18	1	0.00	0.63	1	0.00	1.13		0.00	0.28
19		0.00	0.42		0.00	0.84		0.00	0.19
20		0.00	0.28		0.00	0.62		0.00	0.13
21		0.00	0.18		0.00	0.46		0.00	0.08
22		0.00	0.12		0.00	0.34		0.00	0.06
23		0.00	0.08		0.00	0.25		0.00	0.04
24		0.00	0.05		0.00	0.18		0.00	0.02
≧ 25		0.01	0.08		0.02	0.51		0.01	0.05
M	392			392			400		
N	1967			1804			1343		
p		0.14337			0.13149			0.09593	
p'			2.39496			3.45889			2.80364
n			3.59713			1.87159			1.86151
χ_0^2		394.58875	40.46683		845.96386	77.02236		739.54005	34.69551
df.		7	12		6	12		6	10
Pr.		0.005 >	0.005 >		0.005 >	0.005 >		0.005 >	0.005 >

Other area

Catch by a skate	No. 19 Ob.	No. 19 B.	No. 19 Nb.	No. 24 Ob.	No. 24 B.	No. 24 Nb.	No. 25 Ob.	No. 25 B.	No. 25 Nb.
0	62	3.58	27.74	18	6.40	18.28	66	6.90	42.23
1	33	18.05	48.05	39	28.10	45.39	54	29.73	60.45
2	36	44.24	56.21	75	59.90	64.60	43	62.19	62.20
3	40	70.18	55.21	75	82.63	69.12	46	84.19	55.67
4	39	80.96	49.06	51	82.89	61.74	39	82.89	46.09
5	45	72.38	40.83	49	64.45	48.61	43	63.25	36.31
6	50	52.19	32.45	32	40.41	34.83	26	38.92	27.63
7	23	31.18	24.92	23	20.99	23.20	30	19.84	20.49
8	22	15.74	18.64	19	9.21	14.58	18	8.55	14.91
9	21	6.81	13.65	8	3.47	8.73	12	3.16	10.68
10	6	2.55	9.82	5	1.13	5.02	13	1.01	7.55
11	11	0.84	6.97	5	0.32	2.79	4	0.28	5.28
12	4	0.24	4.89	0	0.08	1.51	2	0.07	3.67
13	2	0.06	3.39	0	0.02	0.79	0	0.02	2.53
14	2	0.01	2.33	0	0.00	0.41	3	0.00	1.73
15	3	0.00	1.59	1	0.00	0.21	1	0.00	1.18
16		0.00	1.08		0.00	0.10	1	0.00	0.80
17		0.00	0.73		0.00	0.05		0.00	0.54
18		0.00	0.49		0.00	0.02		0.00	0.36
19		0.00	0.32		0.00	0.01		0.00	0.24
20		0.00	0.22		0.00	0.01		0.00	0.16
21		0.00	0.14		0.00	0.00		0.00	0.11
22		0.00	0.09		0.00	0.00		0.00	0.07
23		0.00	0.06		0.00	0.00		0.00	0.05
24		0.00	0.04		0.00	0.00		0.00	0.03
≧ 25		0.00	0.08		0.00	0.00		0.00	0.04
M	399			400			401		
N	1760			1560			1538		
p		0.12603			0.11143			0.10958	
p'			2.54649			1.57059			2.67972
n			2.85228			6.83499			2.28336
χ_0^2		441.17892	80.27531		97.01841	6.58422		716.33234	36.41850
df.		6	11		7	9		6	11
Pr.		0.005 >	0.005 >		0.005 >	0.75−0.50		0.005 >	0.005 >

1.2 Idiot

This is one of the most important by-catch of the sablefish setline. It is highly doubtful whether the distribution of this species hooked along the sablefish setline could represent the distribution pattern of idiot or not, because of the following reasons : unnegligible number of sablefish was hooked because they did not take the bait directly but was hooked because they took the hooked individuals of small idiot, suggesting the dominancy of the sablefish over the idiot.

As shown in Table 2, the observed series of frequency distribution of this species caught by a skate in all the strings except one was not agreeable to the binomial series ; that in the 34 ones out of the 39 ones was agreeable to the negative binomial series ; and the distribution in the strings unable to be regarded to be agreeable was more strongly contagious than this theoretical distribution. The relations between the level of fitness and some probable factors were examined through Fig. 5, but it was hard to find any clear relation.

Table 2. The frequency distribution of idiot caught by a skate

Area A

	No. 5			No. 8			No. 14		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	273	255.62	272.39	232	223.35	235.54	242	214.10	238.83
1	83	110.62	86.27	125	134.06	117.53	99	136.11	104.79
2	29	23.25	24.84	35	39.09	38.40	40	42.03	38.57
3	7	3.16	6.91	10	7.37	10.34	13	8.40	13.28
4	0	0.31	1.89	2	1.01	2.49	7	1.22	4.42
5	0	0.02	0.51	0	0.11	0.56	1	0.14	1.44
6	1	0.00	0.14	1	0.01	0.12		0.01	0.46
7		0.00	0.04		0.00	0.02		0.00	0.15
8		0.00	0.01		0.00	0.00		0.00	0.05
9		0.00	0.00		0.00	0.00		0.00	0.01
≧ 10		0.02	0.00		0.00	0.00		0.00	0.00
M	393			405			402		
N	168			239			251		
p		0.01221			0.01686			0.01784	
p'			1.34976			1.18267			1.42299
n			1.22220			3.23052			1.47612
χ_0^2			1.05884		3.75758	0.84979		26.75989	0.75183
df.			1		1	1		1	2
Pr.			0.50−0.25		0.10−0.05	0.50−0.25		0.005 >	0.75−0.50

Area A / Area B

	No. 28 (Area A)			No. 35 (Area A)			No. 6 (Area B)		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	233	206.02	234.43	253	245.48	254.03	164	139.17	167.00
1	105	136.42	101.49	109	119.45	106.87	129	148.81	123.28
2	37	43.88	38.91	29	28.23	29.07	63	77.29	63.29
3	14	9.13	14.27	4	4.32	6.47	24	25.97	27.75
4	4	1.38	5.12	3	0.48	1.28	12	6.35	11.13
5	3	0.16	1.81		0.04	0.23	4	1.20	4.21
6	1	0.02	0.63		0.00	0.04	2	0.18	1.53
7		0.00	0.22		0.00	0.01	1	0.02	0.54
8		0.00	0.08		0.00	0.00		0.00	0.19
9		0.00	0.03		0.00	0.00		0.00	0.06
≧ 10		0.00	0.01		0.00	0.00		0.01	0.02
M	397			398			399		
N	258			191			414		
p		0.01857			0.01371			0.02965	
p'			1.50119			1.14077			1.40554
n			1.29665			3.40916			2.55854
χ_0^2		23.81453	0.23025			0.17891		26.13931	0.92630
df.		1	2			1		2	3
Pr.		0.005 >	0.90−0.75			0.75−0.50		0.005 >	0.90−0.75

Area B

	No. 9			No. 15			No. 22		
Catch by a skate	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
0	219	193.89	220.42	144	131.18	143.34	177	168.10	180.30
1	113	141.38	109.85	140	148.94	138.14	142	148.83	135.29
2	42	50.07	43.98	71	82.14	75.11	55	64.00	59.62
3	16	11.47	16.17	26	29.31	30.32	24	17.81	20.12
4	7	1.91	5.68	19	7.61	10.12	3	3.60	5.75
5	1	0.25	1.94	1	1.53	2.95	1	0.57	1.47
6	0	0.03	0.65		0.25	0.78	0	0.07	0.34
7	1	0.00	0.21		0.03	0.19	1	0.01	0.08
8		0.00	0.07		0.00	0.04		0.00	0.02
9		0.00	0.02		0.00	0.01		0.00	0.00
≧ 10		0.00	0.01		0.01	0.00		0.01	0.01
M	399			401			403		
N	285			441			348		
p		0.02041			0.03142			0.02467	
p'			1.43317			1.14119			1.15083
n			1.64899			7.78913			5.72528
χ_0^2		19.66349	0.21096		15.52194	3.34742		4.22630	2.42889
df.		1	2		2	2		1	2
Pr.		0.005 >	≒ 0.90		0.005 >	0.25−0.10		0.050−0.025	0.50−0.25

Area B

	No. 27			No. 34			No. 36		
Catch by a skate	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
0	163	132.86	158.12	244	217.83	240.82	226	205.44	221.22
1	119	148.76	126.50	98	133.54	103.87	107	138.20	118.03
2	65	80.91	67.22	38	39.76	37.16	49	45.15	42.79
3	34	28.47	29.69	14	7.66	12.38	13	9.55	13.08
4	14	7.29	11.79	5	1.07	3.97	5	1.47	3.62
5	4	1.45	4.36	1	0.12	1.25		0.17	0.94
6	0	0.23	1.54		0.01	0.38		0.02	0.23
7	1	0.03	0.52		0.00	0.12		0.00	0.06
8		0.00	0.17		0.00	0.04		0.00	0.01
9		0.00	0.06		0.00	0.01		0.00	0.00
≧ 10		0.00	0.03		0.01	0.00		0.00	0.02
M	400			400			400		
N	434			241			264		
p		0.03100			0.01721			0.01886	
p'			1.35618			1.39684			1.23703
n			3.04623			1.51823			2.78443
χ_0^2		28.10479	2.13103		26.64631	0.61387		13.54237	2.03538
df.		2	3		1	2		1	1
Pr.		0.005 >	0.75−0.50		0.005 >	0.75−0.50		0.005 >	0.25−0.10

Area C

	No. 7			No. 16			No. 23		
Catch by a skate	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
0	167	149.85	169.58	205	178.03	201.44	189	140.25	181.71
1	136	151.13	131.70	108	143.97	117.35	104	148.85	111.59
2	66	74.03	64.82	56	56.55	49.61	65	76.73	56.80
3	20	23.46	25.76	20	14.37	18.33	19	25.59	26.92
4	14	5.41	9.01	3	2.66	6.28	8	6.21	12.28
5	0	0.97	2.90	3	0.38	2.05	10	1.17	5.48
6	1	0.14	0.88	1	0.04	0.65	0	0.18	2.40
7	1	0.02	0.25		0.00	0.20	2	0.02	1.04
8		0.00	0.07		0.00	0.06	0	0.00	0.45
9		0.00	0.02		0.00	0.02	0	0.00	0.19
≧ 10		0.00	0.01		0.00	0.01	2	0.00	0.14
M	405			396			399		
N	397			313			411		
p		0.02801			0.02258			0.02943	
p'			1.26216			1.35679			1.67729
n			3.73906			2.21531			1.52087
χ_0^2		18.54252	2.11157		18.30445	2.33897		57.70864	6.93703
df.		2	2		1	2		2	3
Pr.		0.005 >	0.50−0.25		0.005 >	0.50−0.25		0.005 >	0.10−0.05

	Area C			Area D					
	No. 29			No. 37			No. 11		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	219	194.73	218.25	222	204.58	227.34	203	169.97	196.97
1	110	141.63	113.37	120	137.97	109.63	110	147.70	118.56
2	46	50.03	44.80	38	45.19	41.30	49	62.33	52.88
3	22	11.44	15.85	13	9.58	14.10	26	17.02	20.84
4	1	1.90	5.28	3	1.48	4.57	11	3.38	7.67
5	0	0.24	1.69	2	0.18	1.43	2	0.52	2.70
6	1	0.03	0.53	0	0.02	0.44		0.06	0.92
7	1	0.00	0.16	1	0.00	0.13		0.01	0.31
8		0.00	0.05		0.00	0.04		0.00	0.10
9		0.00	0.01		0.00	0.01		0.00	0.03
≧ 10		0.00	0.01		0.00	0.01		0.01	0.02
M	400			399			401		
N	285			264			340		
p		0.02036			0.01890			0.02423	
p'			1.37163			1.37209			1.40857
n			1.91723			1.77822			2.07522
χ_0^2		19.94549	5.41547		10.28819	1.51570		34.32083	2.49792
df.		1	2		1	2		1	2
Pr.		0.005 >	0.10−0.05		0.005 >	0.50−0.25		0.005 >	0.50−0.25

	Area D								
	No. 17			No. 26			No. 30		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	172	136.33	170.33	190	151.12	190.48	209	182.22	204.05
1	113	149.02	118.84	114	149.16	111.47	109	144.89	119.69
2	69	79.12	61.77	59	71.51	54.37	55	55.96	49.80
3	26	27.18	28.44	18	22.19	24.76	18	13.99	17.89
4	11	6.79	12.25	11	5.01	10.87	7	2.54	5.92
5	4	1.32	5.06	3	0.88	4.67	2	0.36	1.86
6	4	0.21	2.03	1	0.12	1.97		0.04	0.56
7	1	0.03	0.80	2	0.01	0.83		0.00	0.17
8		0.00	0.31	0	0.00	0.34		0.00	0.05
9		0.00	0.12	1	0.00	0.14		0.00	0.01
≧ 10		0.00	0.05	1	0.00	0.10		0.00	0.00
M	400			400			400		
N	424			384			311		
p		0.03029			0.02743			0.02221	
p'			1.51927			1.64046			1.32549
n			2.04133			1.49893			2.38869
χ_0^2		35.63918	1.53392		45.11120	2.43704		18.83199	1.64007
df.		2	3		2	3		1	2
Pr.		0.005 >	0.75−0.50		0.005 >	0.50−0.25		0.005 >	0.50−0.25

	Area D						Area E		
	No. 32			No. 38			No. 12		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	208	173.37	203.19	188	162.74	179.85	144	117.16	138.80
1	101	141.28	108.21	69	110.07	88.69	117	147.02	130.27
2	45	55.92	46.74	45	36.16	33.26	82	89.61	75.81
3	22	14.32	18.62	13	7.69	11.16	40	35.34	35.10
4	8	2.67	7.11	2	1.19	3.52	14	10.14	14.17
5	4	0.39	2.64	1	0.14	1.07	3	2.25	5.21
6		0.04	0.96		0.01	0.32	0	0.40	1.79
7		0.00	0.35		0.00	0.09	1	0.06	0.59
8		0.00	0.12		0.00	0.03	1	0.01	0.18
9		0.00	0.04		0.00	0.01		0.00	0.06
≧ 10		0.01	0.02		0.00	0.00		0.01	0.02
M	388			318			402		
N	309			211			487		
p		0.02275			0.01896			0.03461	
p'			1.49549			1.34545			1.29074
n			1.60729			1.92076			4.16674
χ_0^2		36.28622	1.32398		26.78612	10.01371		16.45899	3.77279
df.		1	2		1	2		2	3
Pr.		0.005 >	≒ 0.50		0.005 >	0.010−0.005		0.005 >	0.50−0.25

Area E

Catch by a skate	No. 18 Ob.	No. 18 B.	No. 18 Nb.	No. 20 Ob.	No. 20 B.	No. 20 Nb.	No. 21 Ob.	No. 21 B.	No. 21 Nb.
0	165	120.51	162.45	230	184.21	227.70	219	209.57	219.72
1	113	149.56	117.41	98	145.84	98.59	81	94.48	79.52
2	66	90.15	65.74	37	56.08	43.07	21	20.69	21.82
3	34	35.16	33.23	21	13.95	18.87	6	2.93	5.35
4	19	9.97	15.90	12	2.53	8.28	0	0.30	1.23
5	5	2.19	7.35	2	0.35	3.64	1	0.02	0.27
6	2	0.39	3.32	2	0.04	1.60		0.00	0.06
7	3	0.06	1.47	1	0.00	0.70		0.00	0.01
8	1	0.01	0.64		0.00	0.31		0.00	0.00
9		0.00	0.28		0.00	0.14		0.00	0.00
≧ 10		0.00	0.21		0.00	0.10		0.01	0.02
M	408			403			328		
N	489			312			146		
p		0.03424			0.02212			0.01272	
p'			1.65830			1.78794			1.22986
n			1.82065			0.98256			1.93649
χ_0^2		55.80508	1.58139		60.03253	3.13604			0.06124
df.		2	4		1	3			1
Pr.		0.005 >	0.90−0.75		0.005 >	0.50−0.25			0.90−0.75

Area E / Area F

Catch by a skate	No. 31 Ob.	No. 31 B.	No. 31 Nb.	No. 39 Ob.	No. 39 B.	No. 39 Nb.	No. 10 Ob.	No. 10 B.	No. 10 Nb.
0	275	253.56	276.55	199	159.08	192.35	221	213.11	222.98
1	85	113.12	80.90	102	148.63	114.98	126	134.86	121.64
2	23	24.51	25.42	61	67.45	54.09	39	41.45	40.62
3	7	3.44	8.17	19	19.81	23.15	9	8.24	10.70
4	3	0.35	2.66	12	4.23	9.42	3	1.19	2.44
5	2	0.03	0.87	7	0.70	3.71	1	0.13	0.51
6		0.00	0.29		0.09	1.43		0.01	0.10
7		0.00	0.09		0.01	0.54		0.00	0.02
8		0.00	0.03		0.00	0.20		0.00	0.00
9		0.00	0.01		0.00	0.08		0.00	0.00
≧ 10		0.00	0.01		0.00	0.05		0.01	0.00
M	395			400			399		
N	174			364			248		
p		0.01259			0.02600			0.01776	
p'			1.50583			1.52238			1.13937
n			0.87085			1.74204			4.45986
χ_0^2			0.44825		64.09626	4.19162		2.23993	0.28153
df.			1		2	3		1	1
Pr.			0.75−0.50		0.005 >	0.50−0.25		0.25−0.10	0.75−0.50

Area F / Albatross Bank

Catch by a skate	No. 13 Ob.	No. 13 B.	No. 13 Nb.	No. 33 Ob.	No. 33 B.	No. 33 Nb.	No. 1 Ob.	No. 1 B.	No. 1 Nb.
0	197	174.20	199.54	224	197.39	224.83	127	90.85	129.10
1	128	147.87	119.99	110	140.32	107.44	99	128.37	103.93
2	45	60.97	52.54	40	48.45	42.55	76	88.10	63.00
3	22	16.27	20.14	17	10.83	15.69	34	39.12	34.01
4	5	3.16	7.17	4	1.76	5.57	12	12.63	17.23
5	6	0.47	2.44	3	0.22	1.93	8	3.16	8.39
6		0.06	0.80	1	0.02	0.66	2	0.64	3.97
7		0.01	0.26		0.00	0.22	2	0.11	1.84
8		0.00	0.08		0.00	0.07	2	0.02	0.84
9		0.00	0.03		0.00	0.02	0	0.00	0.38
≧ 10		0.00	0.01		0.01	0.02	1	0.00	0.31
M	403			399			363		
N	334			278			493		
p		0.02368			0.01991			0.03880	
p'			1.37823			1.45799			1.68709
n			2.19123			1.52130			1.97664
χ_0^2		18.33904	1.82497		23.12849	0.35454		30.01771	4.57195
df.		1	2		1	2		2	4
Pr.		0.005 >	0.50−0.25		0.005 >	0.90−0.75		0.005 >	0.50−0.25

Albatross Bank

	No. 2			No. 3			No. 4		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	155	129.29	153.76	162	108.33	152.23	198	149.57	196.89
1	127	145.71	124.28	95	141.91	110.63	101	149.22	105.05
2	56	79.76	66.36	63	90.30	63.68	58	72.31	51.66
3	35	28.25	29.37	41	37.18	33.45	21	22.67	24.68
4	12	7.28	11.66	12	11.13	16.72	12	5.17	11.62
5	6	1.45	4.31	15	2.58	8.11	3	0.91	5.42
6	1	0.23	1.51	2	0.46	3.85	4	0.13	2.52
7		0.03	0.51	0	0.07	1.80	3	0.02	1.16
8		0.00	0.17	2	0.01	0.83		0.00	0.54
9		0.00	0.05		0.00	0.38		0.00	0.25
≧ 10		0.00	0.03		0.01	0.32		0.00	0.21
M	392			392			400		
N	428			495			388		
p		0.03120			0.03608			0.02771	
p′			1.35086			1.73764			1.81805
n			3.11187			1.71189			1.18575
χ_0^2		27.35156	2.80286		70.31929	13.14102		74.13708	1.50261
df.		2	3		2	4		2	3
Pr.		0.005 >	0.50−0.25		0.005 >	0.025−0.010		0.005 >	0.75−0.50

Other area

	No. 19			No. 24			No. 25		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	269	218.62	261.15	154	127.15	151.76	265	229.50	261.05
1	69	132.67	81.45	124	148.14	127.34	82	129.10	88.63
2	29	39.10	32.13	71	83.83	69.71	32	35.27	32.18
3	23	7.46	13.56	30	30.69	31.39	15	6.24	11.94
4	5	1.03	5.91	10	8.17	12.61	4	0.80	4.48
5	3	0.11	2.62	11	1.69	4.69	3	0.08	1.69
6	0	0.01	1.13		0.28	1.66		0.01	0.64
7	1	0.00	0.54		0.04	0.56		0.00	0.24
8		0.00	0.24		0.00	0.18		0.00	0.09
9		0.00	0.11		0.00	0.06		0.00	0.04
≧ 10		0.00	0.11		0.01	0.04		0.00	0.02
M	399			400			401		
N	238			451			222		
p		0.01704			0.03221			0.01582	
p′			1.91250			1.34371			1.63063
n			0.65369			3.28040			0.87788
χ_0^2		108.31630	9.28874		23.05041	2.76523		53.99030	1.34651
df.		1	2		2	3		1	2
Pr.		0.005 >	≒ 0.010		0.005 >	0.50−0.25		0.005 >	≒ 0.50

1.3 Rockfish

This group of fish is also one of the most important marketable by-catches, although the landing by the present trip was very small. As shown in Table 3, the observed series of frequency distribution of catch by a skate was compared with the estimated series of binomial distribution. It was, however, impossible to test the fitness through chi-square test, because of insufficient number of catch classes of higher frequency than 5 due to low rate of catch. The observed series showed a tailing in the direction to the classes of good catch. Accordingly, the observed series of frequency distribution was compared with the estimated series of the negative binomial distribution. In this case, the tailing of the estimated series of frequencies in the direction of good catch made it possible to compare the observed series with the estimated one through chi-square test in the 15 strings out of the 38 ones (no individual was caught in a string; and the total number of string was 38). And it was found out that the distribution in the 11 strings was agreeable to this theoretical series, but that in the other four strings was more strongly contagious than this theoretical series.

It was difficult to find any clear relation between the level of fitness and some probable factors except unclear trend of better fitness with increase in the deepest limit of the settled depth estimated from the echogram during hauling.

Table 3. Frequency distribution of rockfishes caught by a skate

Area A

	No. 5			No. 8			No. 14		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	314	262.97	309.07	359	316.90	357.46	317	280.45	317.75
1	42	106.27	48.06	25	78.01	25.77	52	101.50	51.67
2	14	20.86	18.41	10	9.33	10.02	21	17.84	18.31
3	14	2.65	8.45	3	0.72	4.95	6	2.03	7.66
4	5	0.24	4.20	2	0.04	2.71	2	0.17	3.45
5	1	0.02	2.18	2	0.00	1.57	1	0.01	1.62
6	2	0.00	1.17	2	0.00	0.94	2	0.00	0.78
7	0	0.00	0.64	1	0.00	0.58	1	0.00	0.38
8	1	0.00	0.35	1	0.00	0.36		0.00	0.19
9		0.00	0.20		0.00	0.23		0.00	0.10
≧ 10		0.00	0.27		0.00	0.41		0.00	0.09
M	393			405			402		
N	157			99			144		
p		0.01141			0.00698			0.01023	
p'			2.56883			3.39019			2.20283
n			0.25464			0.10227			0.29781
χ_0^2			5.54442			0.07755			0.81511
df.			2			1			2
Pr.			0.10−0.05			0.90−0.75			0.75−0.50

	Area A						Area B		
	No. 28			No. 35			No. 6		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	367	367.15	367.02	356	343.06	354.39	359	332.13	356.25
1	29	28.73	28.98	29	51.07	32.80	23	61.08	26.72
2	1	1.09	0.98	10	3.69	7.68	8	5.46	8.88
3		0.03	0.02	2	0.17	2.16	5	0.32	3.72
4		0.00	0.00	1	0.01	0.66	1	0.01	1.71
5		0.00	0.00		0.00	0.21	3	0.00	0.84
6		0.00	0.00		0.00	0.07		0.00	0.42
7		0.00	0.00		0.00	0.02		0.00	0.22
8		0.00	0.00		0.00	0.01		0.00	0.11
9		0.00	0.00		0.00	0.00		0.00	0.06
≧ 10		0.00	0.00		0.00	0.00		0.00	0.07
M	397			398			399		
N	31			59			73		
p		0.00223			0.00424			0.00523	
p'			0.98892			1.60155			2.43960
n			−7.04838			0.24643			0.12709
χ_0^2									1.10501
df.									1
Pr.									0.50−0.25

Area B

	No. 9			No. 15			No. 22		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	375	366.37	373.44	344	320.96	344.10	337	319.71	334.31
1	16	31.30	19.59	40	71.69	37.83	45	74.27	51.29
2	6	1.30	4.28	9	7.78	11.62	16	8.38	12.53
3	2	0.03	1.17	2	0.55	4.34	4	0.61	3.44
4		0.00	0.35	5	0.03	1.76	1	0.03	1.00
5		0.00	0.11	1	0.00	0.75		0.00	0.30
6		0.00	0.04		0.00	0.33		0.00	0.09
7		0.00	0.01		0.00	0.15		0.00	0.03
8		0.00	0.00		0.00	0.07		0.00	0.01
9		0.00	0.00		0.00	0.03		0.00	0.00
≧ 10		0.00	0.01		0.00	0.02		0.00	0.00
M	399			401			403		
N	34			89			93		
p		0.00243			0.00634			0.00659	
p'			1.62474			2.01904			1.50415
n			0.13640			0.21780			0.45774
χ_0^2						0.75585			
df.						1			
Pr.						0.50−0.25			

Area B / Area C

	No. 27 (Area B)			No. 36 (Area B)			No. 7 (Area C)		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	352	333.95	354.93	359	343.31	357.64	354	332.22	353.28
1	35	60.42	29.60	27	52.58	30.25	33	66.00	34.76
2	9	5.31	9.18	10	3.91	8.02	12	6.37	10.43
3	0	0.30	3.54	3	0.19	2.61	3	0.40	3.83
4	3	0.01	1.50	0	0.01	0.93	2	0.02	1.54
5	0	0.00	0.67	1	0.00	0.35	0	0.00	0.65
6	0	0.00	0.31		0.00	0.13	1	0.00	0.28
7	1	0.00	0.15		0.00	0.05		0.00	0.12
8		0.00	0.07		0.00	0.02		0.00	0.06
9		0.00	0.03		0.00	0.01		0.00	0.03
≧ 10		0.01	0.02		0.00	0.00		0.00	0.02
M	400			400			405		
N	72			61			80		
p		0.00514			0.00436			0.00564	
p'			2.15873			1.80283			2.00743
n			0.15534			0.18995			0.19607
χ_0^2			1.84657						0.36993
df.			1						1
Pr.			0.25−0.10						0.75−0.50

Area C

	No. 16			No. 23			No. 29		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	323	316.06	320.81	326	274.11	329.67	379	373.87	379.91
1	57	71.49	63.38	43	103.46	36.35	18	25.28	15.29
2	16	7.85	10.09	12	18.97	14.81	1	0.83	3.39
3		0.56	1.48	8	2.25	7.50	1	0.02	0.96
4		0.03	0.21	4	0.19	4.17	1	0.00	0.30
5		0.00	0.03	3	0.01	2.44		0.00	0.10
6		0.00	0.00	1	0.00	1.48		0.00	0.03
7		0.00	0.00	0	0.00	0.92		0.00	0.01
8		0.00	0.00	0	0.00	0.58		0.00	0.00
9		0.00	0.00	0	0.00	0.37		0.00	0.00
≧ 10		0.01	0.00	2	0.01	0.71		0.00	0.01
M	396			399			400		
N	89			149			27		
p		0.00642			0.01067			0.00193	
p'			1.13768			3.38673			1.67743
n			1.63244			0.15646			0.09964
χ_0^2						1.86600			
df.						2			
Pr.						0.50−0.25			

	Area C			Area D					
	No. 37			No. 11			No. 17		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	371	358.18	378.36	370	359.27	372.23	368	365.53	367.62
1	25	38.72	11.33	25	39.54	19.66	28	32.98	29.15
2	1	2.03	4.26	3	2.11	5.62	4	1.45	2.89
3	0	0.07	2.09	1	0.07	2.04		0.04	0.31
4	0	0.00	1.15	0	0.00	0.82		0.00	0.03
5	0	0.00	0.67	2	0.00	0.35		0.00	0.00
6	0	0.00	0.41		0.00	0.15		0.00	0.00
7	1	0.00	0.25		0.00	0.07		0.00	0.00
8	0	0.00	0.16		0.00	0.03		0.00	0.00
9	1	0.00	0.10		0.00	0.01		0.00	0.00
≧ 10		0.00	0.22		0.01	0.02		0.00	0.00
M	399			401			400		
N	43			44			36		
p		0.00308			0.00314			0.00257	
p'			3.59892			2.07727			1.13506
n			0.04147			0.10186			0.66637
χ_0^2									
df.									
Pr.									

	Area D								
	No. 26			No. 30			No. 32		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	365	363.70	364.84	362	355.59	361.72	362	358.17	361.25
1	32	34.65	32.53	31	41.92	31.39	21	28.68	23.17
2	3	1.60	2.45	5	2.40	5.47	5	1.12	3.03
3		0.05	0.17	2	0.09	1.11		0.03	0.46
4		0.00	0.01		0.00	0.24		0.00	0.08
5		0.00	0.00		0.00	0.05		0.00	0.01
6		0.00	0.00		0.00	0.01		0.00	0.00
7		0.00	0.00		0.00	0.00		0.00	0.00
8		0.00	0.00		0.00	0.00		0.00	0.00
9		0.00	0.00		0.00	0.00		0.00	0.00
≧ 10		0.00	0.00		0.00	0.01		0.00	0.00
M	400			400			388		
N	38			47			31		
p		0.00271			0.00336			0.00228	
p'			1.06556			1.35397			1.24589
n			1.44908			0.33195			0.32492
χ_0^2									
df.									
Pr.									

	Area D			Area E					
	No. 38			No. 12			No. 18		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	297	293.93	296.41	331	303.91	325.64	390	388.47	389.81
1	17	23.16	18.71	42	85.35	53.12	16	19.07	16.56
2	4	0.89	2.43	19	11.64	15.34	2	0.45	1.46
3		0.02	0.37	8	1.03	5.07		0.01	0.15
4		0.00	0.06	2	0.07	1.78		0.00	0.02
5		0.00	0.01		0.00	0.65		0.00	0.00
6		0.00	0.00		0.00	0.24		0.00	0.00
7		0.00	0.00		0.00	0.09		0.00	0.00
8		0.00	0.00		0.00	0.04		0.00	0.00
9		0.00	0.00		0.00	0.01		0.00	0.00
≧ 10		0.00	0.01		0.00	0.02		0.00	0.00
M	318			402			408		
N	25			112			20		
p		0.00225			0.00796			0.00140	
p'			1.24530			1.70778			1.15381
n			0.32049			0.39363			0.31871
χ_0^2						3.84753			
df.						1			
Pr.						≒ 0.05			

	Area E								
	No. 20			No. 21			No. 31		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	322	298.09	321.63	292	279.81	292.02	335	325.69	334.65
1	56	90.28	55.86	26	44.56	25.60	47	63.01	48.15
2	16	13.28	16.62	6	3.45	6.84	11	5.92	9.54
3	4	1.26	5.63	3	0.17	2.24	1	0.36	2.06
4	4	0.09	2.03	0	0.01	0.80	1	0.02	0.46
5	1	0.00	0.75	1	0.00	0.30		0.00	0.11
6		0.00	0.29		0.00	0.12		0.00	0.03
7		0.00	0.11		0.00	0.05		0.00	0.01
8		0.00	0.04		0.00	0.02		0.00	0.00
9		0.00	0.02		0.00	0.01		0.00	0.00
≧ 10		0.00	0.02		0.00	0.00		0.00	0.00
M	403			328			395		
N	121			52			76		
p		0.00858			0.00453			0.00550	
p'			1.72884			1.80852			1.33730
n			0.41196			0.19608			0.57043
χ_0^2			0.02527						
df.			1						
Pr.			0.90−0.75						

	Area E			Area F					
	No. 39			No. 10			No. 13		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	388	387.20	387.93	325	297.98	326.94	281	248.19	281.06
1	11	12.60	11.22	54	87.36	46.55	74	121.14	77.78
2	1	0.20	0.78	8	12.44	15.19	34	28.72	27.30
3		0.00	0.07	5	1.15	5.89	10	4.41	10.25
4		0.00	0.01	4	0.08	2.46	1	0.49	3.98
5		0.00	0.00	3	0.00	1.08	2	0.04	1.57
6		0.00	0.00		0.00	0.48	0	0.00	0.63
7		0.00	0.00		0.00	0.22	0	0.00	0.25
8		0.00	0.00		0.00	0.10	1	0.00	0.10
9		0.00	0.00		0.00	0.05		0.00	0.04
≧ 10		0.00	0.00		0.00	0.04		0.01	0.04
M	400			399			403		
N	13			116			194		
p		0.00093			0.00831			0.01375	
p'			1.12416			2.04198			1.73942
n			0.26177			0.27901			0.65104
χ_0^2						4.88062			2.86471
df.						1			2
Pr.						0.050−0.025			0.25−0.10

	Area F			Albatross Bank					
	No. 33			No. 1			No. 2		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a skate 0	339	319.81	337.44	350	341.64	348.89	368	360.31	366.87
1	40	70.98	43.96	8	20.74	9.53	17	30.41	19.47
2	15	7.65	11.86	2	0.61	2.75	5	1.25	4.11
3	3	0.53	3.75	2	0.01	1.03	2	0.03	1.09
4	1	0.03	1.27	1	0.00	0.43		0.00	0.32
5	1	0.00	0.45		0.00	0.19		0.00	0.10
6		0.00	0.16		0.00	0.09		0.00	0.03
7		0.00	0.06		0.00	0.04		0.00	0.01
8		0.00	0.02		0.00	0.02		0.00	0.00
9		0.00	0.01		0.00	0.01		0.00	0.00
≧ 10		0.00	0.02		0.00	0.02		0.00	0.00
M	399			363			392		
N	88			22			33		
p		0.00630			0.00173			0.00241	
p'			1.69278			2.21823			1.58653
n			0.31836			0.04975			0.14353
χ_0^2			1.29067						
df.			1						
Pr.			0.50−0.25						

	Albatross Bank						Other area		
	No. 3			No. 4			No. 19		
Catch by a skate	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
0	361	335.39	364.68	385	375.74	382.16	321	269.29	325.82
1	21	52.42	14.30	6	23.53	13.11	43	106.48	38.49
2	6	3.98	5.63	8	0.72	3.18	20	20.45	15.70
3	0	0.20	2.88	1	0.01	0.99	7	2.54	7.92
4	0	0.01	1.64		0.00	0.34	2	0.23	4.38
5	1	0.00	1.00		0.00	0.13	2	0.02	2.55
6	1	0.00	0.63		0.00	0.05	1	0.00	1.53
7	0	0.00	0.41		0.00	0.02	0	0.00	0.94
8	1	0.00	0.27		0.00	0.01	2	0.00	0.59
9	1	0.00	0.18		0.00	0.00	0	0.00	0.37
≧ 10		0.00	0.38		0.00	0.01	1	0.00	0.71
M	392			400			399		
N	61			25			156		
p		0.00445			0.00179			0.01117	
p'			3.96927			1.82206			3.30963
n			0.05241			0.07603			0.16928
χ_0^2			4.75570						2.73572
df.			1						2
Pr.			0.050−0.025						0.50−0.25

	Other area					
	No. 24			No. 25		
Catch by a skate	Ob.	B.	Nb.	Ob.	B.	Nb.
0	384	381.43	384.20	388	386.27	387.74
1	14	18.14	13.25	11	14.46	11.77
2	1	0.42	2.04	2	0.26	1.29
3	1	0.01	0.40		0.00	0.17
4		0.00	0.08		0.00	0.03
5		0.00	0.02		0.00	0.00
6		0.00	0.00		0.00	0.00
7		0.00	0.00		0.00	0.00
8		0.00	0.00		0.00	0.00
9		0.00	0.00		0.00	0.00
≧ 10		0.00	0.01		0.01	0.00
M	400			401		
N	19			15		
p		0.00136			0.00107	
p'			1.37700			1.23233
n			0.12600			0.16100
χ_0^2						
df.						
Pr.						

2. Depth regression

In spite of a well-known bathymetric difference in the density of groundfish, a string of setline was settled over wide depth range. The examination in the preceding section suggested that the seeming contagiousness of catch should be derived from the variation of the settled depth within a string and the difference of density relating to the settled depth. The depth regression of catch was, accordingly, examined in the present section. Here, the catch (y) by a skate was used after the log ($y + n/2$) transformation, because the frequency distribution was either agreeable to the negative binomial series or more strongly contagious than this series, and better results may be obtained when the catch by a skate ,y, was transformed into this value than used without any transformation.

The most probable pattern of the bathymetric change of the density is as follows : the density shows the maximum at an intermediate depth and decreases with approach to both of the extreme depths. When the string covers this depth, the estimated regression equation of catch on depth should be quadratic with the significantly negative quadratic coefficient and positive liner one. It is, however, probable that the catch shows a cubic relation, when the estimated depth shows a phase lag to the actual one. When the depth of maximum density is out of the depth range covered by the string, the equation should be linear. The possibility like this can not be neglected, especially in the distribution of by-catch or trash fish. Accordingly, the cubic, quadratic, and linear regressions of catch by a skate on the depth were examined. The settled depth was estimated in the present records through the echograms during setting and during hauling. And both of them were used in this section.

2.1 Regression of sablefish

2.1.1 Regression of sablefish on the depth sounded during setting

As expected, the quadratic regression equations showed the clearest trend among the estimated cubic, quadratic, and the linear equations. The quadratic regression coefficient in the 34 strings out of the 39 ones was negative including the significant one in the 25 strings. This fact meant that the density of hooked individuals showed the maximum at an intermediate depth and decreased with departure from this depth zone. In regard to cubic regression equations, the cubic coefficient in the one third of the strings was significantly negative and that in the other one third was insignificantly negative. These facts indicated as the general trend that the density showed a maximum at an intermediate depth and decreased with the departure from this depth but increased again in the very shallow part, although the increasing trend in the very shallow part was not remarkable. The linear regression was significant in the two thirds of the strings, but showed an increasing trend of catch in the one third and the decreasing one in the other one third of the strings.

The depths showing the maximum of catch were estimated from the cubic equations and the negative quadratic ones, and they were shown in Table 6 and Fig. 7. The cubic equations and the positive quadratic ones showed the depth of minimum catch. The estimated depths of minimum catch were added to this figure and Table 7. As shown in Table 6, the depths showing the maximum of catch estimated from the significantly cubic equations were distributed in the range from 400 m to 900 m deep, mainly 600 m to 800 m deep. Those from the significantly quadratic ones were distributed in the same depth range, except that for No. 14, mainly being in the 601-700 m zone. Those estimated from the insignificantly cubic or quadratic equations showed somewhat less clearly the similar trend. The depths of minimum catch estimated from either the significant or the insignificant cubic and quadratic equations scattered over mainly in the applicable depth range of the equations, but were distributed less densely in the zone between 600 m and 800 m deep. As shown in Fig. 7, the estimated depth of maximum catch through the cubic equation took the value very closely similar to that estimated from the quadratic equation of the same string, when either or both of the cubic equation and the quadratic one was significant. This figure also showed the following trend : the depths of maximum catch estimated from the significant equations took the similar value one another in Areas A,B,C, and F, mainly being 600 m to 800 m deep ; but those in the other areas showed somewhat large within-area variation.

Table 4. Regression of the number of sablefish caught by a skate on the echo-sounded depth during setting

No.	d_1	d_2	$a_{3\cdot0}$	$a_{3\cdot1}\times10^2$	$a_{3\cdot2}\times10^4$	$a_{3\cdot3}\times10^6$	$F_{3\cdot3}$	$a_{2\cdot0}$	$a_{2\cdot1}\times10^2$	$a_{2\cdot2}\times10^4$	$F_{2\cdot2}$	$a_{1\cdot0}$	$a_{1\cdot1}\times10^2$	$F_{1\cdot1}$	N
5	265	910	0.5150	0.1655	−0.0175	0.0004	0.049	0.5839	0.1236	−0.0096	8.190**	0.8567	0.0145	6.903**	393
8	275	1005	0.3367	0.1783	−0.0158	0.0002	0.042	0.3868	0.1506	−0.0112	22.807**	0.7798	0.0099	4.677*	405
14	335	925	−0.2329	0.3612	−0.0313	0.0004	38.855**	0.6817	0.0275	−0.0003	9.501**	0.7873	0.0085	9.834**	402
28	325	975	0.9565	−0.1900	0.0371	−0.0019	0.822	0.4749	0.0542	−0.0015	0.183	0.5426	0.0328	22.248**	397
35	295	1010	1.6424	−0.6401	0.1150	−0.0063	7.558**	0.0995	0.1528	−0.0111	5.974*	0.5444	0.0067	0.527	398
6	320	790	3.1597	−1.2213	0.2255	−0.0134	9.983**	0.9396	0.0377	−0.0035	0.508	1.0545	−0.0034	0.241	399
9	375	875	2.0887	−0.6633	0.1236	−0.0072	6.718**	0.4461	0.1686	−0.0127	10.138**	0.9572	0.0047	0.784	399
15	440	840	4.5614	−1.7653	0.2837	−0.0148	5.294*	0.6620	0.0896	−0.0056	0.754	0.9009	0.0152	5.231*	401
22	510	940	2.1784	−0.6799	0.1207	−0.0065	2.544	−0.1134	0.3132	−0.0201	18.946**	0.8551	0.0303	34.014**	403
27	350	825	1.2345	−0.1463	0.0280	−0.0016	0.268	0.8934	0.0332	−0.0026	0.360	0.9900	0.0008	0.025	400
34	500	925	−0.8604	0.7931	−0.1258	0.0064	0.467	1.4011	−0.1824	0.0126	1.055	0.7653	−0.0017	0.019	400
36	355	900	1.3168	−0.2467	0.0393	−0.0024	0.413	0.7998	0.0204	−0.0052	0.934	0.9927	−0.0443	28.954**	400
7	385	870	2.1761	−0.5376	0.0735	−0.0029	0.515	1.5388	−0.2094	0.0190	13.434**	0.8469	0.0253	15.779**	405
16	380	925	0.2893	0.1762	−0.0158	0.0002	0.004	0.3526	0.1455	−0.0110	4.586*	0.8132	0.00005	0.00006	396
23	350	900	1.6186	−0.5106	0.1053	−0.0066	6.198*	0.2206	0.2216	−0.0173	22.345**	0.8406	0.0080	2.558	399
29	500	920	4.1005	−1.6756	0.2731	−0.0143	5.625*	−0.9420	0.5039	−0.0355	29.558**	0.8698	−0.0100	1.923	400
37	400	920	4.1583	−2.0187	0.3602	−0.0201	21.931**	−1.3952	0.6161	−0.0442	54.698**	0.5579	0.0182	4.366*	399
11	380	880	−0.0519	0.4099	−0.0473	0.0014	0.151	0.2942	0.2377	−0.0196	16.276**	1.0620	−0.0130	4.202*	401
17	365	895	1.6719	−0.3098	0.0423	−0.0020	0.274	1.2001	−0.0734	0.0040	0.573	1.0431	−0.0218	7.972**	400
26	440	900	4.3683	−1.5262	0.2193	−0.0102	4.222*	1.5968	−0.2138	0.0167	6.752**	0.8914	0.0069	0.872	400
30	435	945	0.0771	0.2509	−0.0162	−0.0004	0.007	−0.0387	0.3052	−0.0244	15.404**	1.0275	−0.0229	6.927**	400
32	565	980	1.1427	−0.4836	0.1040	−0.0060	0.523	−1.5915	0.6020	−0.0376	16.829**	0.6143	0.0202	3.769	388
38	460	850	−2.6091	1.7066	−0.2708	0.0134	1.064	0.9781	0.0064	−0.0069	0.334	1.2750	−0.0854	41.818**	318
12	340	780	0.8553	0.0720	−0.0066	−0.0002	0.005	0.8102	0.0976	−0.0113	6.216*	1.1372	−0.0268	25.159**	402
18	375	895	−0.1209	0.4037	−0.0490	0.0018	0.258	0.3288	0.1798	−0.0129	6.736**	0.8589	0.0111	2.617	408
20	225	1010	0.1861	0.1909	−0.0117	0.00001	0.0001	0.1887	0.1894	−0.0114	16.718**	0.6572	0.0370	31.045**	403
21	475	1045	3.5353	−1.3225	0.1836	−0.0080	3.762	0.1160	0.0798	−0.0029	0.202	0.2894	0.0338	11.871**	328
31	475	1090	2.5186	−0.8012	0.1216	−0.0060	3.120	0.0004	0.2446	−0.0184	9.438**	1.0278	−0.0358	12.613**	395
39	425	980	3.3643	−1.2188	0.1960	−0.0103	7.797**	0.1716	0.2385	−0.0195	13.307**	1.0872	−0.0336	17.992**	400
10	325	1055	−1.5520	1.1550	−0.1635	0.0071	17.285**	0.5411	0.1559	−0.0135	16.434**	1.1263	−0.0287	17.829**	399
13	325	910	1.7004	−0.5171	0.1085	−0.0073	4.774*	0.3339	0.2330	−0.0226	20.111**	1.0755	−0.0340	20.759**	403
33	300	980	0.0927	0.4812	−0.0780	0.0039	7.449**	0.9851	0.0139	−0.0019	0.629	1.0582	−0.0104	5.171*	399
19	280	985	−1.4229	1.0896	−0.1696	0.0080	9.801**	0.2348	0.1952	−0.0185	17.072**	0.8928	−0.0359	20.143**	399
24	425	755	10.9871	−5.2751	0.8924	−0.0492	24.749**	1.1907	−0.1613	0.0166	3.493	0.6057	0.0385	25.240**	400
25	400	995	1.3657	−0.4611	0.0864	−0.0050	1.468	−0.1522	0.2448	−0.0189	8.973**	0.7005	−0.0158	2.322	401
1	250	840	0.9598	−0.0634	0.0136	−0.0011	0.079	0.7910	0.0382	−0.0057	0.729	0.9581	−0.0256	6.393*	363
2	260	720	2.0408	−0.9646	0.2385	−0.0189	5.241*	0.2565	0.2611	−0.0305	9.178**	0.8949	−0.0262	5.391*	392
3	210	880	−1.4894	1.1191	−0.1944	0.0112	9.086**	−0.2248	0.2672	−0.0188	7.171**	0.2219	0.0763	32.676**	392
4	160	785	−0.2031	0.1485	0.0219	−0.0042	0.698	−0.5149	0.3948	−0.0361	18.233**	0.2372	0.0526	13.039**	400

Note: No. . . . . . String number
d_1. . . . . . . The shallowest limit in the string (in meters)
d_2. . . . . . . The deepest one

$\log(y+\frac{n}{2}) = a_{3\cdot0} + a_{3\cdot1}x + a_{3\cdot2}x^2 + a_{3\cdot3}x^3$

$\log(y+\frac{n}{2}) = a_{2\cdot0} + a_{2\cdot1}x + a_{2\cdot2}x^2$

$\log(y+\frac{n}{2}) = a_{1\cdot0} + a_{1\cdot1}x$

x. . . . . Echo-sounded depth in meters
y. . . . . Number of individuals caught by a skate
n . . . . A parameter of the negative binomial series (shown in Table 1)
$F_{i\cdot i}$ . . . . . . The estimated value of the Snedecor's F for $a_{i\cdot i}$ with 1 and $N-i-1$ degrees of freedom
N. . . . . . . Number of skates in the string
* significant at 0.05 level ** significant at 0.01 level

Table 5. Trend and significance of the depth regression of sablefish caught by a setline

Area		Setting A	Setting B	Setting C	Setting D	Setting E	Setting F	Setting Sum	Hauling A	Hauling B	Hauling C	Hauling D	Hauling E	Hauling F	Hauling Sum
$a_{3\cdot3}$	Significantly positive	1	0	0	0	0	4	5	1	0	2	0	1	3	7
	Insignificantly positive	2	1	1	2	2	0	8	3	4	1	2	2	5	17
	Insignificantly negative	1	3	1	3	3	3	14	1	2	1	3	3	2	12
	Significantly negative	1	3	3	1	1	3	12	0	1	1	1	0	0	3
$a_{2\cdot2}$	Significantly positive	0	0	1	1	0	0	2	0	1	1	1	0	0	3
	Insignificantly positive	0	1	0	1	0	1	3	1	4	2	3	3	3	16
	Insignificantly negative	1	4	0	1	1	2	9	2	0	1	1	1	3	8
	Significantly negative	4	2	4	3	5	7	25	2	2	1	1	2	4	12
$a_{1\cdot1}$	Significantly positive	4	2	2	0	2	3	13	4	2	3	1	2	3	15
	Insignificantly positive	1	2	2	2	1	0	8	1	3	0	2	0	1	7
	Insignificantly negative	0	2	1	0	0	4	7	0	0	1	2	2	4	9
	Significantly negative	0	1	0	4	3	3	11	0	2	1	1	2	2	8

Note : In the column F, the strings settled in the other areas than Areas A—E are included.

Table 6. Bathymetric distribution of the estimated depth of maximum catch

Sablefish

Depth range (m)	No. S	No. H	signif. set 3	signif. set 2	signif. haul 3	signif. haul 2	insignif. set 3	insignif. set 2	insignif. haul 3	insignif. haul 2
0— 100	0	0	0	0	0	0	0	1	0	0
101— 200	1	1	0	0	0	0	0	1	0	0
201— 300	9	6	0	0	0	0	0	0	1	0
301— 400	25	17	0	0	0	0	0	2	1	0
401— 500	35	31	3	2	2	2	1	0	4	2
501— 600	39	39	3	4	1	2	4	1	2	1
601— 700	39	39	4	13	4	3	6	1	6	1
701— 800	39	37	6	4	1	3	3	1	5	0
801— 900	34	28	1	1	0	2	2	0	3	0
901—1000	21	8	0	0	0	0	2	0	1	1
1001—1100	6	1	0	0	0	0	0	0	0	1
1101—1200	0	1	0	0	0	0	0	0	0	0
1201—			0	1	0	0	1	2	1	2

Idiot

Depth range (m)	No. S	No. H	signif. set 3	signif. set 2	signif. haul 3	signif. haul 2	insignif. set 3	insignif. set 2	insignif. haul 3	insignif. haul 2
0— 100	0	0	0	0	0	0	0	1	0	0
101— 200	1	1	0	0	0	0	0	1	0	0
201— 300	9	6	0	0	0	0	2	1	2	0
301— 400	25	17	1	0	0	0	1	0	1	4
401— 500	35	31	2	0	2	1	4	1	7	3
501— 600	39	39	2	6	1	2	10	4	7	5
601— 700	39	39	0	13	2	2	11	2	7	5
701— 800	39	37	3	1	2	0	2	2	3	0
801— 900	34	28	0	0	0	0	0	0	2	1
901—1000	21	8	0	0	0	0	0	0	0	0
1001—1100	6	1	0	0	0	0	0	0	0	0
1101—1200	0	1	0	0	0	0	0	0	0	0
1201—			0	0	0	0	0	3	2	0

Rockfish

Depth range (m)	No. S	No. H	signif. set 3	signif. set 2	signif. haul 3	signif. haul 2	insignif. set 3	insignif. set 2	insignif. haul 3	insignif. haul 2
0— 100	0	0	0	0	0	0	0	0	0	0
101— 200	1	1	0	0	0	1	1	0	0	0
201— 300	9	6	1	0	2	0	0	2	3	0
301— 400	24	17	0	0	1	0	0	0	0	0
401— 500	34	31	0	0	1	0	1	1	1	1
501— 600	37	37	1	0	0	0	2	0	4	4
601— 700	37	37	1	0	8	0	2	0	2	0
701— 800	37	35	7	0	2	1	2	0	2	0
801— 900	32	26	3	0	0	0	1	0	1	0
901—1000	19	7	0	0	1	0	1	0	0	1
1001—1100	6	1	0	0	0	0	0	0	1	0
1101—1200	0	1	0	0	0	0	0	0	0	0
1201—			1	0	0	0	9	0	4	1

Note : No .... Number of the regression equations covering respective depth ranges
S or set .... Regression on the depth echo-sounded during setting
H or haul ...... Regression on the depth echo-sounded during hauling
Coulmn 3 ...... Number of the maximum of catch estimated from the cubic equation
Column 2 ...... That estimated from the quadratic one
In the depth range "1201— ", the estimated depth shallower than 0 m is included

Table 7. Bathymetric distribution of the estimated depth of minimum catch

Depth range (m)	Sablefish										Idiot										Rockfish									
	No.		signif.				insignif.				No.		signif.				insignif.				No.		signif.				insignif.			
			set		haul		set		haul				set		haul		set		haul				set		haul		set		haul	
	S	H	3	2	3	2	3	2	3	2	S	H	3	2	3	2	3	2	3	2	S	H	3	2	3	2	3	2	3	2
0— 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
101— 200	1	1	0	0	1	0	0	0	2	0	1	1	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0
201— 300	9	6	0	0	0	0	0	0	0	2	9	6	0	0	1	0	1	0	1	0	9	6	0	0	0	0	0	0	0	0
301— 400	25	17	2	0	0	0	2	0	0	2	25	17	0	0	0	0	1	0	0	2	24	17	0	0	0	0	0	0	0	0
401— 500	35	31	5	0	0	0	3	1	2	1	35	31	0	0	2	0	5	0	2	1	34	31	1	0	0	0	0	0	0	0
501— 600	39	39	5	1	2	2	3	0	6	3	39	39	3	0	0	0	0	0	4	1	37	37	2	2	6	3	3	2	1	0
601— 700	39	39	1	1	3	1	0	0	4	1	39	39	2	0	3	3	2	0	5	2	37	37	8	5	6	6	4	1	6	2
701— 800	39	37	0	0	1	0	1	1	5	1	39	37	1	0	1	1	0	2	9	0	37	35	2	14	2	7	8	0	7	4
801— 900	34	28	1	0	1	0	1	1	2	3	34	28	0	0	0	1	6	0	4	1	32	26	1	4	1	1	3	1	3	1
901—1000	21	8	2	0	0	0	0	0	2	0	21	8	1	0	0	0	4	0	1	1	19	7	0	0	0	0	1	3	0	1
1001—1100	6	1	0	0	0	0	1	0	1	1	6	1	0	0	0	0	1	0	2	0	6	1	0	0	0	0	0	0	0	0
1101—1200	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
1201—			1	0	0	0	8	0	0	2			1	0	0	0	7	2	2	3			0	1	0	0	0	1	1	3

Note : No............Number of the regression equations covering respective depth ranges
S or set ....Regression on the depth echo-sounded during setting
H or haul ......Regression on the depth echo-sounded during hauling
Column 3 ......Number of the minimum of catch estimated from the cubic equation
Column 2 ......That estimated from the quadratic one
In the depth range "1201— ", the estimated depth shallower than 0 m is included

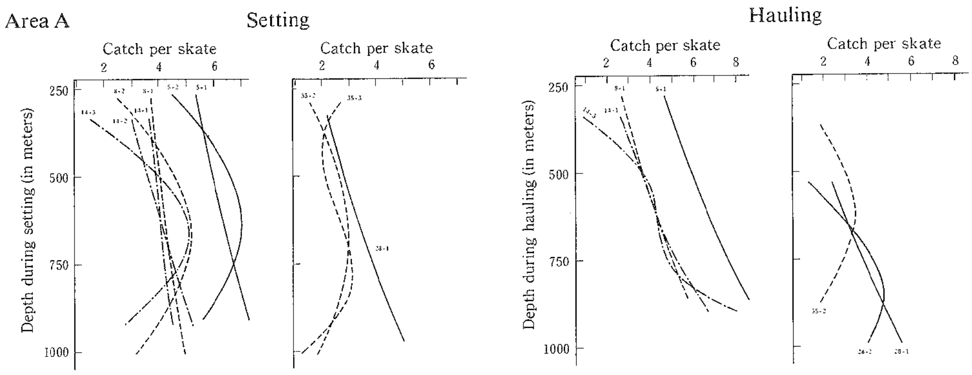


Fig. 6. Bathymetric change of catch per skate of sablefish.

Note : 1. For the number attached to the line, *i-j*, *i* indicates the string number and *j* indicates the order of regression equation.
2. The thick line shows the relation estimated from the significant equation. When the regression equations of all the cubic, quadratic, and linear ones in a string are insignificant, the relation estimated from the linear one is added to the figure by the thin line.
3. The strings are distinguished from one another by drawing the different line (solid, broken, or chain line).
4. The estimated value of catch per skate should be represented by log $(y + n/2)$, but is represented converting into y for easy comparison of catch by the different strings with one another.

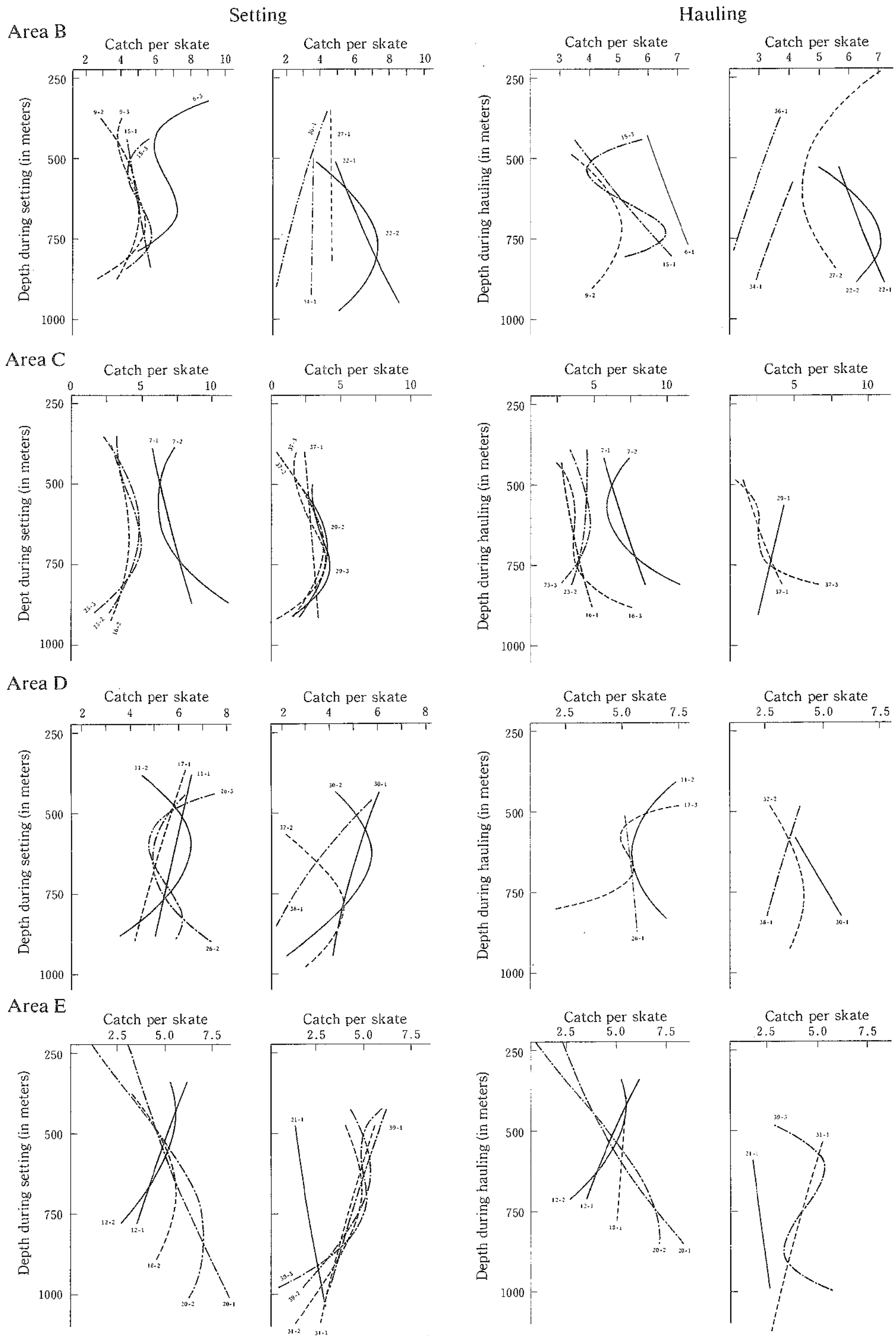

Setting
Hauling
Area B
Area C
Area D
Area E
Catch per skate
Depth during setting (in meters)
Depth during hauling (in meters)
250
500
750
1000

Fig. 6—2.

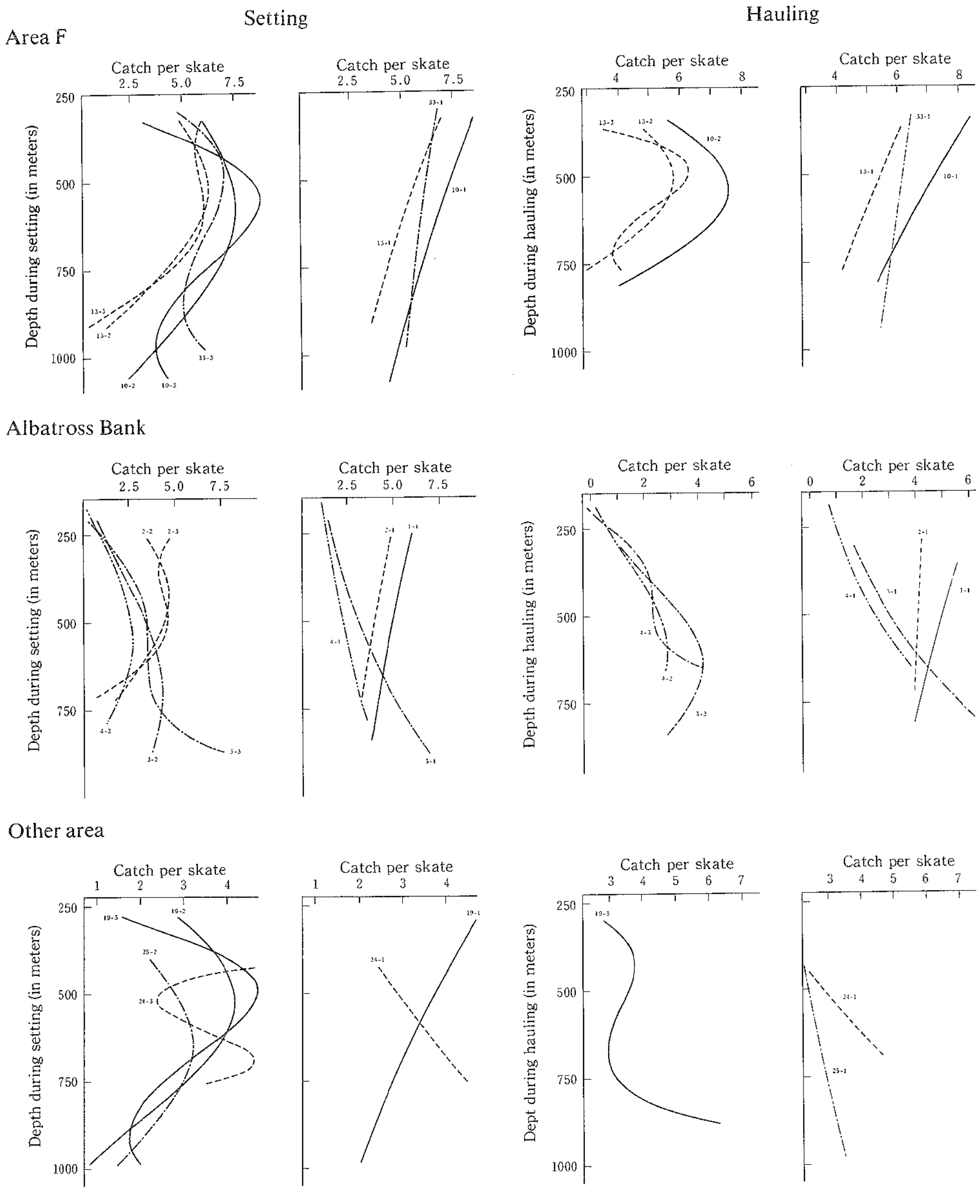

Setting
Hauling
Area F
Albatross Bank
Other area
Catch per skate
Depth during setting (in meters)
Depth during hauling (in meters)
Dept during hauling (in meters)

Fig. 6—3.

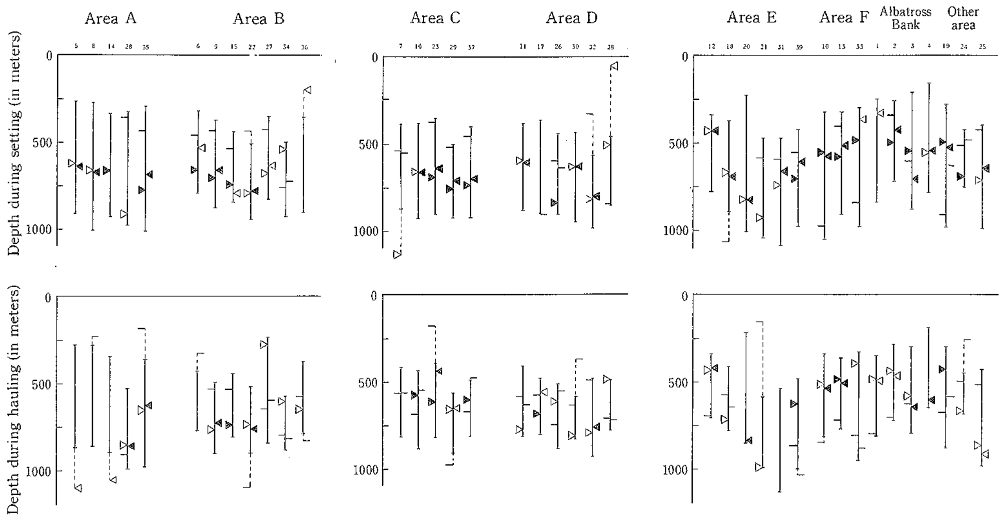


Fig. 7. The depth range covered by respective strings and the estimated depths of maximum catch of sablefish and the minimum one.

Note : 1. Triangle indicates the estimated depth of maximum catch and bar indicates the minimum one.
2. Solid triangle and thick bar are the estimated depths from the significant equation, and open triangle and thin bar are those estimated from the insignificant equation.
3. The marks on the left side of line are the depths of maximum catch and the minimum one estimated from the cubic equation, and those on the right side are those estimated from the quadratic equation.

In regard to the depth range covered by a string, this figure revealed the following between-area variation, in spite of the fact that the trend within the depth range coverd by a string differs according to the locality of the depth range covered (deep or shallow) as well as the size of within-string variation (wide or narrow). The strings in the same area coverd the similar depth range —— wide in Area A but narrow in Areas B,C, and D. In contrast with this, the strings in Areas E and F showed a large between-string variation not only in the depth range but also in the depth difference. For the purpose of comparing the pattern shown by respective equations within the same area with one another and of finding out the reason of causing the diversity in the results, the estimated curves and lines within the applicable depth range of respective equations are illustrated in Fig. 6. The distribution patterns along respective strings were examined with the assistance of this figure and the below-mentioned trends were found out.

In Area A, the positive linear regression (significant in most of the strings) may be due to the fact that the strings in this area were settled from shallower zone than those in the other areas, and the negative quadratic one (also significant in most of the strings) may be due to wide depth range covered by respective strings. The cubic regression was significantly positive in No. 14 and negative in No.35. Practically, however, the estimated minimum of catch in No.14 was very deep out of the applicable depth range, and the relation shown by the cubic equation within the applicable depth range was a simple convex one. In No.35, the estimated depth of minimum catch was shallower than the depth of maximum catch, and the increasing trend in the shallower part than the estimated depth of minimum catch was only in 12% of the skates settled in 20% of the applicable depth range. The density of the hooked individuals in this string was very low and the difference of the density between the estimated minimum and that at the shallowest end was very small when compared with the variation in the other strings. And whether this difference was worthy to discuss or not was doubtful, because the distribution could be at the same time regarded the convex relation as supported by the significantly negative quadratic regression.

The repeat exploitation over the same ground induced the following change in the catch pattern : in No.5, the catch was high throughout the depth zones, showing convex relation to the depth. From No.5 to No.8, the catch declined throughout the depth zones, also keeping the convex relation to the depth. From No.8 to No.14, the catch at an intermediate depth zone was kept at the same level, but that at both the shallowest and the deepest extremes showed further decline. Between No.14 and No.28, the ground was left unfished about two weeks ; however, any symptom of recovery of density of catchable population could not be found out throughout the depth zones. From No.28 to No.35, the catch in the zone deeper than 750 m declined. In consequence, the catch by a string decreased to the level lower than a half of the first shooting in this area (No.5).

In Area B, the linear regression coefficient was positive in the four strings, including the significant one in the two strings, but negative in the three strings, including the significant one in a string. It was, however, hard to find any difference in the settled depth either between the strings taking the positive coefficient and those taking the negative one or between those taking the significant one and those taking the insignificant one, although the difference in the shallowest limit seems to have some relation to the sign of the significant coefficient. The strings were stretched over the wide depth range covering the probable layer of maximum density, and it is natural that most of the strings took negative quadratic coefficient in the quadratic equation. It was, however, hard to find the reason why the coefficient was insignificant in most of the strings. The cubic regression coefficient was negative in all the strings except No. 34, which is the string lacking the skates settled in shallow ground. This fact suggested the possibility of the presence of densely populated zone in shallow part. The significantly negative linear regression in No. 36 may be due to the fact that the string extended to this layer, but the significantly positive one in No.15 and in No. 22 may be due to the fact that these strings were not extended to this layer.

With progress of the repetitious shootings over the same ground, the following change occurred in the catch pattern : in No. 6, the density of the hooked individuals was very high throughout the depth zones especially in the shallowest part (350 m zone); in consequence, a good catch was yielded. From No. 6 to No. 9, the density of hooked individuals declined in the zone shallower than 750 m, especially in the very shallow ground, and the catch decreased into the three quarters. Notable change in the density of hooked sablefish did not occur between No. 9 and No. 15 throughout the depth zones, in consequence the similar amount of fish was landed. The catch recovered from No. 15 to No. 22, attaining the same level to No. 6, but the pattern of bathymetric change in the density was completely different. This string covered the deeper zone than the preceding strings, and the recovery of catch was mainly derived from the high rate of catch in the deep ground where was not fished by the preceding shootings. From No. 22 to No. 27, then to No. 34 and No. 36, the density in the shallow zone was kept in the similar level (being 4 to 5 individuals per skate), but that in the deep ground declined sharply from 7 individuals per skate to 4.5 then into 3.5 and finally into 2 individuals per skate. This resulted in a gradual decrease of catch by a string with repetition of shootings.

In Area C, the linear regression suggested the increasing trend of catch with increase in depth, but the coefficient was significant only in No. 7 and No. 37. The former was the very rare example showing the significantly positive quadratic regression on the depth, contradicting not only to the expectation but also to the trend in the other strings. This string should be left aside the consideration till the reason why showing the significantly positive regression was found out. The increase of catch with increase in depth in No. 37 was significant but very slight when compared with the variation indicated by the significant cubic equation and the significant quadratic one. The quadratic regression coefficient was significantly negative in all the strings except No.7, coinciding with the expectation. This fact meant that the sablefish shows a well-defined bathymetric change in the density showing the maximum at an intermediate depth zone and the strings were settled covering this layer. The cubic regression coefficient was significantly negative in Nos. 23, 29, and 37. The increase of catch in the zone shallower than the estimated depth of minimum catch was negligible in these strings, and there were no inconvenience of regarding them as quadratic.

The comparison of the bathymetric distribution of hooked individuals along the different strings of setlines revealed the following change in accordance with the progress of repetitious shootings in Area C : string No. 7 was one of the very rare examples showing the significantly concave relation of catch to the depth, contradicting not only to the expectation but also to the general trend. The catch was best in this string ; and even the estimated minimum of catch in this string was better than the estimated maximum in the other strings. The catch decreased with repetition of shootings. From No. 7 to No. 16, the catch decreased throughout the depth zones, conspicuously in the shallow part and the deep one but less conspicuously in the intermediate zone. In consequence, the catch in No. 16 attained the level lower than the others, showing the convex relation to the depth. Notable change did not occur between No. 16 and No. 23. The density of catch in the zone deeper than 700 m was kept at the same level from No. 23 to No. 29 and No. 37, but that in the zone shallower than this depth especially around the 500 m zone continued to decrease, in consequence, the occupied rate of a hook dropped from 0.130 (in No. 23) to 0.109 (in No. 29). The decline of catch from No. 29 (0.109) to No. 37 (0.102) was due to the fact that No. 37 extended to shallow zone of low density, although the bathymetric distribution of density on these two strings in the zone deeper than 500 m resembled very closely to each other.

According to the master fisherman, the Areas D and E are recognized commonly as the best grounds for sablefish setlining in the Gulf of Alaska, in respect of high rate of catch and quick recovery of the influence of exploitation. The master fisherman of the boat collecting the records of the present series of reports expected that the boat occupying these areas soon sailed back to her home port, based on the number of days fished and on the capacity of fish hold. And he settled the fishing position at the adjacent and unoccupied areas, for waiting the shift of the boat occupying there. As shown by the string number, this boat repeated shootings in Areas A to C, and could expand her fishing area into these areas about a week after entering into this water. And the boat could occupy 5 main spots including the best two ones. And even the first shooting in this area by this boat did not show the pattern of bathymetric distribution of catch in the ground left unfished over sufficient intervals. In Area D, as expected, the catch was kept at high level till No. 30 or No. 32. This was due to the good catch throughout the depth zones in all the strings except shallower part in No.32 and the deep one in No. 38. As mentioned above, the estimated depth of maximum catch fluctuated string by string, suggesting that the major parts of catch by respective strings should be brought from the different depth zones. The cubic regression was significantly negative in No.26. This was due to poor catch in about 600 m zone, and the same fact made the quadratic regression coefficient significantly positive, although the level of catch in this depth zone of minimum catch was lower than the other strings in this area but was higher than the average level of the strings in the other areas. In the other strings, the linear regression coefficient and the quadratic one inclined to take significantly negative value.

The comparison of the trends shown by respective equations (Fig.6) suggested the reason why the catch was kept at high level till far latter than in the other areas and why the estimated depth of maximum catch fluctuated string by string. From No. 11 to No. 30, the catch throughout the strings was kept at the similar level to one another, being about 6 individuals per skate. In No. 11, the catch was mainly brought from the 600 m zone, showing a significantly convex relation to depth. In No. 17, the catch from this depth zone declined, but the catch from shallow zone compensated this decline, and the catch by a string was kept at the same level. In No. 26, the catch from the 600 m zone showed further decrease, although this was slight. But further increase of catch from shallow zone and marked increase from deep zone sustained the catch by a string at the same level. In No. 30, the catch from these depth zones of good catch decreased, but that from the zone of the estimated minimum catch recovered, in consequence, the catch by a string was kept at the same level showing again the significantly convex relation to depth. The decline of catch from No. 30 to No. 32 was mainly due to that in the estimated depth of maximum catch. This string did not attain the shallow zone ; in consequence, catch by a string dropped and the depth of maximum catch shifted to deep zone (800 m). In No.38, the catch from this zone decreased, but the string attained shallow zone where was left unfished with the preceding strings. Thus, the catch by a string was sustained repeating the following pattern : the zone supplying a good catch to the preceding string declined, but the zone of poor catch recovered. In consequence, the pattern of bathymetric distribution of catch differed string by string, in spite of the fact that the strings were settled in the same area covering the similar depth range. This pattern may be not due to the daily fluctuation of the distribution of fish but may be due to the following technical reason said common to the master fishermen : once a spot was fished, it is necessary to wait the accumulation of fish at least five consecutive days without fishing, otherwise it is hard to expect a good catch. The master fishermen are familiar with the bottom topography of respective fishing spots. And when they are obliged to repeat shootings at the same spot, they endeavor to settle the string along a meandering course of different phase, for the purpose of setting the string passing the unfished parts —— for example, shifting to a little deep or a little shallow, or to start shooting at the shallow part of the turning point in the deepest extreme of the preceding string and turning to shallowward at the point of the shallowest extreme. The pattern obtained in this area may be a good example of the change of catch pattern along this way of consecutive shootings.

Area E was the example showing a large between-string fluctuation of both the level of catch and the pattern of its bathymetric change. The cubic regression coefficient was significant only in No. 39. As shown in Fig. 6, however, the difference of catch between the estimated maximum and the minimum of catch was practically negligible, and there was no inconvenience when the distribution was regarded as quadratic. The quadratic regression was significantly negative in most of the strings; but the estimated depth of maximum catch showed a large between-string fluctuation from 430 m to 830 m (through the significant equations), hardly indicating the guide depth of shooting the line. This fact resulted in the fluctuation of linear regression from significantly positive to significantly negative. In the first string of this area (No. 12), the catch was at a level of five individuals per skate, showing significantly negative linear regression and significantly negative quadratic one. From No. 12 to No. 18, the string shifted deep. There is a narrow and steep ridge protruding to off-shore. No. 18 was shot passing it along its foot. And a good catch was yielded from deep ground. No. 20 was shot in the same ground covering deep zone only two days after the preceding string, for a good catch was yielded from the deep zone in No. 18. It is necessary to shoot the string No. 20 with some phase lag to No. 18, for the purpose of yielding a good catch escaping from the decline of catch due to consecutive shooting over the same ground. And No. 20 resulted in stretched over the ridge, in consequence covering very wide depth range. Better catch than that from the deep zone in No. 18 was yielded in No. 20 from the deep zone not covered by the preceding strings. In accordance with the shift to deep from No. 12 to No. 20 the catch became better and the estimated depth of maximum catch shifted deeper, and the linear regression changed from significantly negative, insignificantly positive, then to significantly positive. The relation between No. 20 and No. 21 was the best example showing the influence of consecutive shootings over the same ground. For a good catch was yielded in No. 20, mainly from very deep ground, No. 21 was shot over the deep zone of the same ground with phase lag, but the catch dropped throughout the depth zones and this trial ended in the poorest catch. From No. 21 to No. 31 and No. 39, this ground was kept unfished longer than one week intervals, for the purpose of waiting for the accumulation of fish. Then, the catch level and its pattern of bathymetric change recovered again into the same level and the same pattern to the first shooting in this area.

The three strings were shot in Area F. The cubic regression was significantly negative in No. 13 but significantly positive in Nos. 10 and 33, suggesting the different pattern. As shown in Fig. 6, these cubic regression equations practically showed the similar pattern to one another. The catch showed the maximum at the 480 m to 580 m zone and decreased sharply in deep grounds. The change in the pattern shown by the regression equations of the same order indicated the drop of catch due to consecutive shootings of short interval and recovery of catch due to a long interval without fishing.

The four strings were shot around the Albatross Bank, south of Kodiak Island, and the three were the other spots than the above-mentioned seven areas. The estimated regression equations, the depth showing either the maximum of catch or the minimum, and the pattern shown by the significant regression equations were illustrated in Tables 4-7 and Figs. 6 and 7, for reference.

2.1.2 Regression of sablefish on the depth estimated from the echogram during hauling

The descriptions in the preceding section were those relating to the regression of catch on the depth sounded during setting. It is, however, very hard to suppose that the line is settled on the depth echo-sounded during setting. The master fishermen endeavored to haul up the line keeping it vertical, otherwise the line was dragged on the sea bed and the catch was slipped off or the line was fastened with bottom objects and it became hard to haul it up. If the line is hauled up being kept vertical, it is possible to estimate the actually settled depth of the line from the echogram during hauling, although the catch and the sounded depth show a phase lag corresponding to the length of the suspended part of the line in water, i.e. corresponding to the sounded depth. If the condition is like this, the bathymetric change of the distribution can be found through examining the regression of catch on the depth estimated from the echogram during hauling.

Contrary to the above-mentioned expectation, however, the results were less clear, when compared with the regression on the depth sounded during setting. The major changes from the regression on the depth sounded during setting to that on the depth estimated from the echogram during hauling were the decrease of the number of strings showing the significantly negative cubic regression and the increase in that showing the insignificantly positive one. The same was true of the quadratic regression. The strings showing the significant cubic regression decreased from 17 to 10, and those showing the significant quadratic one from 27 to 15. When the significance level was left aside the consideration, the negative cubic regression was from 26 to 15 and the negative quadratic one from 34 to 20. In the linear regression, the negative regression became less clear.

As shown in Table 9, the regression on the depth estimated from the echogram during hauling showed the same results to those of the regression on the depth during setting throughout the cubic, quadratic, and linear regressions only in the three strings (Nos. 7,20, and 32). The difference in the trend of the cubic regression on the depth estimated from the echogram during hauling from that on the depth during setting was mainly in the direction of less clear negative regression (or clearer positive one) : the distribution in the 16 strings showed the same trend, that in the 17 strings shifted to less clear negative one or clearer positive one, but the shift to the counter direction was found only in the six strings. The same was true of the quadratic regression : the distribution in the 15 strings showed the same trend, that in the 21 strings shifted to the direction of clearly positive regression but the shift to the counter direction was found only in the three strings. In the linear regression, the distribution in the 11 strings shifted to the direction of positive regression but that in the four strings shifted to the counter direction.

The other differences worthy to note were narrowing trend of the depth range covered and the unclear results of the depth showing the maximum of catch or the minimum one. The former was caused by the deepening trend of the shallowest extreme and the shallowing one in the deepest extreme, probably due to the towing of the line during shooting as the results of insufficient slackness of paying the line and/or due to the dragging of the line over the bottom near the turning points during hauling. The unclear results of the estimated depth of maximum (or minimum) catch were not only due to the decrease in the number of strings showing the significant regression but also due to large fluctuation of the estimated depths.

In Area A, the quadratic regression was significantly positive in No.14, but the estimated equation showed a simple increase of catch without showing clear minimum of catch. The quadratic regression was significantly negative in Nos.28 and 35, but the estimated depth of maximum catch differed greatly (860 m in No.28 and 620 m in No.35). All the strings in this area except No. 35 showed a common trend of increase in the catch with increase in depth. With progress of consecutive shootings, the catch decreased from No. 5 to No. 28 throughout the depth zones. The decrease of catch from No.28 (0.128) to No.35 (0.105) was due to that in deep zone. In spite of the above-mentioned difference between the regression on the depth estimated

Table 8. Regression of the number of sablefish caught by a skate on the echo-sounded depth during hauling

No.	d_1	d_2	$a_{3\cdot0}$	$a_{3\cdot1}\times10^2$	$a_{3\cdot2}\times10^4$	$a_{3\cdot3}\times10^6$	$F_{3\cdot3}$	$a_{2\cdot0}$	$a_{2\cdot1}\times10^2$	$a_{2\cdot2}\times10^4$	$F_{2\cdot2}$	$a_{1\cdot0}$	$a_{1\cdot1}\times10^2$	$F_{1\cdot1}$	N
5	280	865	0.6591	0.0806	−0.0060	0.0001	0.005	0.6865	0.0638	−0.0029	0.570	0.7668	0.0318	27.482**	393
8	280	860	0.0195	0.4335	−0.0803	0.0050	3.493	0.7785	−0.0229	0.0050	1.499	0.6309	0.0339	33.776**	405
14	345	895	−1.5306	1.0862	−0.1667	0.0086	7.774**	0.3475	0.1156	−0.0054	1.458	0.5474	0.0480	54.799**	402
28	530	990	−4.4948	1.8229	−0.2078	0.0078	1.748	−1.1406	0.4630	−0.0269	13.356**	0.4155	0.0483	30.314**	397
35	365	875	0.5645	−0.1584	0.0553	−0.0044	0.511	−0.4075	0.3448	−0.0277	9.518**	0.5657	0.0052	0.224	374
6	430	770	−0.4626	0.7539	−0.1274	0.0072	0.441	1.0407	−0.0181	0.0028	0.087	0.9379	0.0161	3.746	393
9	495	900	3.2851	−1.1404	0.1821	−0.0093	3.597	0.2527	0.2075	−0.0142	7.745**	0.9149	0.0108	3.423	399
15	445	805	7.7582	−3.3675	0.5447	−0.0286	10.160**	0.7605	0.0369	0.0002	0.0007	0.7519	0.0396	29.881**	389
22	520	895	−0.6841	0.6212	−0.0705	0.0025	0.242	0.1935	0.2375	−0.0156	11.615**	0.9594	0.0157	8.559**	403
27	235	840	0.8862	0.1312	−0.0340	0.0024	1.888	1.2649	−0.0942	0.0078	6.881**	0.9925	0.0004	0.008	400
34	575	880	−6.8736	3.4124	−0.4986	0.0238	1.549	1.8410	−0.2753	0.0169	1.024	0.9734	−0.0313	5.069*	386
36	375	785	3.6095	−1.4312	0.2358	−0.0129	3.134	1.1368	−0.1103	0.0066	0.789	0.9071	−0.0311	9.360**	400
7	415	810	2.0560	−0.4070	0.0402	−0.0004	0.004	1.9507	−0.3534	0.0313	19.835**	0.8129	0.0311	19.006**	402
16	435	880	−2.8741	1.7837	−0.2863	0.0152	5.224*	1.1528	−0.1359	0.0124	2.547	0.6049	0.0306	9.995**	396
23	395	815	0.8732	−0.1193	0.0432	−0.0036	12.948**	0.8351	0.0377	−0.0043	6.279*	0.9219	−0.0047	0.876	399
29	565	905	−3.0750	1.5367	−0.1963	0.0080	0.561	−0.0050	0.2548	−0.0196	3.474	1.0588	−0.0360	15.669**	400
37	490	810	−14.8924	7.3370	−1.1516	0.0601	11.123**	1.0242	−0.1884	0.0200	1.812	0.1648	0.0758	36.508**	395
11	410	810	3.1724	−1.0093	0.1515	−0.0074	0.874	1.6305	−0.2116	0.0167	4.256*	1.0347	−0.0090	1.146	401
17	480	800	14.3318	−6.5010	1.0416	−0.0552	9.131**	0.5052	0.1491	−0.0133	0.732	1.0340	−0.0199	2.616	400
26	510	880	−2.9933	1.7697	−0.2633	0.0129	1.676	1.0114	−0.0296	0.0027	0.070	0.8888	0.0071	0.621	400
30	585	825	12.5602	−5.0419	0.7130	−0.0331	0.432	0.8716	−0.0530	0.0071	0.067	0.5164	0.0483	9.305**	380
32	480	925	2.4155	−0.8837	0.1460	−0.0076	1.297	−0.1227	0.2402	−0.0158	4.123*	0.6864	0.0115	1.043	388
38	485	775	−3.5539	2.3185	−0.4022	0.0224	0.714	2.0646	−0.3864	0.0268	1.621	0.9473	−0.0375	4.202*	318
12	340	705	−0.8250	1.0805	−0.2025	0.0119	2.371	0.7411	0.1319	−0.0156	5.951*	1.1528	−0.0318	26.021**	402
18	415	780	4.0718	−1.4911	0.2331	−0.0120	1.287	1.5178	−0.1846	0.0143	2.037	0.9772	−0.0065	0.407	400
20	220	850	−0.0219	0.2992	−0.0305	0.0010	0.150	0.1264	0.2034	−0.0121	7.787**	0.5289	0.0588	45.733**	403
21	590	990	0.3803	−0.0415	0.0153	−0.0008	0.274	0.3753	0.0180	0.0006	0.085	0.3589	0.0254	8.616**	328
31	540	1130	3.6017	−0.9993	0.1175	−0.0046	0.987	0.9840	−0.0257	−0.0004	0.004	1.0156	−0.0337	9.809**	395
39	485	1000	−5.7868	2.8217	−0.3892	0.0174	14.264**	1.1066	−0.0553	0.0026	0.191	0.9619	−0.0154	2.879	400
10	340	810	−1.4662	1.2065	−0.1887	0.0092	1.733	0.2469	0.2759	−0.0256	9.749**	1.1360	−0.0322	9.960**	399
13	365	770	−3.8117	2.5192	−0.4338	0.0239	6.772**	0.1937	0.2813	−0.0276	8.623**	1.0315	−0.0286	7.319**	403
33	330	950	0.7970	0.1346	−0.0255	0.0014	0.837	1.1040	−0.0292	0.0016	0.499	1.0402	−0.0077	3.412	399
19	300	880	−0.7982	0.8953	−0.1708	0.0103	4.424*	0.9768	−0.1081	0.0092	1.633	0.6936	−0.0023	0.055	399
24	450	685	8.8390	−4.3121	0.7571	−0.0433	2.465	0.8021	−0.0473	0.0091	0.280	0.4997	0.0586	25.100**	400
25	430	980	1.9094	−0.6640	0.1030	−0.0049	0.781	0.0766	0.1217	−0.0066	0.534	0.4204	0.0246	3.341	401
1	350	810	−0.9478	0.9327	−0.1546	0.0080	1.087	0.4652	0.1526	−0.0154	2.688	0.9510	−0.0236	3.750	363
2	285	720	−0.1714	0.5569	−0.1032	0.0060	0.372	0.4740	0.1345	−0.0143	1.609	0.7950	−0.0049	0.185	392
3	300	795	−2.9613	1.8065	−0.2992	0.0164	2.985	−0.7390	0.4495	−0.0349	8.624**	0.1517	0.0881	27.406**	392
4	190	650	−2.3512	1.8567	−0.4024	0.0291	7.073**	−0.5481	0.3742	−0.0310	6.470*	0.0338	0.0986	29.036**	400

Note: No. . . . . . String number
d_1. . . . . . . The shallowest limit in the string (in meters)
d_2. . . . . . . The deepest one

$$\log\left(y+\frac{n}{2}\right) = a_{3\cdot0} + a_{3\cdot1}x + a_{3\cdot2}x^2 + a_{3\cdot3}x^3$$

$$\log\left(y+\frac{n}{2}\right) = a_{2\cdot0} + a_{2\cdot1}x + a_{2\cdot2}x^2$$

$$\log\left(y+\frac{n}{2}\right) = a_{1\cdot0} + a_{1\cdot1}x$$

x. . . . . Echo-sounded depth in meters
y. . . . . Number of individuals caught by a skate
n . . . . A parameter of the negative binomial series (shown in Table 1)
$F_{i\cdot i}$ . . . . . . The estimated value of the Snedecor's F for $a_{i\cdot i}$ with 1 and $N-i-1$ degrees of freedom
N . . . . Number of skates in the string
* significant at 0.05 level   ** significant at 0.01 level

Table 9. Comparison of the regression of sablefish on the depth estimated from the echogram during hauling with that on the depth during setting

1) Cubic regression

		Hauling			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Setting	Significantly positive	14A, 19	10F, 33F, 3		
	Insignificantly positive	16C	5A, 8A, 34B, 38D, 20E	11D, 18E	
	Insignificantly negative	4	28A, 22B, 27B, 12E, 1	36B, 7C, 30D, 32D, 21E, 31E, 25	17D
	Significantly negative	37C, 39E, 13F	6B, 29C, 26D, 2	35A, 9B, 24	15B, 23C

2) Quadratic regression

		Hauling			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Setting	Significantly positive	7C	26D		
	Insignificantly positive		34B, 24	17D	
	Insignificantly negative	27B	6B, 15B, 36B, 38D, 21E, 33F	1	28A
	Significantly negative	11D	8A, 16C, 37C, 30D, 18E, 39E, 19	5A, 14A, 29C, 31E, 2, 25	35A, 9B, 22B, 23C, 32D, 12E, 20E, 10F, 3, 4

3) Linear regression

		Hauling			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Setting	Significantly positive	5A, 8A, 14A, 28A, 15B, 22B, 7C, 37C, 20E, 21E, 3, 4, 24			
	Insignificantly positive	16C	35A, 9B, 27B, 26D, 32D	23C, 18E	
	Insignificantly negative		6B, 25		34B, 29C
	Significantly negative	30D		11D, 17D, 39E, 33F, 1, 2, 19	36B, 38D, 12E, 31E, 10F, 13F

Note : For example, 14A means the string No.14 in Area A.

from the echogram during hauling and that on the depth during setting in respect of the general trend and the order and sign of the estimated regression equations, the relations represented by the estimated equations did practically not show any notable difference except the trend in the zone deeper than 850 m in No. 14. And the number of skates relating to this difference was only 31. The comparison of the present results with those of the regression on the depth during setting revealed the following facts : both of the results showed the similar pattern in regard to the decrease of catch with the progress of repetitious shootings.

In Area B, the cubic regression was significantly negative only in No.15. The same trend was found also in the regression on the depth during setting. The quadratic regression was significantly negative in Nos. 9 and 22, showing the maximum of catch about 750 m zone. The same trend was also found in the regression on the depth during setting. That was significantly positive in No.27, due to the high rate of catch in shallow zone not covered by the preceding strings. The linear regression was significantly positive in Nos.15 and 22 showing the major parts of catch from deep zone, but was significantly negative in Nos.34 and 36 due to decrease of catch from deep zone. The similar trend was found in the regression on the depth during setting. The comparison of the regression on the depth estimated from the echogram during hauling with that on the depth during setting revealed the following trends : there was no basic difference between them in Nos.9, 15, 22, and 36 ; but somewhat clear difference between them was found in Nos.6, 27, and 34. Namely, when both the regression on the depth during setting and that on the depth estimated from the echogram during hauling were significant, the estimated equations showed the similar pattern regardless of their order and sign.

With progress of the consecutive shootings in this area, the bathymetric distribution of catch showed the following changes : in the first shooting (No. 6) the catch was high, being from 6 to 7 individuals per skate. From No.6 to No.9, the catch decreased throughout the depth zones, especially in deep zone, because of short interval between them. From No.9 to No.19, the catch in deep zone (about 750 m) recovered. From No.15 to No.22, the string shifted a little deeper and the catch increased throughout the depth zones, probably because this ground was left unfished over a week. String No.27 extended to shallow zone which was not exploited by the preceding strings. The catch from the zones fished by No.22 decreased, but that from unexploited shallow zone was in high level. This fact resulted in significantly positive quadratic regression. No.34 shifted deep, but the catch decreased, in spite of the fact that this ground was left unfished a week. From No.34 to No.36, the catch decreased throughout the depth zones, due to short interval between these two strings.

In Area C, the clearest trend of the bathymetric distribution of catch was a sharp increase of catch with increase in depth found in the zone deeper than 750 m. This trend resulted in the significantly positive cubic regression in Nos. 16 and 37 and the significantly positive quadratic one in No. 7. The similar trend was found only in No. 7 through the regression on the depth during setting. But no symptoma of this pattern in Nos.16 and 37 were found in the regression on the depth during setting. The other notable trend found in Fig. 10 was a marked drop of catch from No. 7 to No. 16 throughout the depth zones. This was also clearly shown in the regression on the depth during setting. The clearest difference of the regression on the depth estimated from the echogram during hauling from that on the depth during setting was as follows : the clear bathymetric change of catch was found through the regression on the depth during setting, but it was hard to find it through the regression on the depth estimated from the echogram during hauling.

With progress of the consecutive shootings in this area the following changes of catch pattern occurred : in spite of the fact that this ground was exploited interrupting sufficient intervals, the catch did not show any clear symptom of recovery. This may have some relations to the fact that all the strings were settled covering the similar depth range, because the recovery of catch in the other areas were mainly brought from the zones not exploited by the preceding shootings. The catch was best in the first string (No. 7) of this area. Then, the catch was kept at low level from No. 16 to No. 29, and finally dropped into very low level. This trend was clear in the zone shallower than 750 m.

In Area D, the estimated pattern of the bathymetric distribution of catch through the regression on the depth estimated from the echogram during hauling showed a marked difference from that through the regression on the depth during setting : the number of equations with the significant coefficient was only five, one being cubic, and each two being quadratic and linear. And both of the examinations showed the similar pattern (significance and sign) only in the quadratic relation in No. 32 and the linear one in No. 38. In No. 11, the quadratic regression was significantly positive in the present examination, but was significantly negative in the preceding one. In No.17, the cubic regression was significantly negative in the preceding examination, but the difference of the density of catch between the estimated depth of maximum catch and the estimated depth of minimum one was far smaller than the density variation within this string. And if it was regarded that the density decreased with the depth (although the linear regression coefficient was insignificant), the similar pattern was found in the precedng examination. But the present examination showed far large bathymetric difference than the preceding examination, in spite of the narrow depth range covered (530 m in the depth range during setting and 320 m in that during hauling). In No. 26, the significant cubic and quadratic equations in the preceding examination showed the similar trend with minimum of catch at 600 m ; but all the regressions became insignificant in the present examination. And the similar pattern to that found in the preceding examination was found through the present one only in Nos. 32 and 38.

With progress in the consecutive shootings, the following changes occurred in the bathymetric distribution of catch : the catch was kept at the similar level from No. 11 to Nos. 17 and 26, in spite of the fact that the type of bathymetric distribution differed according to the string, especially in the deep zones. This may be due to sufficiently long intervals between the succeeding strings. The catch showed gradual decrease from No. 26 to No. 38, first due to the decrease in shallow zone, then in the deep one, because of short intervals except the last one.

In Area E, the significantly negative cubic regression in No.39 was changed into the significantly positive one in the present examination and some equations with significant coefficient became insignificant. But they all did not cause any basic difference in the estimated pattern. And it may be said that the present examination showed the similar results to those of the preceding one.

With progress in consecutive shootings in this area, the bathymetric distribution of catch showed the following changes : in No.12, the catch showed a significantly negative quadratic regression on depth. From No. 12 to No. 18, the catch in the shallow grounds was kept at the similar level, but that in the deep grounds recovered. In consequence, the catch increased and the trend of decrease in deep zone disappeared. The boat shifted a short distance toward the ridge, for attacking again this area within a short interval. The parts in No.20 extending to very shallow zones were for passing over this ridge. And as the result of this trial, the boat encountered a dense population in deep zone at the foot of this ridge and yielded a very good catch. For the purpose of attacking again this dense population, the boat shot the line consecutively in the same area but in the different phase of meandering. And the line passed along the foot of this ridge ; and the string shifted a little deeper and no part extended into very shallow zone. In spite of this intention, the result ended in extremely poor catch throughout the depth zones. This is the best example of showing the marked decline of catch by the successive attack in the same area. The comparison of the distribution in Nos. 21, 31, and 39 showed the process of recovery of catch in the area left unfished over about 10 days.

In Area F, the significantly negative cubic regression in No. 13 of the preceding examination was changed into the significantly positive one in the present examination. They differed in the form of the equation, however, they showed the similar trend of a negative quadratic equation. The cubic regression in Nos.10 and 33 and the linear one in No.33 became insignificant in the present examination. But it may be said that there were no basic differences of the pattern of bathymetric change between the present and the preceding examinations.

The four strings were settled around the Albatross Bank. There were no basic differences between the present and the preceding examinations in the pattern deduced from the linear regression, although that in Nos.1 and 2 became insignificant in the present examination. The same was true of the pattern deduced from the cubic and the quadratic equations except in No.2.

The three strings were settled in the other areas. The estimated equations and the trends shown by them were illustrated in Table 8 and Fig. 6 for reference.

2.2 Regression of idiot

The idiot is the most important by-catch, but this can not be the main objective, because of its low density and insufficiently high commercial value. If this fish were dense in the other zone than that covered by the present strings, it were hard to estimate not only the pattern of bathymetric distribution but also the depth of maximum density through the present records. And the present records were useful only for evaluating whether the method of analysis adopted here can effectively show the bathymetric change of sablefish or not, i.e. whether the bathymetric distribution pattern of sablefish deduced from the results in the preceding sections is valid or not. If the strings covered at least a part of the zone occupied by idiot, and if the method adopted here can represent the bathymetric change of the distribution, a clear and simple pattern of bathymetric change of this species may be deduced from the results. It is very hard to settle all the skates in a string without accident : some skates are hung over the bottom because the fishing ground is very rough or the line is settled too tight over rough ground or because some hooks are tangled with the marker line or marker line is tangled within itself. Some other skates are tangled within the skates. Some are settled safe, but the catch are slipped off because the line is dragged over the rough ground during careless hauling. The accidents of the last two types are apt to occur near the turning points of the string. And the accidents of these types modify the catch even from the ground of equal density into seemingly negative quadratic depth regression. If the case were like this, the catch of idiot showed the similar pattern to that of sablefish. Some clues to clear up the above-mentioned doubts may be found through the examination of the depth regression of number of idiot caught by respective skates. The examination on the depth regression of sablefish indicated the significant cubic relation in some strings showing sharp increase of catch either near the shallowest extreme or near the deepest one.

It is hard to neglect the possibility of this pattern derived from the phase lag of estimated depth of respective skates to the catch by them. This possibility may be tested through examining whether or not the significant cubic regression of the similar pattern to that of sablefish can be found in the catch pattern of idiot in the strings showing the significant cubic regression of sablefish.

Besides the above-mentioned technical problems in the fishing process and in the data analysis, the following biological facts should be kept in mind in interpreting the results : it is probable that the distribution of hooked individuals of idiot suffers from that of sablefish, for during hauling work we frequently observed the sablefish hooked because they took not directly the bait but took the small individuals of idiot hooked along the line.

2.2.1 Regression of idiot on the depth sounded during setting

The cubic regression coefficient in more than the three quarters of the strings was insignificant, distributing evenly in positive side and in negative one. The quadratic regression coefficient was negative in the 35 strings (significantly in the 20 strings but insignificantly in the 15 ones) out of the 39 ones. The linear regression coefficient was significantly negative in the 24 strings and insignificantly negative in the 11 ones. No strings showed either the significanlty positive quadratic regression or the significantly positive linear one. These facts meant that there was very little possibility of the distribution showing the cubic regression on the depth, but showed the convex relation to the depth and the skates were settled mainly between the estimated depth of maximum catch and the deepest extreme.

The distribution of equations with significant regression coefficient showed some areal differences : all the strings in Area A did not show any significant quadratic and linear regressions except the latter in No.35, and all those settled around the Albatross Bank did not show any significant quadratic one. And most of the quadratic and linear regression equations for the strings settled in the other areas were apt to be significantly negative.

As shown in Table 6, the depths of maximum catch estimated from the regression equations were concentrated into the zone a little shallower than those of sablefish —— from 500 m to 700 m. Areal difference was found also in the distribution of the estimated depths of maximum catch : those in Areas B,D, and F were concentrated into the above-mentioned depth range ; but those in Areas C and E showed deepening trend with progress of consecutive shootings, and those in Area A were scattering over wide depth range, and those around the Albatross Bank shifted shallowward.

In Area A, it was difficult to find the trend of bathymetric distribution of catch and its change with progress of consecutive shootings, because most of the estimated regression equations were insignificant. Figure 8 showed, however, somewhat clear trend of increase of catch with progress of consecutive shootings, which was contrary to the change of the catch of sablefish, suggesting the dominancy of sablefish over idiot in taking bait.

In Areas B, C, D, and E, most of the strings showed the significantly negative quadratic regression with the maximum of catch at an intermediate depth zone. This is the expected form of bathymetric distribution of catch, in spite of the fact that the line is settled for aiming at the sablefish as the main objective and the idiot is no more than the most important by-catch. The linear regression was also significantly negative in most of the strings, indicating that the major parts of the line settled deeper zone than the estimated depth of maximum catch. This may be due to the fact that the idiot is a by-catch and occupys the shallower zone than the main

Table 10. Regression of the number of idiot caught by a skate on the echo-sounded depth during setting

No.	d_1	d_2	$a_{3\cdot0}$	$a_{3\cdot1}\times10^2$	$a_{3\cdot2}\times10^4$	$a_{3\cdot3}\times10^6$	$F_{3\cdot3}$	$a_{2\cdot0}$	$a_{2\cdot1}\times10^2$	$a_{2\cdot2}\times10^4$	$F_{2\cdot2}$	$a_{1\cdot0}$	$a_{1\cdot1}\times10^2$	$F_{1\cdot1}$	N
5	265	910	−0.9409	0.5211	−0.0959	0.0055	5.280*	−0.1091	0.0143	−0.0009	0.056	−0.0825	0.0037	0.339	393
8	275	1005	−0.0622	0.1798	−0.0264	0.0012	1.913	0.1945	0.0377	−0.0026	2.145	0.2865	0.0047	1.946	405
14	335	925	−0.4168	0.1890	−0.0187	0.0002	6.829**	0.1452	−0.0160	0.0002	3.119	0.0598	−0.0006	0.032	402
28	325	975	−1.2669	0.6261	−0.0945	0.0045	2.640	−0.1527	0.0608	−0.0048	1.028	0.0548	−0.0046	0.266	397
35	295	1010	−0.1063	0.2276	−0.0353	0.0016	2.963	0.2994	0.0190	−0.0021	1.299	0.3861	−0.0094	6.000*	398
6	320	790	0.0011	0.0793	0.0058	−0.0016	0.074	−0.2642	0.2298	−0.0215	9.926**	0.4315	−0.0194	4.055*	399
9	375	875	−0.0084	−0.1404	0.0554	−0.0046	0.659	−1.0498	0.3870	−0.0310	14.905**	0.1943	−0.0120	1.234	399
15	440	840	−1.5098	0.9542	−0.1346	0.0061	1.835	0.1182	0.1796	−0.0138	9.045**	0.7024	−0.0021	0.196	401
22	510	940	0.4598	0.0358	−0.0009	−0.0002	0.005	0.3616	0.0783	−0.0069	2.678	0.6973	−0.0196	17.450**	403
27	350	825	−0.3270	0.3134	−0.0411	0.0015	0.088	−0.0254	0.1545	−0.0139	4.307*	0.4883	−0.0179	4.638*	400
34	500	925	−0.6142	0.4413	−0.0732	0.0034	0.117	0.5993	−0.0821	0.0010	0.006	0.5449	−0.0667	25.645**	400
36	355	900	−0.8036	0.6086	−0.1045	0.0055	2.626	0.3845	−0.0056	−0.0020	0.161	0.4577	−0.0302	16.146**	400
7	385	870	−0.0713	0.2901	−0.0503	0.0026	0.505	0.5107	−0.0096	−0.0005	0.012	0.5301	−0.0161	7.814**	405
16	380	925	−1.6993	0.8398	−0.1140	0.0048	1.439	−0.4568	0.2377	−0.0196	11.209**	0.3603	−0.0204	6.506*	396
23	350	900	−0.4123	−0.0268	0.0426	−0.0041	0.373	−1.2859	0.4307	−0.0340	13.450**	−0.0699	0.0118	0.886	399
29	500	920	0.7202	−0.4698	0.1030	−0.0065	0.656	−1.5975	0.5319	−0.0388	19.753**	0.3827	−0.0297	9.638**	400
37	400	920	4.0857	−1.9271	0.3071	−0.0159	10.419**	−0.3168	0.1615	−0.0135	3.983*	0.2809	−0.0214	5.264*	399
11	380	880	1.6723	−0.8593	0.1607	−0.0095	3.540	−0.6125	0.2773	−0.0222	11.116**	0.2569	−0.0066	0.589	401
17	365	895	0.8241	−0.3619	0.0719	−0.0045	0.882	−0.2393	0.1708	−0.0142	4.410*	0.3086	−0.0093	0.912	400
26	440	900	−2.7720	1.3060	−0.1879	0.0084	0.846	−0.4839	0.2225	−0.0206	3.036	0.3847	−0.0493	13.352**	400
30	435	945	0.3552	−0.1792	0.0484	−0.0034	0.637	−0.6379	0.2856	−0.0221	14.573**	0.3298	−0.0121	2.251	400
32	565	980	−1.7728	0.5852	−0.0469	0.0004	0.002	−1.5557	0.4990	−0.0357	11.303**	0.5366	−0.0528	19.428**	388
38	460	850	−6.0709	2.7065	−0.3779	0.0169	1.793	−1.5469	0.5624	−0.0452	14.887**	0.3790	−0.0337	6.583*	318
12	340	780	−1.5377	1.1759	−0.2158	0.0125	6.862**	0.4880	0.0236	−0.0041	0.548	0.6087	−0.0222	11.394**	402
18	375	895	−1.0229	0.4355	−0.0380	0.0003	0.002	−0.9491	0.3987	−0.0320	16.373**	0.3623	−0.0185	2.812	408
20	225	1010	−1.1986	0.5483	−0.0747	0.0030	2.406	−0.6589	0.2281	−0.0186	22.903**	0.1051	−0.0203	4.735*	403
21	475	1045	−2.3858	0.9901	−0.1243	0.0049	2.883	−0.2825	0.1274	−0.0095	4.331*	0.2805	−0.0217	9.830**	328
31	475	1090	0.3901	−0.3401	0.0621	−0.0034	0.976	−1.0541	0.2596	−0.0182	8.804**	−0.0393	−0.0173	2.842	395
39	425	980	3.6682	−1.6240	0.2486	−0.0125	6.823**	−0.1882	0.1362	−0.0117	2.886	0.3617	−0.0271	7.243**	400
10	325	1055	−0.2864	0.3326	−0.0475	0.0021	6.693*	0.3403	0.0334	−0.0026	2.701	0.4530	−0.0020	0.434	399
13	325	910	0.1073	0.0187	0.0073	−0.0010	0.102	−0.0908	0.1275	−0.0117	5.554*	0.2932	−0.0107	2.213	403
33	300	980	0.4523	−0.2136	0.0435	−0.0028	1.528	−0.1970	0.1263	−0.0118	9.546**	0.2569	−0.0255	11.799**	399
19	280	985	−0.2424	0.0993	−0.0205	0.0007	0.054	−0.0819	0.0127	−0.0059	1.049	0.1280	−0.0610	36.493**	399
24	425	755	4.1548	−2.1400	0.3953	−0.0237	3.429	−0.5609	0.3216	−0.0261	5.423*	0.3574	0.0077	0.634	400
25	400	995	2.2909	−1.1628	0.1816	−0.0092	4.909*	−0.4810	0.1263	−0.0107	2.860	0.0018	−0.0212	4.205*	401
1	250	840	−1.1332	0.9280	−0.1828	0.0111	6.848**	0.4532	−0.0268	−0.0004	0.003	0.4658	−0.0316	9.267**	363
2	260	720	0.7453	−0.1837	0.0366	−0.0029	0.229	0.4718	0.0041	−0.0046	0.393	0.5680	−0.0391	23.121**	392
3	210	880	−0.0760	0.2802	−0.0669	0.0045	2.545	0.4391	−0.0667	0.0046	0.742	0.3294	−0.0198	3.869*	392
4	160	785	−0.1140	0.2594	−0.0738	0.0057	1.456	0.3087	−0.0744	0.0050	0.407	0.2031	−0.0264	3.886*	400

Note : No. . . . . . String number

d_1. . . . . . . The shallowest limit in the string (in meters)

d_2. . . . . . . The deepest one

$\log(y+\frac{n}{2}) = a_{3\cdot0} + a_{3\cdot1}x + a_{3\cdot2}x^2 + a_{3\cdot3}x^3$

$\log(y+\frac{n}{2}) = a_{2\cdot0} + a_{2\cdot1}x + a_{2\cdot2}x^2$

$\log(y+\frac{n}{2}) = a_{1\cdot0} + a_{1\cdot1}x$

x. . . . . Echo-sounded depth in meters

y. . . . . Number of individuals caught by a skate

n . . . . A parameter of the negative binomial series (shown in Table 2)

$F_{i\cdot i}$ . . . . . . The estimated value of the Snedecor's F for $a_{i\cdot i}$ with 1 and $N-i-1$ degrees of freedom

N. . . . . . . Number of skates in the string

* significant at 0.05 level ** significant at 0.01 level

Table 11. Trend and significance of the depth regression of idiot caught by a setline

Area		Setting A	B	C	D	E	F	Sum	Hauling A	B	C	D	E	F	Sum
$a_{3\cdot3}$	Significantly positive	2	0	0	0	1	2	5	0	1	0	0	1	1	3
	Insignificantly positive	3	4	2	3	3	3	18	3	3	2	3	3	6	20
	Insignificantly negative	0	3	2	3	1	4	13	2	2	2	3	2	1	12
	Significantly negative	0	0	1	0	1	1	3	0	1	1	0	0	2	4
$a_{2\cdot2}$	Significantly positive	0	0	0	0	0	0	0	2	1	0	0	1	1	5
	Insignificantly positive	1	1	0	0	0	2	4	3	3	1	2	1	1	11
	Insignificantly negative	4	2	1	1	2	5	15	0	3	4	3	3	5	18
	Significantly negative	0	4	4	5	4	3	20	0	0	0	1	1	3	5
$a_{1\cdot1}$	Significantly positive	0	0	0	0	0	0	0	1	0	0	0	0	1	2
	Insignificantly positive	2	0	1	0	0	1	4	1	1	2	2	1	2	9
	Insignificantly negative	2	2	0	3	2	2	11	2	2	1	1	2	4	12
	Significantly negative	1	5	4	3	4	7	24	1	4	2	3	3	3	16

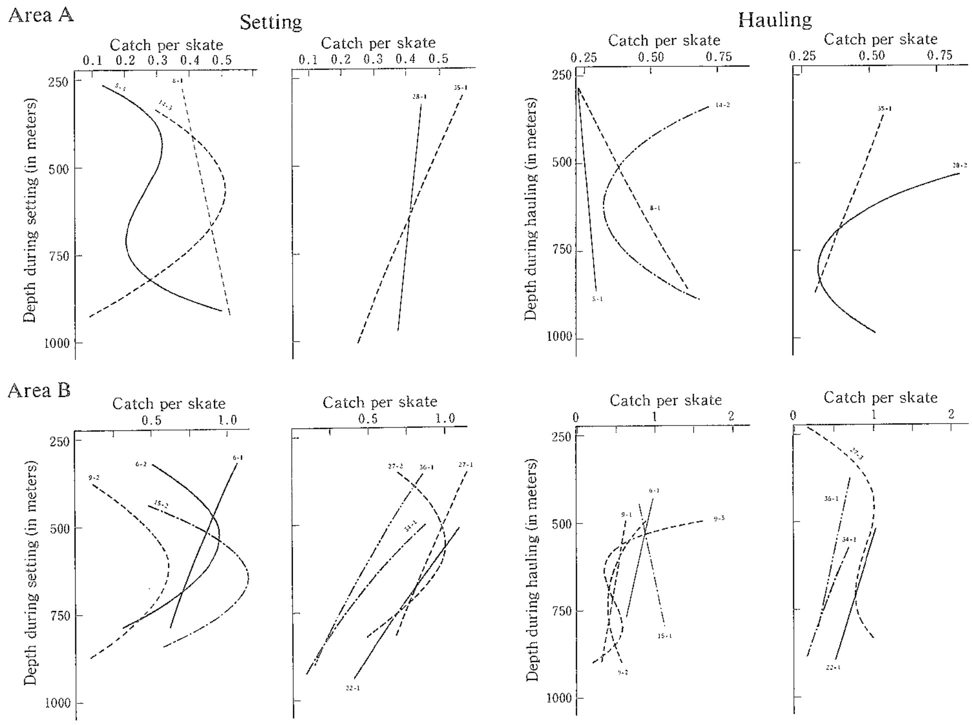


Fig. 8—1.

Fig. 8. Bathymetric change of catch per skate of idiot.

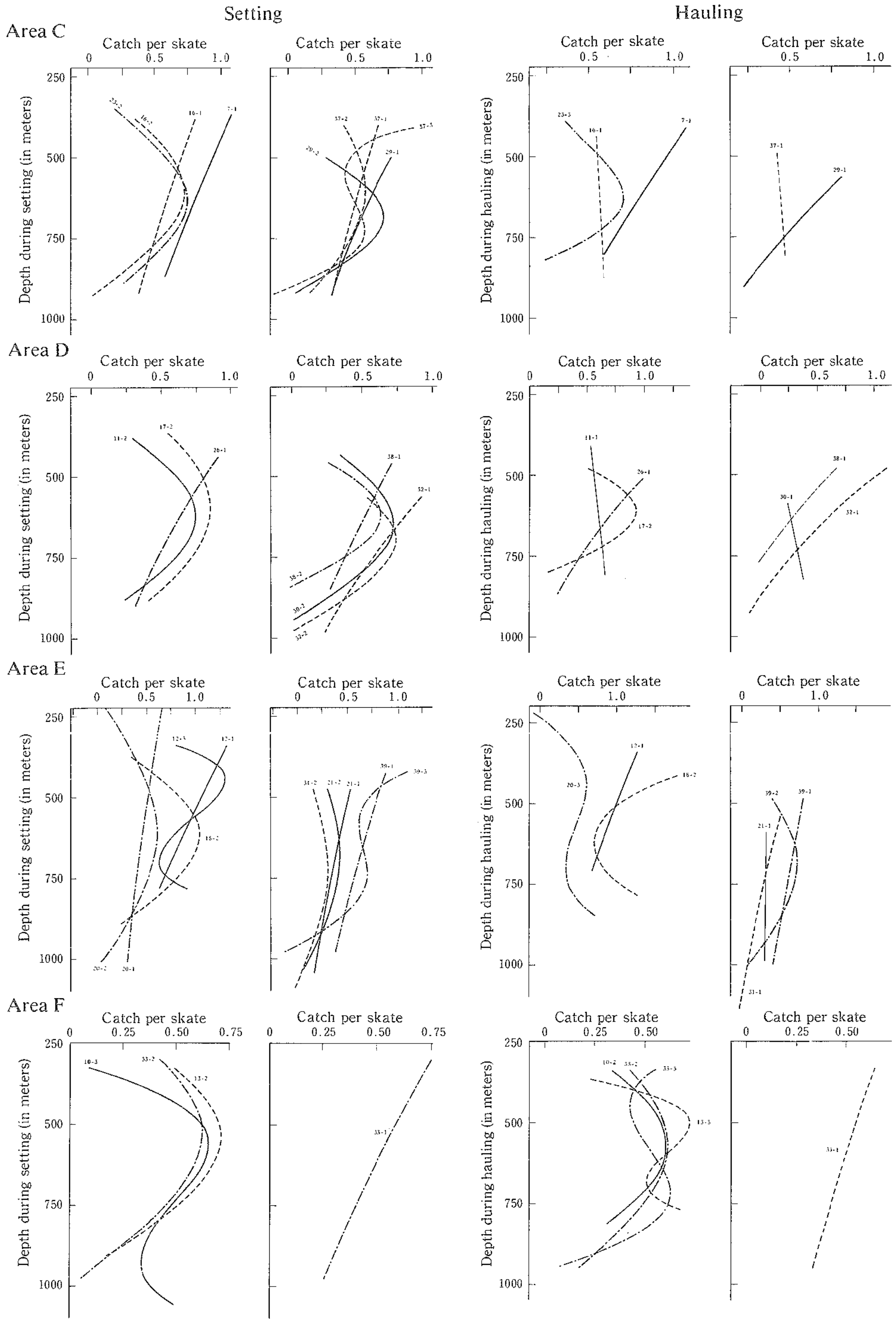

Setting
Hauling
Area C
Area D
Area E
Area F
Catch per skate
Depth during setting (in meters)
Depth during hauling (in meters)
250
500
750
1000
0
0.5
1.0
0.25
0.50
0.75

Fig. 8—2.

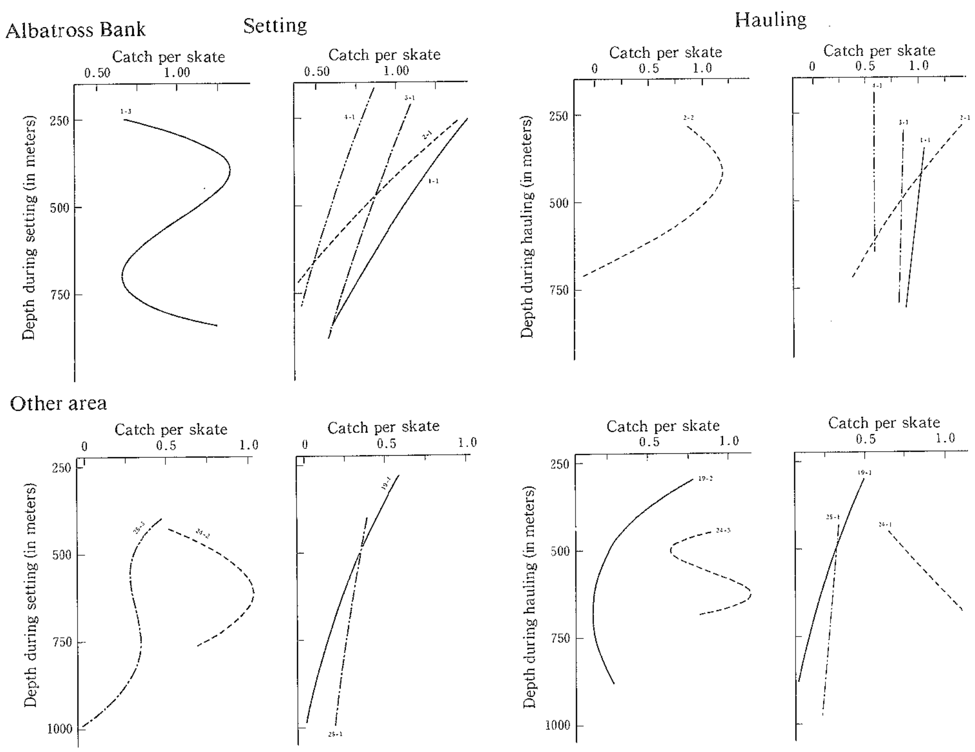


Fig. 8—3.

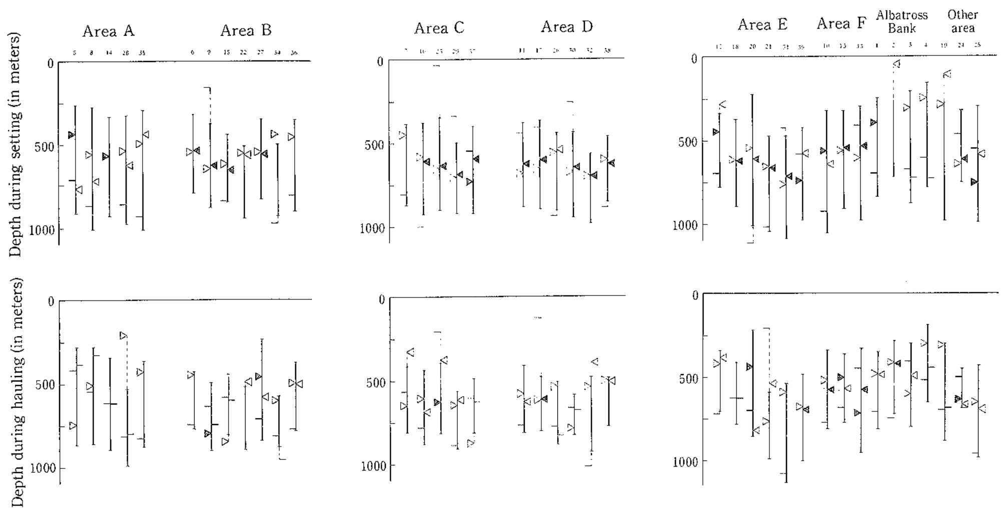


Fig. 9. The depth range covered by respective strings and the estimated depths of maximum catch of idiot and the minimum one.

objective, sablefish. In Area B, the quadratic equations indicated that the estimated depth of maximum catch was found between 530 m and 650 m. The distribution of curves and lines in Fig. 8 showed a trend of a good catch in Nos.6, 15, and 27, and a poor catch in the other strings, but it was hard to find any clear relation between the sablefish and this species both in the distribution pattern and in the level of catch. In area C, the estimated depth of maximum catch shifted from 450 m to 730 m with repetition of shootings. In Area D, the distribution of catch showed a clear convex relation to depth, and the estimated depths of maximum catch through respective equations were concentrated in the zone from 500 m to 700 m deep, mainly 600 m to 700 m, in spite of the fact that the estimated depths of maximum catch of the main objective (sablefish) showed a large fluctuation which made it hard to find the general trend. In Area E, the estimated depths of maximum catch shifted to deep zone in accordance with deepening trend of the depth range covered, i.e. in accordance with the progress of consecutive shootings. And Fig.8 added the following information : the catch decreased with the progress of consecutive shootings except in No.39, because of the same trend throughout the depth zones especially in the zone shallower than 800 m. In Area F, the catch along No.10 showed a significantly positive cubic regression and that along Nos.13 and 33 showed a significantly negative quadratic one. At the same time, however, the catch along these strings could be regarded as showing convex relation to the depth, taking closely similar values to one another, except the catch in the very shallow and deep parts in No.10. And the estimated depths of maximum catch concentrated into the zone of 500 m to 600 m deep.

Four other strings were settled around the Albatross Bank. The distribution pattern of catch along these strings was examined, but it was hard to find any other notable change than the decreasing trend of catch with depth. The three strings were settled in the other areas. The estimated patterns of the bathymetric distribution of catch of idiot along these strings were shown in Fig. 8, for reference.

The above-mentioned results were those relating to the distribution pattern of idiot. It is necessary to give a short consideration on the question as to the validity of the method of data analysis employed here. There were several strings showing the significantly negative or positive cubic relation of catch of sablefish to the depth, indicating some parts of low catch at an intermediate depth zone and/or extremely good catch near either of the extreme depths. There were some other strings showing significantly positive quadratic regression of catch of sablefish, contrary to the expectation, also indicating a part of low catch at an intermediate depth zone. If these trends were not derived from the distribution pattern of fish but derived from either the uncorrect estimation of depth or due to the presence of the skates unable to fulfill their efficiency because of accident of technical reason, the catch of idiot along these strings should take the similar pattern to that of sablefish. To examine this possibility, the trend of bathymetric change of the catch of idiot was compared with that of sablefish. As shown in Table 12, the catch pattern of both of the sablefish and the idiot took the same form (sign and significance) of cubic regression in the 14 strings, quadratic one in the 16 strings, and linear one in the 9 strings. And when all the cubic, quadratic, and the linear regressions were taken into account, both of the sablefish and the idiot took the same form of regression in no string. Even when the significance was left aside the consideration, both of the species took the similar pattern throughout the order of regression in the 5 strings (Nos. 23, 29, 30, 31, and 13) out of the 39 ones. These facts suggested that the above-mentioned distribution pattern of sablefish and idiot should be neither due to the uncorrect estimation of the depth nor due to the presence of skates of low efficiency derived from accident at an intermediate depth zone, but due to the bathymetric change of the density of respective species.

Table 12. Comparison of the regression of idiot on the depth during setting with that of sablefish on the same depth

1) Cubic regression

		Idiot			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Sablefish	Significantly positive	14A, 10F	3, 19	33F	
	Insignificantly positive	5A	8A, 34B, 16C, 38D, 18E, 20E	11D	
	Insignificantly negative	12E, 1	28A, 27B, 36B, 7C, 32D, 21E, 4	22B, 17D, 30D, 31E	25
	Significantly negative		35A, 15B, 26D	6B, 9B, 23C, 29C, 13F, 2, 24	37C, 39E

2) Quadratic regression

		Idiot			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Sablefish	Significantly positive			7C, 26D	
	Insignificantly positive		34B		17D, 24
	Insignificantly negative			28A, 36B, 1	6B, 15B, 27B, 38D, 21E, 33F
	Significantly negative		14A, 3, 4	5A, 8A, 35A, 22B, 12E, 39E, 10F, 2, 19, 25	9B, 16C, 23C, 29C, 37C, 11D, 30D, 32D, 18E, 20E, 31E, 13F

3) Linear regression

		Idiot			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Sablefish	Significantly positive		5A, 8A, 24	14A, 28A, 15B	22B, 7C, 37C, 20E, 21E, 3, 4
	Insignificantly positive		23C	9B, 18E	35A, 27B, 16C, 26D, 32D
	Insignificantly negative				6B, 34B, 29C, 25
	Significantly negative			11D, 17D, 30D, 31E, 10F, 13F	36B, 38D, 12E, 39E, 33F, 1, 2, 19

2.2.2 Regression of idiot on the depth estimated from the echogram during hauling

In spite of high possibility of catch of sablefish showing clear regression on the depth estimated from the echogram during hauling, the examinations ended in only finding out less clear result than the regression on the depth sounded during setting, and the cubic and quadratic regressions on the depth during hauling inclined to shift more positive side (from significantly negative to insignificantly negative, from insignificantly negative to insignificantly positive, or from insignificantly positive to significantly positive). If these were due to uncorrect estimation of the depth from the echogram during hauling, the regression of catch of idiot on the depth estimated through the same method should also end in obtaining less clear results and should show the shift to positive side. For the purpose of finding out this possibility and of finding out the distribution pattern of idiot, the regression of catch of idiot on the depth estimated through the echogram during hauling was examined in this section.

As shown in Table 11, the regression on the depth estimated from the echogram during hauling also ended in less clear results than those on the depth sounded during setting, due to the shift of the regression to the positive side. The difference of distribution pattern of idiot according to the difference in the method of estimating the settled depth was the same to that of sablefish in these points. But the discrepancies in the results between these two species were found in the following points : the shift of regression of idiot to positive side was mainly in the quadratic and linear ones, in contrast with the fact that the shift of regression of sablefish was mainly in the cubic and quadratic one. The cubic regression coefficient on the depth estimated from the echogram during hauling was significant only in about the one fifth of the strings (7/39), and took positive value (either significant or insignificant) in about the three fifths (23/39) and negative value in about the two fifths (16/39). The same trend was found also in the preceding section dealing with the regression on the depth sounded during setting. The clearest difference of the results was found in the quadratic regressions, especially in the significant and positive ones. The former decreased from 20 (all being negative) in the preceding section to 10 (5 being positive and the same number being negative) in the present section. The latter increased from 4 (all being insignificant) in the preceding section to 15 (5 being significant) in the present section. The shift of the regression to the positive side was also found in the linear regression : the strings taking the negative coefficient decreased from 35 (24 being significant) to 28 (16 being significant), and those taking the positive one increased from 4 (all being insignificant) to 11 (2 being significant). These facts indicated very low possibility of the distribution of idiot showing either cubic or quadratic regression on the depth estimated from the echogram during hauling, but indicated that the catch of this species decreased with increase in the depth estimated from the echogram during hauling.

The above-mentioned changes were the general trend. It is necessary to examine the difference in detail, for the purpose of finding out the validity of the estimated pattern of bathymetric distribution. As shown in Table 14, the estimated regression equations on the depth took the similar form regrardless of the ways of depth estimation throughout the order (either cubic, quadratic, or linear) only in the two strings (Nos. 7 and 34) out of the 39 ones. There was no marked difference in the general trend of cubic regression due to the difference in the way of depth estimation. This is not due to the trend of the catch in most of the strings taking the equations of the same form regardless of the method of depth estimation, but was due to the fact that the coefficient in the 11 strings shifted to the positive side (8 from negative to positive) and that in the 16 strings shifted to the negative side (8 from positive to negative) although that in the 12 strings was kept in the same sign and significance. A clear trend of negative quadratic regression found in the preceding examination disappeared in the present one. This was due to the shift of the coefficient to the positive side in the 25 strings although the coefficient in the 10 strings was kept in the same sign and significance and that in the 4 strings shifted to the negative side. The clear trend of negative linear regression was found regardless of the way of depth estimation. However, this trend became less clear in the present section, for the coefficient in the 16 strings shifted to the positive side although that in the 20 strings was kept in the same sign and significance and that in the 3 strings shifted to the negative side.

The other notable difference was as follows : the clear trend of the estimated depths of maximum catch from the significant cubic and quadratic regression equations concentrating in the zone from 500 m to 700 m deep was found in the preceding examination. This trend was remaining in the results of the present examination, but became far less clear in the depths estimated from the insignificant equations in the present examination.

For Area A, the catch along no strings showed the significant cubic or significantly negative quadratic regression on the depth estimated from the echogram during hauling, like in the examination of the regression on the depth during setting. And it was difficult to find any trend other than the increase of catch with progress of consecutive shootings. For other areas, the findings in the preceding section were those relating to the estimated depth of maximum catch. The examination in the present section did not show any clear results of the trend of change of the depth of maximum catch in accordance with the progress of succeeding shootings, mainly because of insufficient number of strings showing the significantly cubic or significantly negative quadratic regression equations. The leading trend found in the present examination was the decrease of catch with depth, but the trend of increase of catch with depth at least in the zone deeper than an intermediate zone was found in Nos. 27, 20, 13, and 24 through the cubic equations, and Nos.14, 28, and 18 through the quadratic one, and Nos. 8 and 24 through the linear one. The figure showing the regression of catch of idiot on the depth sounded during setting (Fig. 8) was examined, but it was hard to find any symptoma suggesting the similar pattern in these strings except insignificantly positive linear equation in No. 8. In contrast with this, the symptom suggesting the similar trend was found in the results of the regression of catch of sablefish on the depth estimated from the echogram during hauling in Nos.8 (linear), 14 (cubic and linear), 28 (quadratic and linear), 27 (quadratic), 20 (quadratic and linear), and 24 (linear) ; but it was hard to find any symptoma in Nos.18 and 13. To find the clue to answer the question whether this should be due to uncorrect estimation of the depth at least in these strings or due to the distribution pattern, the trend of the sablefish relating to the depth sounded during setting was checked again. And it was found out that the similar trend to the above-mentioned one was found in Nos. 8 (linear), 14 (quadratic and linear), 28 (linear), 20 (quadratic and linear), and 24 (cubic) ; but it was hard to find any symptoma in Nos.27 and 13. Accordingly, it was less probable that the above-mentioned trend of increase of catch of idiot with depth at least in the zone deeper than an intermediate depth zone was due to the uncorrect estimation of the depth.

Table 13. Regression of the number of idiot caught by a skate on the echo-sounded depth during hauling

No.	d_1	d_2	$a_{3\cdot0}$	$a_{3\cdot1}\times10^2$	$a_{3\cdot2}\times10^4$	$a_{3\cdot3}\times10^6$	$F_{3\cdot3}$	$a_{2\cdot0}$	$a_{2\cdot1}\times10^2$	$a_{2\cdot2}\times10^4$	$F_{2\cdot2}$	$a_{1\cdot0}$	$a_{1\cdot1}\times10^2$	$F_{1\cdot1}$	N
5	280	865	0.3059	−0.2279	0.0425	−0.0024	0.678	−0.0459	−0.0129	0.0017	0.138	−0.0931	0.0058	0.649	393
8	280	860	−0.1054	0.2321	−0.0441	0.0027	1.835	0.3146	−0.0205	0.0031	1.022	0.2218	0.0152	11.739**	405
14	345	895	0.8538	−0.2934	0.0296	−0.0006	0.018	0.7186	−0.2235	0.0180	7.379**	0.0603	−0.0007	0.006	402
28	530	990	0.1910	0.1745	−0.0525	0.0034	0.189	1.6465	−0.4156	0.0259	7.135**	0.1511	−0.0171	2.240	397
35	365	875	0.0913	0.1447	−0.0256	0.0013	0.268	0.3914	−0.0105	0.00003	0.00008	0.3901	−0.0101	4.679*	374
6	430	770	−0.4658	0.4546	−0.0814	0.0045	0.089	0.4861	−0.0342	0.0009	0.005	0.4497	−0.0220	3.538	393
9	495	900	14.0891	−5.9988	0.8467	−0.0393	15.895**	1.3813	−0.3499	0.0235	5.133*	0.2900	−0.0258	4.764*	399
15	445	805	2.2473	−0.7025	0.1021	−0.0047	0.510	1.0783	−0.1337	0.0111	3.721	0.6346	0.0083	2.412	389
22	520	895	2.5052	−0.8441	0.1223	−0.0059	1.612	0.4867	0.0381	−0.0038	0.890	0.6762	−0.0167	12.468**	403
27	235	840	−0.5835	0.5453	−0.0974	0.0055	3.883*	0.2659	0.0395	−0.0034	0.524	0.3838	−0.0013	0.030	400
34	575	880	−10.5981	4.7435	−0.6859	0.0323	2.362	1.2283	−0.2610	0.0136	0.552	0.5276	−0.0639	17.486**	386
36	375	785	−1.7961	1.0728	−0.1769	0.0092	1.993	−0.0168	0.1222	−0.0120	3.191	0.3992	−0.0212	5.317*	400
7	415	810	2.6360	−1.1037	0.1834	−0.0101	2.386	0.4282	0.0216	−0.0033	0.261	0.5504	−0.0196	9.048**	402
16	435	880	−2.3854	1.1682	−0.1713	0.0082	1.110	−0.2009	0.1268	−0.0092	1.032	0.2072	0.0026	0.055	396
23	395	815	0.0625	−0.2851	0.0909	−0.0072	7.971**	−0.0130	0.0267	−0.0035	0.681	0.0589	−0.0084	0.443	399
29	565	905	−7.8644	3.3006	−0.4412	0.0191	1.802	−0.5433	0.2437	−0.0198	2.002	0.5336	−0.0507	17.511**	400
37	490	810	1.0375	−0.3943	0.0552	−0.0024	0.014	0.3762	−0.0816	0.0065	0.154	0.0950	0.0047	0.116	395
11	410	810	−2.5899	1.3029	−0.1973	0.0097	0.815	−0.5678	0.2567	−0.0205	3.473	0.1629	0.0082	0.519	401
17	480	800	−0.0731	−0.1798	0.0865	−0.0077	0.114	−2.0163	0.7548	−0.0617	10.257**	0.4334	−0.0287	3.436	400
26	510	880	−8.4527	4.1718	−0.6562	0.0332	3.430	1.8357	−0.4508	0.0272	2.208	0.5975	−0.0795	23.732**	400
30	585	825	19.1679	−7.9659	1.1092	−0.0511	1.132	1.1272	−0.2658	0.0197	0.556	0.1506	0.0131	0.747	380
32	480	925	−1.8797	0.9725	−0.1385	0.0059	0.629	0.1067	0.0929	−0.0118	1.844	0.7140	−0.0787	38.875**	388
38	485	775	−0.1902	0.1464	−0.0088	−0.0007	0.0009	−0.3834	0.2394	−0.0236	1.455	0.5992	−0.0673	15.647**	318
12	340	705	−0.3603	0.5170	−0.0977	0.0057	0.347	0.3892	0.0630	−0.0082	1.063	0.6062	−0.0233	9.114**	402
18	415	780	2.1592	−0.6300	0.0517	−0.0001	0.00006	2.1301	−0.6152	0.0492	9.228**	0.2803	−0.0059	0.126	400
20	220	850	−2.1309	1.2540	−0.2328	0.0136	11.404**	−0.2882	0.0646	−0.0039	0.395	−0.1570	0.0175	1.978	403
21	590	990	0.0632	−0.0655	0.0203	−0.0014	1.338	0.0554	0.0278	−0.0025	2.652	0.1202	−0.0017	0.076	328
31	540	1130	−2.1108	0.8482	−0.1112	0.0044	0.925	0.3767	−0.0769	0.0009	0.019	0.3138	−0.0609	33.288**	395
39	485	1000	−1.8360	0.7091	−0.0762	0.0023	0.165	−0.8988	0.3179	−0.0229	9.112**	0.3383	−0.0233	4.189*	400
10	340	810	−0.6491	0.5486	−0.0883	0.0045	1.950	0.1965	0.0892	−0.0078	4.165*	0.4671	−0.0045	0.915	399
13	365	770	−3.2894	1.8714	−0.3230	0.0181	4.162*	−0.2593	0.1785	−0.0157	3.008	0.2166	0.0024	0.060	403
33	330	950	1.2642	−0.6712	0.1217	−0.0069	7.993**	−0.2410	0.1323	−0.0115	9.487**	0.2039	−0.0175	6.645*	399
19	300	880	−0.8808	0.6278	−0.1476	0.0098	2.559	0.8113	−0.3287	0.0240	7.108**	0.0725	−0.0529	17.294**	399
24	450	685	13.3590	−7.0673	1.2664	−0.0746	4.664*	−0.4692	0.2707	−0.0204	0.888	0.2053	0.0342	5.439*	400
25	430	980	−3.6544	1.4114	−0.1824	0.0075	1.817	−0.8696	0.2174	−0.0157	2.999	−0.0572	−0.0119	0.780	401
1	350	810	−1.9473	1.2257	−0.2151	0.0121	2.320	0.1861	0.0479	−0.0049	0.258	0.3422	−0.0086	0.476	363
2	285	720	−1.4082	1.1118	−0.2097	0.0120	3.083	−0.1173	0.2671	−0.0320	16.447**	0.5980	−0.0435	28.661**	392
3	300	795	0.8298	−0.3857	0.0796	−0.0052	0.521	0.1177	0.0490	0.0050	0.304	0.2456	−0.0028	0.050	392
4	190	650	−0.7186	0.6940	−0.1828	0.0149	2.036	0.2052	−0.0656	0.0074	0.414	0.0654	0.0005	0.001	400

Note: No. ..... String number

d_1....... The shallowest limit in the string (in meters)

d_2....... The deepest one

$$\log\left(y+\frac{n}{2}\right) = a_{3\cdot0} + a_{3\cdot1}x + a_{3\cdot2}x^2 + a_{3\cdot3}x^3$$

$$\log\left(y+\frac{n}{2}\right) = a_{2\cdot0} + a_{2\cdot1}x + a_{2\cdot2}x^2$$

$$\log\left(y+\frac{n}{2}\right) = a_{1\cdot0} + a_{1\cdot1}x$$

x........ Echo-sounded depth in meters

y........ Number of individuals caught by a skate

n .... A parameter of the negative binomial series (shown in Table 2)

$F_{i\cdot i}$ ...... The estimated value of the Snedecor's F for $a_{i\cdot i}$ with 1 and $N-i-1$ degrees of freedom

N....... Number of skates in the string

* significant at 0.05 level ** significant at 0.01 level

Table 14. Comparison of the regression of idiot on the depth estimated from the echogram during hauling with that on the depth during setting

1) Cubic regression

		Hauling			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Setting	Significantly positive		12E, 10F, 1	5A, 14A	
	Insignificantly positive	27B, 20E	8A, 28A, 35A, 34B, 36B, 16C, 26D, 32D, 4, 19	15B, 7C, 38D, 18E, 21E, 3	
	Insignificantly negative	13F	6B, 29C, 11D, 31E, 2	17D, 30D	9B, 22B, 23C, 33F, 24
	Significantly negative		39E, 25	37C	

2) Quadratic regression

		Hauling			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Setting	Significantly positive				
	Insignificantly positive	14A	34B, 4	3	
	Insignificantly negative	28A, 19	5A, 8A, 35A, 26D	22B, 36B, 7C, 12E, 1, 25	39E, 10F, 2
	Significantly negative	9B, 18E	6B, 15B, 37C, 30D, 31E	27B, 16C, 23C, 29C, 11D, 32D, 38D, 20E, 21E, 13F, 24	17D, 33F

3) Linear regression

		Hauling			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Setting	Significantly positive				
	Insignificantly positive	8A, 24	5A	23C	
	Insignificantly negative		15B, 11D, 30D, 13F	14A, 28A, 17D, 18E, 10F	9B, 31E
	Significantly negative		16C, 37C, 20E, 4	6B, 27B, 21E, 1, 3, 25	35A, 22B, 34B, 36B, 7C, 29C, 26D, 32D, 38D, 12E, 39E, 33F, 2, 19

Table 15. Comparison of the regression of idiot on the depth estimated from the echogram during hauling with that of sablefish on the same depth

1) Cubic regression

		Idiot			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Sablefish	Significantly positive	13F	16C, 39E, 4, 19	14A, 37C	
	Insignificantly positive	27B, 20E	8A, 28A, 6B, 34B, 29C, 26D, 12E, 10F, 1, 2	5A, 22B, 38D, 3	33F
	Insignificantly negative		35A, 36B, 11D, 32D, 31E, 25	7C, 30D, 18E, 21E	9B, 24
	Significantly negative			15B, 17D	23C

2) Quadratic regression

		Idiot			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Sablefish	Significantly positive			27B, 7C, 11D	
	Insignificantly positive	18E, 19	8A, 6B, 15B, 34B, 37C, 26D, 30D	36B, 16C, 38D, 21E, 24	39E, 33F
	Insignificantly negative	14A	5A, 31E	29C, 1, 25	17D, 2
	Significantly negative	28A, 9B	35A, 4	22B, 23C, 32D, 12E, 20E, 13F, 3	10F

3) Linear regression

		Idiot			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Sablefish	Significantly positive	8A, 24	5A, 15B, 16C, 37C, 30D, 20E, 4	14A, 28A, 21E, 3	22B, 7C
	Insignificantly positive			6B, 27B, 25	35A, 9B, 26D, 32D
	Insignificantly negative		11D	23C, 17D, 18E, 1	39E, 33F, 2, 19
	Significantly negative		13F	10F	34B, 36B, 29C, 38D, 12E, 31E

2.3 Regression of rockfish

The rockfish is also the marketable by-catch. This is far less densely hookd than the sablefish and the idiot, but is hooked concentrating in several parts in a string. Mainly for the purpose of describing its bathymetric distribution, but partly for the purpose of examining the validity of the methods adopted here through comparing with the results of the other species, its bathymetric change was examined here through the same methods adopted in the above-mentioned two species.

2.3.1 Regression of rockfish on the depth sounded during setting

As shown in Tables 16 and 17, very clear results were found in the regression of catch on the depth sounded during setting. The cubic regression coefficient was negative in the 25 strings including the significant one in the 12 strings out of the 37 ones. And the quadratic one was positive in the 34 strings including the significant one in the 26 strings ; and the linear regression coefficient in most of the strings (34/37) was significantly negative. In contrast with the fact that the estimated depths of maximum catch in the above-mentioned two species were concentrated into an intermediate depth, those of this group of fish were scattering over wide depth range, but the estimated depths of minimum catch were concentrated into the 500 m to 900 m zones. And the increase of catch in the zone between the estimated depth of minimum catch and the deepest limit of the applicable depth range was negligible in all the significant cubic equations and all the significantly positive quadratic ones except the cubic one in No.31.

Figure 10 showed a sharp increase of catch near the shallowest extreme of respective strings, although the level and sharpness of increase differed according to the string. But it may be useless of giving consideration on this fluctuation because of the following three reasons : 1) the density even at the shallowest extreme was very low, 2) the skates were settled mainly on the intermediate depth zones and those relating to this sharp increase of catch were few near the turning points, and 3) the estimated density at this zone fluctuated greatly depending on the presence or absence of a few skates fortunately catching a few individuals.

Fig. 10—1.

Fig. 10. Bathymetric change of catch per skate of rockfish.

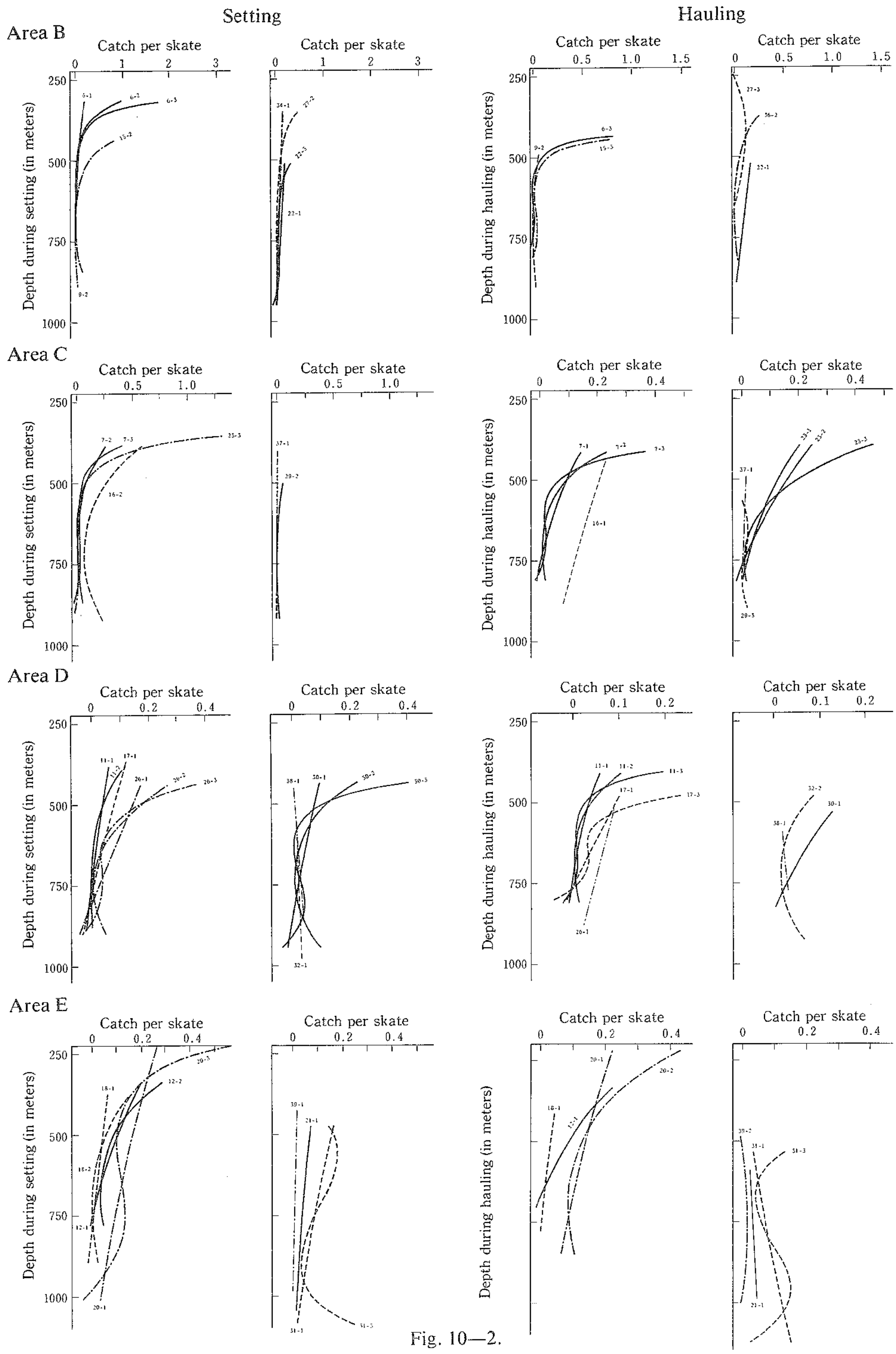

Setting
Hauling
Area B
Area C
Area D
Area E
Catch per skate
Depth during setting (in meters)
Depth during hauling (in meters)

Fig. 10—2.

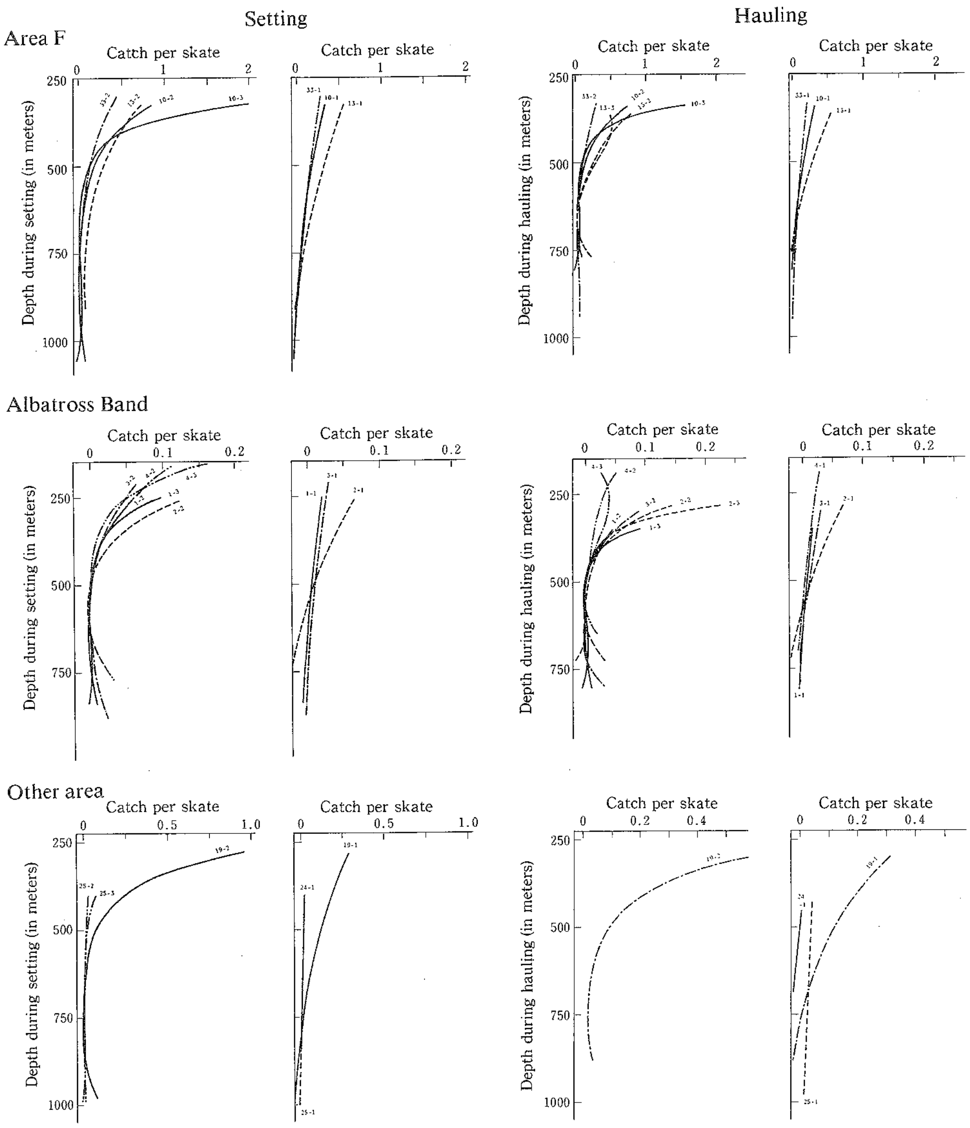


Fig. 10—3.

The above-mentioned results revealed the following two facts : one is that the rockfish are distributed mainly far shallow zone than that covered by the strings and the strings reached the deepest parts of the zone occupied by this group of fish. The other is as follows : it is highly probable that the bathymetric distribution of catch can be shown through the regression of catch on the depth estimated from the echogram obtained during setting, in spite of high possibility of the line drifted during sinking process and of settled on the bottom of different depth.

Table 16. Regression of the number of rockfish caught by a skate on the echo-sounded depth during setting

No.	d_1	d_2	$a_{3\cdot0}$	$a_{3\cdot1}\times10^2$	$a_{3\cdot2}\times10^4$	$a_{3\cdot3}\times10^6$	$F_{3\cdot3}$	$a_{2\cdot0}$	$a_{2\cdot1}\times10^2$	$a_{2\cdot2}\times10^4$	$F_{2\cdot2}$	$a_{1\cdot0}$	$a_{1\cdot1}\times10^2$	$F_{1\cdot1}$	N
5	265	910	−1.0499	0.5482	−0.1361	0.0087	3.985*	0.2557	−0.2472	0.0129	3.286	−0.1101	−0.1009	75.345**	393
8	275	1005	1.5443	−0.8868	0.0869	−0.0025	0.970	1.0128	−0.5927	0.0376	52.370**	−0.3070	−0.1201	130.889**	405
14	335	925	1.2323	−0.5335	0.0397	−0.0005	10.278**	0.1116	−0.1246	0.0017	46.770**	−0.4278	−0.0277	17.743**	402
35	295	1010	0.0538	−0.1232	−0.0105	0.0014	0.348	0.3973	−0.2998	0.0175	14.001**	−0.3021	−0.0700	53.078**	398
6	320	790	9.6377	−4.9804	0.7639	−0.0389	13.413**	3.2190	−1.3401	0.1014	65.571**	−0.0510	−0.1684	79.917**	399
9	375	875	0.7967	−0.5388	0.0360	0.0001	0.0006	0.8386	−0.5600	0.0395	14.407**	−0.7452	−0.0519	13.700**	399
15	440	840	9.9657	−3.9090	0.4441	−0.0154	0.708	5.8975	−1.9737	0.1422	59.210**	−0.1048	−0.1058	27.237**	401
22	510	940	8.9108	−3.8941	0.5344	−0.0243	4.685*	0.3895	−0.2012	0.0103	0.663	−0.1082	−0.0558	15.968**	403
27	350	825	5.6530	−2.7829	0.3858	−0.0178	2.862	2.0688	−0.8948	0.0638	20.316**	−0.2731	−0.1086	37.238**	400
36	355	900	−0.2229	−0.0355	−0.0309	0.0028	0.151	0.3919	−0.3534	0.0221	4.272*	−0.4170	−0.0813	25.067**	400
7	385	870	7.7349	−3.9327	0.5914	−0.0294	10.121**	1.3509	−0.6446	0.0449	14.316**	−0.2830	−0.0902	38.156**	405
16	380	925	1.7820	−0.7013	0.0880	−0.0035	1.478	0.8507	−0.2500	0.0173	15.983**	0.1289	−0.0220	13.643**	396
23	350	900	8.1215	−3.8711	0.5463	−0.0256	9.520**	2.6970	−1.0298	0.0702	37.075**	0.1861	−0.1650	104.333**	399
29	500	920	−3.6688	1.4424	−0.2503	0.0133	1.283	1.0294	−0.5881	0.0373	8.668**	−0.8738	−0.0483	12.379**	400
37	400	920	−3.9748	1.1894	−0.1801	0.0085	0.664	−1.6227	0.0735	−0.0088	0.390	−1.2315	−0.0462	5.661*	399
11	380	880	−0.9186	0.2827	−0.0938	0.0065	0.626	0.6470	−0.4961	0.0315	8.465**	−0.5840	−0.0939	44.703**	401
17	365	895	0.8328	−0.4985	0.0654	−0.0029	0.734	0.1416	−0.1522	0.0094	3.824	−0.2218	−0.0326	21.996**	400
26	440	900	2.6921	−1.1831	0.1655	−0.0077	6.139*	0.6007	−0.1928	0.0126	9.761**	0.0687	−0.0262	31.863**	400
30	435	945	9.3285	−4.3062	0.6047	−0.0278	24.711**	1.3868	−0.5887	0.0403	27.533**	−0.3721	−0.0474	18.913**	400
32	565	980	6.5800	−2.9044	0.3780	−0.0161	3.196	−0.6767	−0.0231	0.0020	0.043	−0.7979	0.0088	0.647	388
38	460	850	3.9619	−2.1774	0.3275	−0.0160	1.366	−0.3210	−0.1475	0.0125	0.975	−0.8552	0.0177	1.624	318
12	340	780	3.5831	−2.0554	0.3370	−0.0184	2.759	0.6142	−0.3666	0.0268	4.261*	−0.1598	−0.0720	22.295**	402
18	375	895	0.1071	−0.1750	−0.0032	0.0013	0.120	0.4371	−0.3393	0.0232	18.767**	−0.5117	−0.0374	25.034**	408
20	225	1010	1.1872	−0.8536	0.1390	−0.0073	12.076**	−0.1244	−0.0753	0.0028	0.432	−0.2397	−0.0378	14.433**	403
21	475	1045	−4.7446	1.6318	−0.2180	0.0092	2.415	−0.8102	0.0181	−0.0032	0.123	−0.6160	−0.0333	5.599*	328
31	475	1090	−3.2857	1.3270	−0.1918	0.0087	7.768**	0.3375	−0.1778	0.0098	3.171	−0.2086	−0.0287	9.794**	395
39	425	980	−1.3227	0.2260	−0.0336	0.0015	0.243	−0.8420	0.0065	−0.0011	0.064	−0.7882	−0.0094	2.054	400
10	325	1055	5.3470	−2.4226	0.3137	−0.0133	28.366**	1.4360	−0.5559	0.0335	45.890**	−0.0094	−0.0996	91.565**	399
13	325	910	2.2283	−1.0924	0.1602	−0.0081	2.364	0.7218	−0.2654	0.0155	3.905*	0.2115	−0.0816	50.743**	403
33	300	980	1.6460	−0.8894	0.1143	−0.0050	2.628	0.5001	−0.2895	0.0166	10.409**	−0.1385	−0.0759	57.411**	399
19	280	985	1.8965	−0.8415	0.0629	−0.0005	0.016	1.7854	−0.7815	0.0528	54.458**	−0.0873	−0.1234	85.643**	399
24	425	755	6.6756	−3.8210	0.6196	−0.0334	3.462	0.0242	−0.3489	0.0250	2.522	−0.8549	−0.0484	12.752**	400
25	400	995	1.5283	−1.0588	0.1410	−0.0061	5.295*	−0.3237	−0.1974	0.0125	9.424**	−0.8880	−0.0249	13.831**	401
1	250	840	1.4094	−1.3907	0.2121	−0.0106	4.042*	−0.1159	−0.4727	0.0367	18.096**	−1.1788	−0.0663	24.957**	363
2	260	720	0.2655	−0.4764	0.0345	0.0008	0.007	0.3469	−0.5323	0.0468	15.586**	−0.6311	−0.0920	47.135**	392
3	210	880	−0.3216	−0.4202	0.0386	−0.0004	0.008	−0.3700	−0.3876	0.0319	13.048**	−1.1282	−0.0636	14.144**	392
4	160	785	0.6140	−1.0410	0.1724	−0.0090	4.505*	−0.0522	−0.5148	0.0480	45.045**	−1.0518	−0.0601	22.371**	400

Note: No. ..... String number

d_1....... The shallowest limit in the string (in meters)

d_2....... The deepest one

$$\log\left(y+\frac{n}{2}\right) = a_{3\cdot0} + a_{3\cdot1}x + a_{3\cdot2}x^2 + a_{3\cdot3}x^3$$

$$\log\left(y+\frac{n}{2}\right) = a_{2\cdot0} + a_{2\cdot1}x + a_{2\cdot2}x^2$$

$$\log\left(y+\frac{n}{2}\right) = a_{1\cdot0} + a_{1\cdot1}x$$

x........ Echo-sounded depth in meters

y........ Number of individuals caught by a skate

n .... A parameter of the negative binomial series (shown in Table 3)

$F_{i\cdot i}$ ...... The estimated value of the Snedecor's F for $a_{i\cdot i}$ with 1 and $N-i-1$ degrees of freedom

N....... Number of skates in the string

* significant at 0.05 level   ** significant at 0.01 level

Table 17. Trend and significance of the depth regression of rockfish caught by a setline

Area		Setting							Hauling						
		A	B	C	D	E	F	Sum	A	B	C	D	E	F	Sum
$a_{3\cdot3}$	Significantly positive	1	0	0	0	1	0	2	0	1	2	0	0	2	5
	Insignificantly positive	1	2	2	1	3	1	10	0	1	1	3	4	3	12
	Insignificantly negative	1	2	1	3	1	5	13	3	2	1	1	1	2	10
	Significantly negative	1	2	2	2	1	4	12	1	2	1	2	1	3	10
$a_{2\cdot2}$	Significantly positive	3	5	4	3	2	9	26	1	4	1	2	1	8	17
	Insignificantly positive	1	1	0	3	2	1	8	3	0	1	2	3	2	11
	Insignificantly negative	0	0	1	0	2	0	3	0	2	2	2	1	0	7
	Significantly negative	0	0	0	0	0	0	0	0	0	1	0	1	0	2
$a_{1\cdot1}$	Significantly positive	0	0	0	0	0	0	0	0	0	0	0	1	0	1
	Insignificantly positive	0	0	0	2	0	0	2	0	0	0	2	2	0	4
	Insignificantly negative	0	0	0	0	1	0	1	0	1	3	1	0	0	5
	Significantly negative	4	6	5	4	5	10	34	4	5	2	3	3	10	27

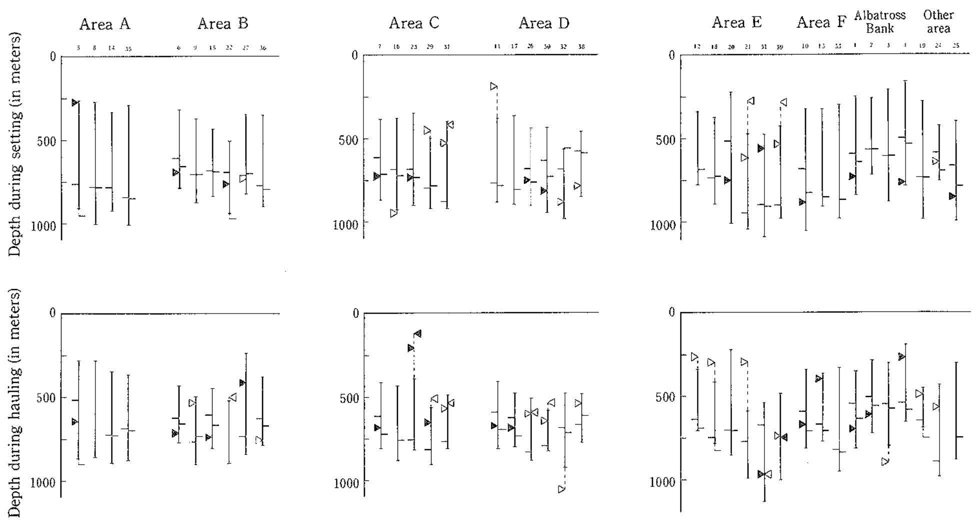


Fig. 11. The depth range covered by respective strings and the estimated depths of maximum catch of rockfish and the minimum one.

2.3.2 Regression of rockfish on the depth estimated from the echogram during hauling

The regression of catch of rockfish on the depth estimated from the echogram during hauling was examined in the present section, because of the following reason : this is a by-catch of less economic importance, occupying the zone shallower than the above-mentioned two species.

Table 18. Regression of the number of rockfish caught by a skate on the echo-sounded depth during hauling

No.	d_1	d_2	$a_{3\cdot0}$	$a_{3\cdot1}\times10^2$	$a_{3\cdot2}\times10^4$	$a_{3\cdot3}\times10^6$	$F_{3\cdot3}$	$a_{2\cdot0}$	$a_{2\cdot1}\times10^2$	$a_{2\cdot2}\times10^4$	$F_{2\cdot2}$	$a_{1\cdot0}$	$a_{1\cdot1}\times10^2$	$F_{1\cdot1}$	N
5	280	865	2.0022	−1.4313	0.2500	−0.0143	6.450*	−0.0716	−0.1646	0.0091	1.073	−0.3244	−0.0637	20.929**	393
8	280	860	0.4916	−0.6194	0.0885	−0.0048	0.490	−0.2419	−0.1782	0.0060	0.329	−0.4195	−0.1097	53.709**	405
14	345	895	0.7668	−0.4647	0.0463	−0.0013	0.027	0.4794	−0.3162	0.0217	3.514	−0.3138	−0.0478	8.280**	402
35	365	875	1.6146	−0.8646	0.0942	−0.0030	0.214	0.9455	−0.5182	0.0369	14.993**	−0.3516	−0.0656	30.339**	374
6	430	770	25.9834	−12.3084	1.8525	−0.0925	10.645**	6.7179	−2.4133	0.1829	52.898**	0.0380	−0.1796	58.131**	393
9	495	900	−6.8380	2.8601	−0.4569	0.0235	3.198	0.7648	−0.5194	0.0355	6.779**	−0.8818	−0.0303	3.804	399
15	445	805	26.0590	−12.2604	1.8444	−0.0916	11.137**	3.6741	−1.3700	0.1025	18.164**	−0.3968	−0.0657	8.394**	389
22	520	895	4.1268	−2.0059	0.2923	−0.0142	1.064	−0.7402	0.1214	−0.0121	0.995	−0.1458	−0.0507	13.030**	403
27	235	840	−4.0305	1.9894	−0.3783	0.0220	13.221**	−0.6489	−0.0238	−0.0038	0.139	−0.5164	−0.0699	16.303**	400
36	375	785	5.7801	−2.9754	0.4344	−0.0209	2.315	1.7621	−0.8290	0.0620	19.193**	−0.3770	−0.0913	21.593**	400
7	415	810	11.8965	−5.9307	0.9121	−0.0466	8.879**	1.7284	−0.7477	0.0516	10.654**	−0.1498	−0.1129	50.359**	402
16	435	880	1.4447	−0.5969	0.0811	−0.0036	0.398	0.4661	−0.1304	0.0085	1.590	0.0876	−0.0153	3.259	396
23	395	815	−0.5085	0.5822	−0.1817	0.0125	13.957**	−0.3774	0.0408	−0.0177	9.533**	−0.0219	−0.1331	62.001**	399
29	565	905	−18.1593	7.0760	−0.9738	0.0441	4.452*	−1.3127	0.0418	−0.0041	0.039	−1.0892	−0.0192	1.174	400
37	490	810	−12.2829	5.0396	−0.7700	0.0383	0.810	−2.1225	0.2357	−0.0220	0.405	−1.1739	−0.0559	3.664	395
11	410	810	13.1688	−6.8613	1.0856	−0.0570	10.641**	1.3663	−0.7548	0.0540	8.968**	−0.5547	−0.1017	28.812**	401
17	480	800	10.4073	−4.9942	0.7651	−0.0389	5.549*	0.6450	−0.2988	0.0202	2.079	−0.1580	−0.0420	14.190**	400
26	510	880	−2.3528	0.9887	−0.1414	0.0065	1.018	−0.3193	0.0750	−0.0062	0.900	−0.0335	−0.0106	3.232	400
30	585	825	−38.3954	16.0916	−2.2642	0.1051	2.539	−1.3049	0.2607	−0.0241	0.440	−0.1090	−0.0808	15.036**	380
32	480	925	2.3876	−1.1690	0.1403	−0.0053	0.590	0.5979	−0.3765	0.0261	10.324**	−0.7393	0.0014	0.014	388
38	485	775	−5.2939	2.3141	−0.3874	0.0213	0.646	0.0580	−0.2625	0.0213	1.015	−0.8269	0.0138	0.566	318
12	340	705	−1.0880	0.6770	−0.1821	0.0134	0.369	0.6757	−0.3911	0.0283	2.397	−0.0675	−0.0954	29.246**	402
18	415	780	−0.8760	0.1674	−0.0395	0.0025	0.044	−0.3373	−0.1081	0.0065	0.331	−0.5840	−0.0269	5.361*	400
20	220	850	0.2550	−0.2524	0.0238	−0.0005	0.016	0.1786	−0.2031	0.0143	4.570*	−0.2984	−0.0317	5.596*	403
21	590	990	−1.0073	0.2082	−0.0491	0.0030	1.578	−0.9904	0.0036	0.0012	0.147	−1.0212	0.0176	2.011	328
31	540	1130	4.5975	−1.9742	0.2493	−0.0101	5.707*	−1.0971	0.1438	−0.0074	1.301	−0.6204	0.0228	5.430*	395
39	485	1000	−1.5211	0.2000	−0.0167	0.0002	0.005	−1.4049	0.1515	−0.0101	4.157*	−0.8572	0.0004	0.003	400
10	340	810	9.4512	−4.8649	0.7736	−0.0408	14.109**	1.8855	−0.7554	0.0534	17.107**	0.0342	−0.1135	49.000**	399
13	365	770	−4.7970	2.9835	−0.6019	0.0377	7.416**	1.5163	−0.5436	0.0383	7.272**	0.3565	−0.1145	51.763**	403
33	330	950	0.0178	−0.0798	−0.0147	0.0016	0.222	0.3639	−0.2646	0.0158	9.544**	−0.2451	−0.0595	41.283**	399
19	450	685	−15.3319	7.8182	−1.4074	0.0829	2.900	0.0334	−0.3354	0.0224	0.539	−0.7054	−0.0764	13.712**	400
24	430	980	−2.8473	0.8237	−0.1195	0.0054	2.234	−0.8283	−0.0418	0.0012	0.047	−0.8953	−0.0229	6.763**	401
25	300	880	2.2899	−1.1723	0.1390	−0.0055	0.484	1.3394	−0.6350	0.0425	13.410**	0.0323	−0.1470	79.171**	399
1	350	810	8.1763	−4.8721	0.7977	−0.0428	20.000**	0.6488	−0.7164	0.0561	21.951**	−1.1204	−0.0746	21.892**	363
2	285	720	4.4511	−3.0629	0.5542	−0.0331	8.923**	0.9112	−0.7466	0.0668	27.161**	−0.5816	−0.0982	53.779**	392
3	300	795	3.4983	−2.3402	0.3456	−0.0160	1.944	1.3415	−1.0234	0.0891	39.007**	−0.9332	−0.1003	22.892**	392
4	190	650	−2.6005	1.3467	−0.3802	0.0315	10.326**	−0.6456	−0.2606	0.0224	4.189*	−1.0675	−0.0608	13.708**	400

Note: No. ..... String number

d_1....... The shallowest limit in the string (in meters)

d_2....... The deepest one

$$\log\left(y+\frac{n}{2}\right) = a_{3\cdot0} + a_{3\cdot1}x + a_{3\cdot2}x^2 + a_{3\cdot3}x^3$$

$$\log\left(y+\frac{n}{2}\right) = a_{2\cdot0} + a_{2\cdot1}x + a_{2\cdot2}x^2$$

$$\log\left(y+\frac{n}{2}\right) = a_{1\cdot0} + a_{1\cdot1}x$$

x........ Echo-sounded depth in meters

y........ Number of individuals caught by a skate

n .... A parameter of the negative binomial series (shown in Table 3)

$F_{i\cdot i}$ ...... The estimated value of the Snedecor's F for $a_{i\cdot i}$ with 1 and $N-i-1$ degrees of freedom

N....... Number of skates in the string

* significant at 0.05 level ** significant at 0.01 level

And only a part of skates reached the deepest extreme of their distribution. The difference between the estimated depth from the echogram during setting and that from the echogram during hauling should be large near the turing points of the shooting course, i.e. in the zone catching this fish. The regression of the above-mentioned two species on the depth estimated from the echogram during hauling showed less clear results than that on the depth during setting. If this was due to low accuracy of the depth estimated from the echogram during hauling, it is highly probable that the regression of this fish on this depth may result in showing very complicated pattern. Accordingly, the results of the examination in the present section may provide us with the clue to answer the question as to the validity of the method adopted here or as to the validity of the distribution pattern of the above-mentioned two species deduced from regression on the depth estimated from the echogram during hauling.

As expected, Table 18 showed the similar results to the regression on the depth during setting, although less clear. The details were, however, complicated : the same results (sign and significance of the regression coefficient) throughout the order of the regression equations (cubic, quadratic, and linear) were found only in the 5 strings (Nos.3, 6, 7, 10, and 1) out of the 37 strings. The cubic coefficient in the 13 strings was kept in the same sign and significance, but that in the 16 strings shifted to the positive side and that in the 8 strings to the counter direction. In consequence, the strings showing the negative cubic regression decreased from 25 to 20 (the significant one from 12 to 10). The quadratic coefficient in the 20 strings was kept in the same sign and significance, but that in the 3 strings shifted to the positive side and that in the 14 strings to the counter direction. In consequence, the strings showing the positive quadratic regression decreased from 34 to 28 (the significant one from 26 to 17). The linear regression coefficient in the 29 strings was kept in the same sign and significance, but that in the 8 strings shifted to the positive side ; in consequence, the strings showing the negative linear regression decreased from 35 to 32 (the significant one from 34 to 27).

The trend of the estimated depths of minimum catch concentrating into the 500 m to 900 m zone and that of maximum catch scattering over wide depth range were clearly shown in those estimated from the significant cubic and quadratic equations but less clearly in those estimated from the insignificant ones, like in the preceding section. Table 6 showed that there were the 10 significant cubic equations showing the maximum of catch in the 600 m to 800 m zone, but all the estimated maximum except that in No.31 were simply in the mathematical meaning and were far lower than the density in the shallow zone, and the relation could practically be regarded as the simple and sharp decrease. The quadratic equations in Nos.23 and 39 were significantly negative ; however, the estimated depth of maximum catch in No.23 was far shallower than the shallowest limit of the depth covered by this string, and that in No.39 was negligible. Somewhat clear increase of catch in the zone deeper than the estimated depth of minimum catch was found in No.32 through Fig. 10 ; but this was due to the scale range, and the difference of catch at the deepest limit from the estimated minimum was very small. The linear regression equation in No.31 showed an increase of catch with increase in depth. But the difference due to depth regression was very small. All other significant equations showed a clear trend of decrease of catch with increase in depth regardless of the order of the equation and sign of the coefficient of the highest order.

From these results, it may be said that 1) the rockfish distributed mainly in shallower zone than that covered by the strings and only very shallow parts of the strings attained its deepest limit, 2) the regression on the depth estimated from the echogram during hauling showed the similar but less clear results than those on the depth estimated from the echogram during setting, 3) however, the difference between them was far smaller than that of sablefish or idiot, and 4) the regression on the depth estimated from the echogram during hauling was applicable to represent the bathymetric distribution pattern of the fish like this.

Table 19. Comparison of the regression of rockfish on the depth estimated from the echogram during hauling with that on the depth during setting

1) Cubic regression

		Hauling			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Setting	Significantly positive				5A, 31E
	Insignificantly positive	29C	9B, 37C, 18E, 21E, 39E	35A, 36B	11D, 2
	Insignificantly negative	27B, 13F	30D, 38D, 12E, 33F, 19, 24	8A, 16C, 32D, 3	15B, 17D
	Significantly negative	23C, 4	26D	14A, 22B, 20E, 25	6B, 7C, 10F, 1

2) Quadratic regression

		Hauling			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Setting	Significantly positive	35A, 6B, 9B, 15B, 36B, 7C, 11D, 10F, 13F, 33F, 1, 2, 3, 4, 25	8A, 14A, 16C, 12E, 18E, 19	27B, 29C, 26D, 30D	23C
	Insignificantly positive	32D, 20E	5A, 17D, 38D, 24	22B, 31E	
	Insignificantly negative		21E	37C	39E
	Significantly negative				

3) Linear regression

		Hauling			
		Significantly positive	Insignificantly positive	Insignificantly negative	Significantly negative
Setting	Significantly positive				
	Insignificantly positive		32D, 38D		
	Insignificantly negative		39E		
	Significantly negative	31E	21E	9B, 16C, 29C, 37C, 26D	5A, 8A, 14A, 35A, 6B, 15B, 22B, 27B, 36B, 7C, 23C, 11D, 17D, 30D, 12E, 18E, 20E, 10F, 13F, 33F, 1, 2, 3, 4, 19, 24, 25

Discussion

The present report dealt with the regression of catch on the depth, for the purpose of finding out the bathymetric change of the distribution of sablefish, idiot, and rockfish through analysing the catch records along 39 strings of setline during the commercial fishing. There remained, accordingly, a doubt as to the density of catch and its bathymetric change would represent the distribution of fish with some accuracy. The setline can catch only the individuals of active appetite and in some size range. If the setline were settled on the ground capable of being fished with other methods, the comparison of the catch patterns by different methods may make it possible to check the discrepancy in the results due to the above-mentioned reasons, although each of the fishing methods can not be free from the effect of gear selection. The setline on the present days is settled mainly in rough and deep grounds unable to be fished effectively and safely with other methods of high efficiency. And it is practically very hard to check the discrepancy in the results due to the above-mentioned reasons. It is, however, probable that the discrepancy in the estimated pattern due to the above-mentioned reasons may be not serious except the density of small individuals, because of the following three reasons : one is large size variation of catch. Another is that it is hard to consider that the sablefish in deep grounds during summer are low in appetite or can get sufficient food as suggested from the fact that most of the individuals trawled or setlined contained hardly any food in their stomach. The other is that the following facts were found during the consecutive work within the same ground : the skates settled over the spot not exploited within a week or so catch the fatty and vigorous individuals hauled up still living till surface. But the parts settled over the bottom exploited within a few days before can catch less abundantly the lean and inert individuals or small ones. This fact also suggested the possibility of dominancy order (peck order) within the population of sablefish, and is adopted as a powerful indicator of finding out whether the spot is exploited recently by the other boats or not or whether the spot is preferable one to shoot the line or not.

It is natural that the distribution depends not only on the depth but also on many other factors including the general topography, bottom character, distribution of prey and predator, etc.[42–45] It is possible to conjecture the general topography around the line by drawing the chart showing the settled course and the change of depth around it. And it is possible to guess the bottom character through the hooked invertebrates and contamination of the line and baits. However, the present report dealt only with the relation between the catch and the depth, because mainly of the following two reasons : one is that it is necessary to describe the outline of distribution pattern. The other is that the depth especially that estimated during setting is the factor easy and quick to estimate continuously over long distance, and is adopted by the master fishermen as the most convenient indicator to choose the fine locality to settle the line within a spot.

The other group of factors causing the difference of the distribution pattern of catch from that of fish population is the technical problem : the catch pattern is the results of the interaction between the biological problem and the technical one. A string of setline consists of many skates of simple and equal construction arranged in a series. If all the skates were settled efficiently capable of fulfilling the full of their fishing ability, there were no problem. During hauling, however, we frequently observed a part of skates soaked inefficiently. The string is settled on the bottom of a slope along a zigzag course. And it is necessary to haul up the line positioning the boat exactly above the point of the line just leaving from the bottom and to maneuver the boat exactly along the settled course. The boat is maneuvered either by the master fisherman or skipper during hauling, but sometimes it becomes very difficult to do so because of strong current and/or wind drift of the boat. If the line is hauled up positioning the boat to a little deepward, there is little problem. If the boat is drifted to shallowward, however, the line hanging catch is dragged over the botton and either most of the catch or even most of the hook droppers are fastened with the bottom objects or torn off. The accident of this type occurs mainly on rough ground or over steep slope or near the turning points of meandering line.

The accident of the other type is "hang-over". The master fisherman prefers to use the low frequency beam (wide one) of echo-sounder during setting, because of insufficient power of high frequency beam and because of finding out the general topography. It is natural that the low frequency beam is wide and unable to detect the fine irregularity of sea bed. There are many small irregularities of the depth on rough ground. The line is settled over a slope. In consequence, the bottom line is somewhat longer than the sailing distance. The line is paid out manually with some slackness. It is natural that the part of the line to be settled on steep slope should be paid out at large slackness, but practically it is hard to adjust the slackness according to the steepness of the slope. The line is settled along a zigzag course : in consequence, a part is laid following the current but the other part against it. It is accordingly natural that the speed against the ground is high during the sailing along the current but is low during the sailing against it. In spite of this fact, the slackness of paying the line is rarely adjusted. Regardless of the reason, the part of the line paid with insufficient slackness is apt to pass over the sea bed from peak of the rock to the peak, and the parts hung over the sea bed can not fulfill the fishing efficiency. In regard to the accident of this type, it is said commonly by the master fishermen that : the part settled during sailing to shallowward is settled surely on the sea bed, but the part shot during deepward sailing is apt to be hung over. Even on the plateau wide enough to settle the line over long distance without turning, it is necessary to turn the course at intervals, otherwise, the line is apt to cause the accident of this type, although the turnings are not exclusively for avoiding the accident of this type but also for making it possible to haul up the line from intermediate markers if necessary. The other role of turnings is for avoiding the line from settled too tight because the slackness is adjusted during sinking by passing the line along short-cut course. It is easy to distinguish the part of the accident of this type from the part attached the sea bed but ended in vacant catch, because of the following reasons : the part not attached the sea bed is hauled up with clean baits of high freshness but without any fish and invertebrates over some range. However, the part laid on the sea bed but ended in no catch over long distance is hauled up with soiled baits of low freshness and with invertebrates. The part settled safely on the sea bed but fastened with the bottom objects or dragged over the sea bed is hauled up without catch and bait, and most of the hook droppers in this part are torn off. The last type can be seen when a part of main line is tangled within itself during setting but is disentangled during hauling because of high tension. The hang-over also occurs either when the marker line is paid out carelessly and entangled within itself or when the current drift is too strong and a part of hook droppers is caught with the marker line. The accident of this type is rare but is apt to occur when the marker is settled during turning.

The accidents of the above-mentioned two types extend usually over several consecutive skates ; in consequence, they affect seriously the results, although it is possible to correct its influence by checking the original records in detail. In contrast with this, there are the accidents of other type .... slip-off of bait, tangling of either a part of main line or hook droppers, and torn-off of hook droppers. They differ from the above-mentioned two types in many points. They occur usually within a part of a skate, but the other parts within the same skate work effectively. In consequence, it is very rare that a skate ends in no fish and no invertebrates. If there are some hook droppers hauled up either without bait or without hook droppers, accordingly, it is very hard to find whether the poor catch by a skate is due to the accident of this type or due to low density of the objective fish and whether the hooks or the baits are slipped off during shooting or during hauling. They occur during shooting mainly because of unsmooth or careless shooting of the line due to either of the reasons. Accordingly, it is hard to neglect of the possibility of the accident of this type occuring in several consecutive skates and occuring in company with the accidents due to insufficient slackness of shooting the line.

The drop-off of catch during hauling also disturbs the estimation of the distribution pattern. This occurs throughout the step of hauling work. That before leaving the line from sea bed differs, however, from that after it: the former occurs consecutively over several skates but the latter at intermittently. And the influence of the former was already discussed. It is hard to estimate the drop-off of catch in deep layer. We observed unnegligible parts of catch dropped off between surface and board side, but most of the dropped fish were successfully gaffed again with remarkable skillfulness, and the un-recaptured fish was practically negligible. The present records included these individuals, too. And there is no need to give consideration on the discrepancy in the results due to this reason. The drop-off of catch of the other type is that by attack of marine mammals. During hauling work especially at night, some marine mammals approach to the boat and rob the catch at several meters beneath the surface. Once line is attacked by them, all the catch in several consecutive skates are stolen till they are droven away with cherry bomb. The skates suffered from this accident showed very closely similar feature to those fastened with or rubbed against the bottom objects. The former occurs regardless of the bottom topography but having a close relation to the hour ; but the latter occurs having a close relation to the bottom topography but regardless of the hour. It is easy to distinguish them from each other, and it is possible to exclude the influence of poor catch due to the former reason by checking the original records in detail.

As mentioned above, the catch records included many sources of error in estimating the distribution pattern of fish population. The uncertainty of the records due to most of them could be excluded from the results by checking the original records in detail, but that was not excluded from the present report. All these sources of error resulted in an increase of the frequencies of the skates of no or very poor catch. In consequence, the frequency distribution of catch by a skate was modified into more strongly contagious than in the actual. The other probable source of modifying the frequency distribution is the bathymetric difference in the density, which is one of the principal subjects of this report. Its influence should be more serious in the by-catch or in the trash than in the major objective. The sablefish, which is the major objective of the present setline, showed a convex relation to depth. This fact increased the skates of poor catch in the extreme depth zones and those of good catch in intermediate depth zone, in consequence, modifies the distribution also seemingly more contagious. The examination on the change of the pattern of bathymetric distribution of catch of sablefish with repeat shootings revealed that the catch from the part of good catch dropped in the succeeding shooting and a good catch inclined to be brought from the parts left unfished by the preceding shootings. This fact suggested that the distribution of catch by successive shootings should be

Table 20. The level of fitness to negative binomial series and the significance of depth regression of catch of sablefish

Level of fitness			<0.005	−0.010	−0.025	−0.05	−0.10	−0.25	−0.50	−0.75
Setting	Cubic	Signif.	8	0	2	0	1	2	2	2
		Insignif.	15	2	1	0	0	3	1	0
	Quadratic	Signif.	16	1	3	0	1	3	2	1
		Insignif.	7	1	0	0	0	2	1	1
	Linear	Signif.	18	2	1	0	0	3	1	2
		Insignif.	5	0	2	0	1	2	2	0
Sum		Signif.	42	3	6	0	2	8	5	5
		Insignif.	27	3	3	0	1	7	4	1
Hauling	Cubic	Signif.	6	0	2	0	1	0	0	1
		Insignif.	17	2	1	0	0	5	3	1
	Quadratic	Signif.	10	0	1	0	1	3	0	0
		Insignif.	13	2	2	0	0	2	3	2
	Linear	Signif.	14	1	2	0	0	2	2	2
		Insignif.	9	1	1	0	1	3	1	0
Sum		Signif.	30	1	5	0	2	5	2	3
		Insignif.	39	5	4	0	1	10	7	3

Table 21. The level of fitness to negative binomial series and the significance of depth regression of catch of idiot

Level of fitness			<0.005	−0.010	−0.025	−0.05	−0.10	−0.25	−0.50	−0.75	−0.90
Setting	Cubic	Signif.	0	0	0	0	0	0	6	2	0
		Insignif.	0	2	1	0	2	2	12	6	6
	Quadratic	Signif.	0	1	0	0	2	1	8	3	5
		Insignif.	0	1	1	0	0	1	10	5	1
	Linear	Signif.	0	2	1	0	1	1	12	4	3
		Insignif.	0	0	0	0	1	1	6	4	3
Sum		Signif.	0	3	1	0	3	2	26	9	8
		Insignif.	0	3	2	0	3	4	28	15	10
Hauling	Cubic	Signif.	0	0	0	0	1	0	3	1	2
		Insignif.	0	2	1	0	1	2	15	7	4
	Quadratic	Signif.	0	1	0	0	0	0	2	3	4
		Insignif.	0	1	1	0	2	2	16	5	2
	Linear	Signif.	0	2	0	0	1	1	9	3	2
		Insignif.	0	0	1	0	1	1	9	5	4
Sum		Signif.	0	3	0	0	2	1	14	7	8
		Insignif.	0	3	3	0	4	5	40	17	10

Table 22. The level of fitness to negative binomial series and the significance of depth regression of catch of rockfish

Level of fitness			<0.005	−0.010	−0.025	−0.05	−0.10	−0.25	−0.50	−0.75	−0.90
Setting	Cubic	Signif.	0	0	0	1	1	0	2	2	1
		Insignif.	0	0	0	2	0	2	3	0	1
	Quadratic	Signif.	0	0	0	3	0	2	5	2	1
		Insignif.	0	0	0	0	1	0	0	0	1
	Linear	Signif.	0	0	0	3	1	2	5	2	2
		Insignif.	0	0	0	0	0	0	0	0	0
Sum		Signif.	0	0	0	7	2	4	12	6	4
		Insignif.	0	0	0	2	1	2	3	0	2
Hauling	Cubic	Signif.	0	0	0	1	1	2	3	1	0
		Insignif.	0	0	0	2	0	0	2	1	2
	Quadratic	Signif.	0	0	0	2	0	1	4	1	1
		Insignif.	0	0	0	1	1	1	1	1	1
	Linear	Signif.	0	0	0	3	1	2	5	2	2
		Insignif.	0	0	0	0	0	0	0	0	0
Sum		Signif.	0	0	0	6	2	5	12	4	3
		Insignif.	0	0	0	3	1	1	3	2	3

modified into more contagious than in the actual. Then, the original pattern should be found only in the first strings of respective grounds or in the strings set after sufficient interval without fishing. It was, however, hard to find the pattern common to them. The catch recovered when the ground was kept unfished a week. However, it was hard to find any clear difference in the level of fitness to negative binomial series between the strings shot after an unfished interval of more than a week (or more than 10 days) and the others. The idiot is the most important by-catch. It is hard to consider that all the skates are settled in the zone with dense population of idiot, but it is natural that some of the skates are out of the distribution range of this species. The catch of this species also showed a convex relation to the depth. These facts made the distribution seemingly more contagious than in the actual. The results showed, however, that the frequency distributions of this species were agreeable to the negative binomial series. These facts threw a doubt as to this species under homogeneous environment would be distributed in the pattern agreeable to this theoretical distribution. The rockfish is a by-catch of little importance, and is caught mainly by the skates settled in very shallow zones. The presence of most of the skates out of the range of its distribution made the frequency distribution of catch far more strongly contagious than in the actual. The observed distributions were, however, agreeable to the negative binomial series.

All the above-mentioned sources of error modify the frequency distribution of catch by a skate seemingly more contagious than in the actual. There is, however, the other group of sources of error, which modifies the distribution less contagious than in the actual. There is no problem in the comparison of the observed series of frequency distribution with the binomial series, when the presence of some hooks occupied by the other species is not taken into account. The conditions are different in the comparison with the negative binomial series : exactly speaking, in the negative binomial series, the number of individuals in a section should be negligibly small when compared with the probable maximum of the number of individuals capable of being captured by a section. However, each of the skates has a limited number of hooks, and it is hard to consider that the number of hooked individuals by a skate is negligibly small when compared with the number of hooks in a skate. This fact modifies the occupied rate of the hooks in the densely occupied part lower than the actual, i.e. the distribution being less contagious than in the actual. In spite of this possibility, the observed series showed a contagious pattern. The other source of error modifying the distribution less contagious is the presence of the individuals of other species in the skate. All these facts and possibilities are taken into account, and it may be said that either respective species showed strongly contagious pattern or the source of error modifying the distribution more contagious is more influential than the error modifying the distribution into the counter direction.

The above-mentioned descriptions are mainly relating to the uncertainty in catch and the probable modification in the frequency distribution of catch by a skate. The present report dealt with the relation between the catch and the depth. And it is necessary to give a consideration on the error included in the depth estimation. First, let us give a short consideration on the influence of beam angle of echo-sounder on the depth sounded. It is natural that the narrow beam is better than the wide one for showing the exact bottom topography. In spite of this fact, the wide beam was used in the present study for sounding, because the narrow beam of the sounder on board was insufficiently powerful to get the echogram from deep ground. On the present days, the echo-sounder of narrow beam powerful enough to get an echogram from deep ground is available, although somewhat expensive. It may be said that the echo-sounder is the sole equipment of collecting the information for determining the course of shooting the line. Accordingly, if the master fisherman needs an excellent sounder, the sounder with the above-mentioned specification should be installed on board. In regard to this point, one of the fresh master fishermen bears the following opinion : the narrow beam is however excellent in finding the exact depth just beneath the boat, it is of no use, for the line is more or less drifted during sinking and the information from somewhat wide area is also needed. The other master fisherman said that too detailed information of minute irregularity in the bottom topography supplied by the echo-sounder of narrow beam is rather harmful, for making the master fisherman too nervous and leading him misunderstanding the general trend of the change of depth along the course. And it may be said, on the today's backgrounds of this fishery, that the preference of the echo-sounder of wide beam angle by the master fishermen should not be due to the economic reason or technical level of echo-sounder, but should be based on their long experience. In any case, if the line were settled on smooth grounds of equal depth, there were no problem in the beam angle relating to the accuracy of sounded depth and the modification of sounded topography. The echogram of the bottom in some parts was narrow with clear edge. This is the typical echogram from smooth grounds. And these parts were thought to be the smooth grounds. The line is, however, set on steep slope of somewhat rough bottom. The echo trace from most of the grounds capable of hauling up the line without accident was also narrow with clear edge but showed the gradual change in sounded depth. In the areas with high possibility of the line being fastened or being hung over, the echo trace of bottom was wide with obscure edge, suggesting on a steep slope. In these areas, the echogram also showed a new trace of shallowing trend a little before the turning points to shallow, besides the echo trace showing the deepening trend continuously from the preceding turning point from shallow to deep, suggesting a complicated topography. In these areas, it was difficult to sound excatly with the echo-sounder of wide beam. The following facts, however, threw a doubt as to the necessity of exact sounding : the strings cover wide depth range, sometimes more than 600 m. And the error in sounded depth due to wide beam was far smaller than the covering depth range, or at least, it is hard to consider that the error in sounded depth in these parts makes it difficult to guess even the general trend of the bathymetric distribution of fish. In addition it is probable that the discrepancy in the results in these areas was mainly due to the slip-off of catch or haning-over of line or due to the below mentioned error in the depth estimation. And these error should be far larger than that in sounded depth with wide beam.

The depth was sounded twice a string, during setting and during hauling. There was no basic difference between them in the general trend, for the line was settled over wide depth range along several courses running nearly parallel to one another and nearly perpendicularly crossing to many isobaths. There were, however, some parts showing unnegligible difference in the sounded depths. And this difference sometimes ended in the different results of the regression, as shown in the preceding sections. Clearer results were obtained from the regression on the depth sounded during setting than that on the depth estimated from the echogram during hauling, in spite of low possibility of the former than the latter in respect of representing the actually settled depth. The echo-sounded depth during setting is that along the setting course. The error involved in this depth is mainly in the drift of line. If the line were settled without anchor, the drift should be serious. However, first, the initial anchor was shot, and the line was weighted with large stone bags or anchors at 80-consecutive-skate intervals and with cement or iron sinkers at every junction of the main line (i.e. about 70-m intervals). The sinkers are small, in addition, connected with the main line. Accordingly, it is hard to consider that they sink at high speed, although the parts already sunken in deep layer may pull the line downwards. Large stone bag or anchor is not settled at turning point but settled during sailing along straight line. Even when the position to shoot the stone bag is during turning, the boat stops turning and sails along a straight line from a little before shooting to a little after it, with an intention of escaping from fouling of the marker line with main line. Accordingly, it is probable that the parts near the markers are very little suffered from the current drift, but the conditions are different in the other parts. The string is settled nearly perpendicular to the isobaths, i.e. to the coast. The component of the current in this direction may cause not only a phase lag between the depth at shooting and that at settled point but also the different slackness according to the sailing direction (either along the current or against it). The former may cause no serious deformation of the results, when only the trend of bathymetric change of density is under consideration. The influence of the latter will be discussed in the succeeding reports which will treat the trend sectioning a string into several parts according to either in the deepening part or in the shallowing one. The component of the current in the direction parallel to isobaths, i.e. perpendicular to the setting course, may cause little difference in the depth however the current drift might be large, when the string is shot on the ground of simple topography. However, the current drift in this direction sometimes causes an unexpectantly large difference in the depth, when the string is settled on the ground of complicated topography. In the string like this, the regression on the depth sounded during shooting becomes less clear and the difference of the depths between shooting and hauling becomes large. The unnegligible influence of current drift was suggested by the following two facts : one is that some of the best master fishermen use an anchored marker line without main line just before starting the shooting work for the purpose of estimating the current drift. The other is as follows : the setline is one of the fishing methods most resistive against the rough weather. The boat, however, becomes unable to fish on some very stormy days. According to the master fishermen, this is not due to the difficulty in the work on deck either during setting or during hauling but is due to the fact that the line is drifted over the grounds of unfavorable depth and ends in vacant catch. These facts meant that the influence of current drift on the relation between the catch and the depth sounded during setting may be practically not serious, when the discussion was confined in finding out a general trend, except on stormy days or in the ground of complicated topography.

The other source of error in estimating the depth at shooting respective skates is involved in the method of depth estimation. The echo-sounder and helming system are naturally installed on wheel house. The echo-sounder is switched on from a little before starting the shooting work. The times of shooting respective anchors (or stone bags) for markers and those of start and end of respective turnings are recorded and marked on the echogram. And the numbers of skates in respective intervals of markers are counted during hauling work. It was, however, hard to count the number of skates shot during respective intervals between the marker and the start or the end of turning and between the start and the end of turning, because the shooting work is conducted in the working space at quarter. And the echogram between the marks of shooting respective markers is sectioned equally according to the number of skates shot during the intervals, and the depth of shooting respective skates is estimated. The main line is shot manually with a slight slackness —— at a speed of about 4 skates a minute with remarkably small variation even during turning, because this work is conducted at the pace made by the most skillful and vigorous young two hands alternately skate by skate. Accordingly, the error in estimating the depth due to the above-mentioned method of depth estimation may be very small. And if it introduced a phase lag, the error in the estimated depth due to this reason may be far smaller than the level of modifying the general trend of the results basically. Based on these consideration, it may be said that the difference between the sounded depth during setting and the depth at the actually settled point should be small. And as shown in the results, the catch showed a clear regression on the depth sounded during setting, in spite of presupposed low possibility of the echo-sounded depth during setting representing the actually settled one.

The boat hauls up the line locating her just above the point of the line leaving from sea bed. And the depth sounded at hauling indicates that of the skate at leaving from sea bed, and the catch by it appears surface at the moment of hauling up the same length of main line to the sounded depth. In spite of this fact, the sounded depth at hauling sometimes showed irregular change especially in the part easy to cause the fastening of main line. And the regression of catch on the depth estimated from the echogram during hauling was less clear than that on the depth during setting. These facts evoked the necessity of giving consideration on the source of error in the depth estimated from the echogram obtained during hauling. The largest source of error should be involved in the dip of the line, because the sounded depth can represent the settled depth only when the line is hauled up vertically. In the echogram of the part of the line settled on the grounds shallower than 500 m, we can frequently record the echo trace of rockfish throughout the steps of hauling just from sea bed to the surface. This should be the best proof indicating that the line is hauled up vertically and the catch appears to the surface after hauling up the same length of the main line to the sounded depth. The difficulty in recording the echo trace of fish from deep bottom should be due to the following reasons : the rockfish reflects strong echo, because this fish has an air bladder. This fish prefers to live on the rocky bottom shallower than 600 m, and scarecely any individuals are found in deep grounds. The catch from deep ground are mainly the sablefish. This fish does not have the sound-reflectory air bladder. The other good proof supporting the accuracy of estimated depth through the echogram during hauling is as follows : either when the main line was torn off or when it was heavily fastened and released from the boat, she is obliged to haul up the line from the adjacent marker. In this case, the adjacent marker is once hauled up, then shot again connecting the branch toward the final marker. And that to the torn-off or released end was hauled up to the counter direction. In this case, the estimated depth at the finish of hauling up the torn-off end took very closely similar values to that just before torn-off or releasing the line. After finish of this work, the boat sailed back to this marker and hauled up the line toward the final marker. The depth sounded at start of hauling the torn-off branch and that at recapture of the marker also took very closely similar value.

It is easy to find the direction of the line when the boat hauls up the parts of main line settled along a straight course because of the following reason : the setting course and the depth along it were recorded exactly and it is easy to find a slight change in the dip with progress of hauling work. In addition, the load increased sharply, when the line was hauled up locating the boat at inadequate position. It is possible to find the approximate position of turning points through the comparison of the echogram obtained during hauling with that obtained during setting and through the number of skates hauled up after the nearest marker. It is, however, difficult to find the exact position of turning point and it is also difficult to haul up the line in the part of turning semi-circle holding the boat just above the point of the line leaving from sea bed, because the line is dragged without any marked increase in the load of hauling. This fact meant that the depth along a straight course is reliable, but that along turning course to shallow inclines to be too shallow and that to deep to be too deep. This can explain the reason of narrower range of the depth estimated from the echogram during hauling than that during setting. The sailing speed of the boat during hauling is far slower than that during setting, the former being slower than one skate a minute and the latter being about 4 skates a minute. Accordingly, the current and wind drift of the boat is more influential during hauling than during setting, but maneuvering of the boat is far difficult during hauling than during setting, in spite of the fact that very fine maneuvering is needed during hauling. And sometimes it is difficult to maintain the boat at the ideal position to haul up the line. The line is hauled up from starboard side at a little forward of the pivotting point of the boat. And the gaff-man stands just behind the power gurdy. Accordingly, the slight dip to aft or to starboard does not cause any inconvenience. The slight dip to port side made the line rubbed against board side, and that to bow made the gaff-man difficult to secure the catch. The dip of these directions is corrected immediately. Usually the direction of bow did not show the direction of hauling course. The boat hauls up the line receiving the wind from starboard, for the purpose of making the boat not drifted over the line and dropped fish. She hauls up the line receiving the current from stern, mainly for the purpose of using the blow-up of suspended parts of line which lessens the load and increases the hauling speed and partly for the purpose of easy to gaff again the dropped fish with a slight ahead propulsion, in spite of the fact that it is easier to maneuver the boat receiving the current from bow. Accordingly, whether the dip of the unfavorable direction modifies the depth into shallow or deep depends on the current and wind.

It is natural that the influence of dip is serious on the steep slope but is less serious on the grounds of smooth bottom. It is clear that the part showing a sharp change in depth is settled on a steep slope, but there is no definite proof of the part showing mild change in depth settled on smooth ground, because the change in depth per skate differs according to the angle between the course and isobaths. It is, however, possible to get a rough idea of the topography of the settled area through drawing a chart basing on the settled course and the echogram obtained during this work. The opinion of master fishermen is also one of the useful bases of understanding the bottom topography, for they are familiar with it. And in most of the cases, it may be said that the line is settled nearly perpendicular to the isobaths, which means that the part showing sharp change in depth is settled on a steep slope and that showing mild change is on smooth ground.

The influence of dip in the horizontal direction is $d \tan \alpha$, and the depth difference between the two points spacing this distance may be small on the smooth ground but large on the steep slope ; and that in the correction for the phase lag between the catch and the sounded depth is d $(\sec \alpha - 1)$, and this is not large (where d is the sounded depth and α is the angle between the vertical line and the main line). In any case, it is very rare that a large dip continues over several skates without correction, and the difference in the depth due to dip should be negligible, and it is difficult to consider that the variation of dip seriously modifies the results.

The other source of error in estimating the settled depth of the line through the echogram during hauling should be in the method of depth estimation. When the depth of a point on the line is sounded to be d, it is clear that the catch by this part appears to the surface when the main line of the same length to d is hauled up. This correction is done graphically through the following way, as shown in Fig. 4 : the length of echogram in the horizontal direction does never indicate the length (or distance) but indicates the passing of time, in spite of a large variation in the speed of hauling up the main line. Accordingly, first, the sounded depths at the center of respective skates of main line passing the power gurdy were measured through the echogram. These measured depths were plotted at equal intervals. This figure shows the echogram after correction for the irregularity of hauling speed. The first source of error lais in this step : sometimes, the sounded depth showed sharper decrease than the hauling speed of main line, especially when the line is fastened and the hauling speed dropped into extremely low level. This phenomenon may be either due to the uncorrect location of the boat for hauling which resulted in fastening of main line or due to the fact that the line was settled on a very complicated bottom which also resulted in the fastening of the main line. Regardless of the reason, the estimated depth around these parts should be uncorrect. These skates were excluded from the estimation of the regression of catch on the sounded depth during hauling. But it is difficult to eliminate completely all the skates severely suffered from the error of this type. The correction of phase lag between the catch and the sounded depth was done in the following way : the parallel lines with the dip corresponding to the horizontal-vertical scale ratio were drawn from respective points showing the center of respective skates on the surface line, and the depths at respective cross points of these parallel lines with the curve showing the change of the echo-sounded depth after hauling speed correction were estimated to be the settled depth of respective skates. As shown in Fig. 4, the parallel lines cross to the deepening phases of the curve of bottom nearly right angle. And the estimated depth in this phase may involve small error. The parallel lines cross, however, at acute angle to the shallowing phase of the bottom curve. And the estimated depths in this phase resulted in involving large error. The error due to this reason may be far larger than that due to dip and other reasons. This may be the most probable reason of the regression on the depth estimated from the echogram during hauling showing unclear results. This possibility will be examined in the succeeding reports, in which the depth regression will be examined after stratification of the records according to either shallowing part or deepening one.

In spite of much sources of error as mentioned above in both the catch and the estimated depth, the catch of respective species changed depending on the depth estimated from the echogram during hauling. Among the three species (or group of species) examined in the present report, both the sablefish and the idiot were distributed over throughout the depth covered by the setline. However, the rockfish was distributed only near the shallowest extreme. Accordingly, the estimated pattern of the distribution of rockfish was hardly affected by the presence of skates unable to fulfill full of their efficiency due to technical miss. Even this species, however, cound not be free from the influence of the error in depth estimation. Accordingly, first, this group of fish was chosen for the discussion on the influence of the error in depth estimation on the estimated pattern. Second, the discussion from the same standpoint will be given to the results of idiot, because of the following reason : as mentioned above, the sablefish is the major objective, and the settled depth or the course is purposively chosen for yielding a good catch of this species. And a high possibility of dominancy of this species over the idiot in the order of taking the bait was suggested from the observations and from the results of the analysis. These facts meant that the pattern of idiot is less probably suffered from the modification due to the above-mentioned reasons than that of the sablefish.

The line is settled sectioned into about 10 parts according to the direction (either toward deep or toward shallow). The depth of turning points at the shallowest extreme differed point by point, and the same was true of the depth of the turning points at the deepest extreme. Accordingly, the depth range covered by the parts between each of adjacent two turning points (one being the deepest extreme and the other being the shallowest one) differed part by part, i.e. some of the turning points were at the intermediate depth when a whole string was taken into account. The estimated depth near the turning points bears larger error than that in the part distant from them. If the error in the depth estimation were large and differed according to the turning points, it were hard to expect the clear results, because of the following reason : some of the shallow parts with more abundant catch than the other parts were mis-estimated to be at intermediate depths or too shallow, in consequence, other turning points resulted in the intermediate depth. These facts modify the results into obscure depth regression. Inadequate correction of phase lag between the catch and the settled depth also brought the similar results. If the delay of catch was insufficiently corrected, the catch in the parts hauled up before the turning point at the shallowest extreme was mis-understood to be from deep but that after the turning point was too shallow ; in consequence, the results were modified into as if the negative cubic regression with the minimum (only in mathematical expression) of catch near the shallowest extreme. The over-correction also brought the similar error into the results. Rather clear results found in the regression on the depth estimated from the echogram during hauling indicated, however, that the probable error in the estimated depth was small, which indirectly supported the validity of the estimated pattern of both sablefish and idiot.

The idiot is also the by-catch, but is different from the rockfish in many respects. The most basic difference is that the idiot is distributed over throughout the depth zones covered by the strings. Accordingly, the estimated pattern of the distribution of this species was suffered both from the error in the depth estimation and the presence of skates with accident at the intermediate and deep zones, but this was rather free from the selective attacking. The other source of error of modifying the distribution pattern of this species is the presence of dominant species as the major objective, although this fact made the idiot somewhat free from the influence of consecutive attacking. If it is set, as shown in the clearest results, that this species is distributed densely in the intermediate depth zone but less densely with approach to both of the extreme depths, the regression of catch on the depth shows convex relation to the depth. But, in the regression on the depth sounded during setting, the symptoma of phase lag of catch and depth were found near the deepest extreme in Nos.5, 12, 10, and 1 and near the shallowest extreme in Nos.37, 39, and 25 (No.14 showed the significantly negative cubic regression but practically showing the convex relation to the depth and this string was not included in this group). If this pattern is due to the distribution of this species in these strings, the symptom suggesting this pattern should be found in the regression on the depth estimated during hauling. But no symtom suggesting the similar pattern of this species was found in the results of the regression on the depth estimated from the echogram during hauling. These facts indicated low possibility of this pattern due to the distribution of this fish in these strings. Then, if this pattern is due to the uncorrect estimation of the depth from the echogram of setting or either of the reasons of depth lag, the similar pattern should be found in the regression of sablefish on the depth during setting. However, only the similar but slight trend to the former was found in No.10 and to the latter was in Nos.37 and 39. They were slight. And it is doubtful that these trends would be worthy to be pointed out. It is hard to consider that this is due to the miss of correction for phase lag, for no correction for phase lag was done in the estimation of the depth during setting. The possibility remained only in the estimation of the skate number at turning points ; but the string repeated many turnings ; and it is hard to consider that all the skate numbers at the turnings in the deepest (or shallowest) extremes were incorrectly estimated but all those in the shallowest (or deepest) extremes were correctly estimated. Accordingly, it may be said that the possibility of this pattern due to uncorrect estimation of the depth or severe drift of the line was denied in these strings.

In regard to the regression on the depth estimated from the echogram during hauling, symptoma suggesting insufficient correction of the lag during deepening process or overcorrection during shallowing one in the deeper part were found in Nos.27, 23 and 13 and the counter trends in the shallowest extreme were found in Nos. 9, 33, and 24. But no symptom supporting them derived from the distribution of this species in these strings was found in the regression on the depth during setting. In contrast with this, the regression of sablefish on the depth during hauling showing the symptom of the former group due to the uncorrect estimation of the depth was found in No.27 (quadratic) and in No.13 (cubic), but did not show any symptom supporing the latter due to the same reason. The concave relation of the catch of idiot on the depth estimated from the echogram during hauling was found in Nos.14, 28, 9, 18, and 19. This is the type contrary to the expectation. No symptom supporting this due to the distribution pattern of this species in these strings was found in the regression on the depth during setting. The negative quadratic regression of sablefish on the depth estimated from the echogram during hauling in Nos.14, 28, and 9 denied the possibility of this pattern due to the uncorrect estimation of the depth in these strings, but the significantly positive cubic regression in No.14 and the positive quadratic one in Nos.18 and 19 (although they were insignificant) suggested this pattern in these strings due to the uncorrect estimation of the depth. However, none of the strings showed significantly positive quadratic regression of both of idiot and sablefish. And even if the insignificant one in sablefish were set to be worthy to point out, it is very hard to suppose that this pattern is due to uncorrect estimation of the depth, because of the following reason : this pattern is probable only when all the intermediate depths in all the parts (either the deepening parts or the shallowing ones) were mis-estimated to be both of the extremes and all the extremes were to be the intermediate depth. The location of marker and the number of skates between adjacent two turnings were taken into account, and it is very hard to suppose the possibility of large mis-estimation like this. And if this pattern were due to the mis-estimation of the depth, the catch of rockfish should show the convex relation to the depth, but there was no symptom suggesting this possibility. There remained the possibility of this pattern due to accidental skates at intermediate depth zones, for the pattern of rockfish was free from the modification of the results caused by these skates. Then, the catch of both of the species should be far lower than the other strings, but it is hard to find any fact in support of this supposition. Accordingly, the reason should be examined by stratifying the records into the deepening parts and the shallowing ones.

These results and the consideration on the bathymetric change of the distribution of idiot were summarized, and it may be said that there was very little possibility of the distribution modified by the error in the depth estimation, and that the estimated pattern through the regression analysis was valid.

The sablefish is the major objective, and is dominant over the idiot in the order of taking the bait. Accordingly, the distribution of this species was suffered from all the kinds of modifications including the influence of consecutive attacking. In Area A, the clearest result in the regression of catch on the depth sounded during setting was the typical pattern of bathymetric change (most densely in the 600—800 m zone, and less densely with approach to extreme depths) and the pattern of decrease of catch with progress of repetitious attacking. And there is no need to give any special discussion on the modification of the pattern due to various sources of error. The comparison with the pattern of idiot deduced from its regression on the depth during setting revealed the compensative relation of idiot to the change of hooked density of sablefish either due to the bathymetric difference or with progress of repetitious attacking. No special consideration was needed to the relation between the pattern of sablefish and rockfish.

There was no basic difference between the regression on the depth estimated from the echogram during hauling and that on the depth during setting, in respect of negative quadratic regression and significantly positive linear one. This fact meant that the above-mentioned pattern deduced from the results of the regression on the depth during setting is valid. The number of strings showing the most probable pattern (significantly negative quadratic regression) decreased from 4 on the depth during setting to 2 on the depth estimated from the echogram during hauling. The obscure results of the regression on the depth estimated from the echogram during hauling may be due to the difficulty in estimating the depth through the echogram during hauling, especially in the shallowing parts as pointed out already. And it is necessary to examine this possibility by stratifying the records according to either deepening parts or shallowing ones. The comparison of the regression of sablefish on the depth estimated from the echogram during hauling with that of the idiot on the same depth revealed the compensative relation between them as the general trend, but the details were complicated.

The bathymetric distribution of sablefish in Area B was characterized by the negative cubic regression on the depth during setting (significantly in the three strings in the earlier half and insignificantly in the same number of strings) suggesting the dense population near the shallowest extreme. The regression of idiot on the depth during setting revealed that this is not due to the error in the depth estimation. The similar pattern was found in the regression of sablefish on the depth estimated from the echogram during hauling as the significantly negative cubic one in No.15, the significantly positive quadratic one in No.27, and the insignificant one in Nos.6, 15, 27, 34, and 36. These facts supported the possibility of this pattern due to the distribution of this species. The notable difference in the distribution pattern of idiot according to the method of estimating the settled depth was found in the shallow zone of No.9 (low in the regression on the depth during setting but high in that on the depth estimated from the echogram during hauling). But there was no symptom suggesting the similar difference in the pattern of sablefish in this string. The distribution of idiot in No.15 seemed to show different pattern according to the method of analysis, but it was also hard to find any symptom suggesting the possibility like this in the distribution of sablefish. And it is hard to guess the reason why the difference in the deduced pattern according to the method was found in the idiot but not in the sablefish.

In Area C, the bathymetric change in the catch pattern of sablefish deduced from both of the methods was similar to each other except the sharp increase in deep zone of Nos.16 and 37 through the regression on the depth estimated from the echogram during hauling. The discrepancy in the results of idiot was notable also in these strings. These facts suggested that the depth estimated from the echogram during hauling in Nos.16 and 37 should be somewhat uncorrect. And the regression on this depth in these strings should be excluded from the consideration on the general trend. For other strings, it may be said that the results may be valid.

In Area D, the estimated pattern of bathymetric distribution of sablefish differed markedly according to the methods except in Nos.32 and 38. The same was true of idiot in Nos.11 and 30. These facts suggested that the estimation of depth from the echogram during hauling should contain less error in Nos.32 and 38, but contained large error in Nos.11 and 30. It was difficult to find the reason why the results differed according to the species in Nos.17 and 26. And it may be said that the results of the regression on the depth estimated from the echogram during hauling in Nos.11 and 30 should be excluded from the consideration on the general trend.

In Area E, the patterns in No.18 and in the shallow part of No.39 showed a marked difference according to the method of estimation. The patterns in these strings estimated from the regression on the depth during setting took the similar pattern to those in the other strings, but those from the regression on the depth estimated from the echogram during hauling took different pattern from those in the other strings. The pattern of idiot in No.18 also showed marked difference according to the method. In regard to the shallow part of No.39, the difference of the pattern according to the method of estimation was suggested in the distribution of idiot, too. These facts indicated the possibility of uncorrect estimation of depth in No.18 and in the shallow part of No.39, especially in the depth estimated from the echogram during hauling.

In Area F, the regression of sablefish on the depth during setting showed slight increase of catch in the shallow zone of No.13, and in the deep zone of Nos. 10 and 33. The similar pattern could not be found in the regression on the depth estimated from the echogram during hauling. The regression of idiot on the depth during setting showed the similar trend in the deep zone of No.10 but not in Nos.13 and 33. These facts suggested the uncertainty in the depth estimation from the echogram during setting in the deep zone of No.10. But this was in the 1000 m zone, and the skates relating to this phenomenon was few. And the difference was far less meaningful than the impression from Fig.6. The regression of sablefish on the depth estimated from the echogram during hauling showed very slight increase of catch near the deepest extreme of No.13. The same trend could not be found in the regression of the same species on the depth during setting, but found in the same relation in idiot. These facts suggested the uncorrect estimation of the depth near the deepest extreme in No.13 through the echogram during hauling, although this trend was not serious and whether noteworthy or not was doubtful.

In regard to the strings set around the Albatross Bank, the pattern of sablefish deduced from the linear regression on both of the estimated depths showed a very good coincidence. The notable difference according to the method was found in the cubic and quadratic regressions in No.2. However, the diversity in the pattern of idiot according to the method of analysis provided with no fact applicable to the discussion.

These results of discussion in regard to the probable sources of error of modifying the deduced pattern were summarized and it may be said that: 1) the estimated pattern of bathymetric distribution through the regression of catch on the depth sounded during setting was less probable to be suffered from various sources of error in depth estimation, 2) however, the modification of the distribution due to the consecutive shootings over the same area could not be neglected, and 3) the pattern deduced from the regression on the depth estimated through the echogram during hauling was somewhat uncorrect, especially in the extreme depth zones of Nos.16 and 37 in Area C, Nos.11 and 30 in Area D, and Nos.18 and 39 in Area E. This was mainly due to the uncertainty in the estimated depth from the shallowing phase of the echogram involved in the graphical method of depth estimation. However, the above-mentioned uncertainty was not serious, and did not modify basically the deduced pattern.

Conclusion

The setline consists of many units of equal and simple construction connected in a series. This gear is immobile and is simply shot and hauled up along a course. And there is little room for causing the variation of catch within a string due to different skill or different conditions of gear handling. In these respects, the setline is one of the most suitable gears for examining the distribution pattern of fish. However, on the present days, the setliners are driven away into steep slope or rough grounds unable to be fished safely with other mobile gears of high efficiency. In consequence, it is difficult to make all the skates of main lines settled under the equal conditions and without accident. A string coveres very wide depth range, usually on the bottom of from 500 m to 900 m deep. Some of the skates are naturally settled in the expected depth zone of good catch but others are out of it. Some of them are hung over the irregular bottom and catch by the others are slipped off because fastened with bottom objects or dragged over the sea bed during hauling. The boats repeat shootings in several favorable spots shifting around one to another. Once a spot is fished, it is necessary to leave it unfished over sufficient intervals, otherwise the catch declines. The depth range covered by the string shifted string by string. And the parts of main line with good catch was found mainly in the zone unfished with the preceding strings. All these facts made the catch pattern fluctuated string by string or made the general trend of the pattern unclear.

The present report dealt with the frequency distribution and bathymetric distribution of catch by a skate. The frequency distribution of catch of sablefish by a skate was agreeable to the negative binomial series in the 10 strings, but was more strongly contagious than this theoretical series in the other strings. That of idiot and rockfish in most of the strings was agreeable to this theoretical series. However, it is doubtful whether the frequency distribution under the uniform environment is agreeable to this series or this pattern is due to the modification of the above-mentioned facts, especially due to the bathymetric difference in density.

In regard to the bathymetric distribution, the regression of catch on the depth, especially that on the depth sounded during setting the line, revealed clearly the following pattern, in spite of the above-mentioned sources of error which are probable to make the results unclear : the sablefish was most densely hooked in the 600—800 m zone but less densely with approach to both of the extreme depths. The idiot was hooked densely in the 500—700 m zone but less densely in deep one, but it was impossible to guess the pattern in the clossed area shallower than 500 m, for the strings were very rarely extended to shallow zone. The rockfish was less densely hooked only near the shallowest extreme of the depth range covered by the strings. The similar pattern was found through the regression on the depth estimated from the echogram during hauling, but it was less clear, because of uncertainty in the estimated depth involved in the graphical method of depth estimation, especially in the depth estimated from the shallowing phase of echogram recorded during hauling.

Summary

The sablefish setline is the fishing method working on the present days on the steep slope or rough ground along the outer edge of the continental shelf from the Aleutian Islands to near Vancouver Island. Before entering the subjects, the outline of this fishery (brief note on history, fishing ground, gear construction, and fishing method) was described. A skate of main line is about 72 m long with 35 hook droppers. A string consists of about 400 skates connected in a series, and is stretched repeating hard turnings nearly to the counter direction along about 10 nearly parallel courses usually in the zone from 500 m to 900 m deep.

The present report dealt with the frequency distribution and the bathymetric distribution of catch by a skate of not only the major objective (sablefish) but also the by-catch (idiot and rockfish) observable in the records along the 39 strings collected July to August in 1974 mainly off Baranof Island in the Gulf of Alaska. And the results obtained were summarized as follows :

1. Catch of sablefish by a skate varied from 0 to 23. The average of catch by a string showed a large between-string variation from 0.0810 per hook to 0.2399.
2. The frequency distribution of sablefish by a skate in none of the strings was agreeable to the binomial series. However, that in the 10 strings was agreeable to the negative binomial series out of the 39 ones, but that in the other strings showed more strongly contagious pattern than this theoretical series.
3. The strings in the lowest level of fitness (< 0.005) to the negative binomial series were put aside the consideration, the frequency distribution showed better fitness to the negative binomial series 1) with deepening trend of the shallowest limit of the depth sounded during setting, 2) as well as that estimated from the echogram during hauling, 3) with the shallowing trend of the deepest limit of the depth sounded during setting, 4) that of the depth estimated from the echogram during hauling, in consequence 5) with the narrowing trend of the depth difference within a string sounded during setting, and 6) that estimated from the echogram during hauling.
4. The frequency distribution of idiot, which is the most important by-catch, in all the strings except one was not agreeable to the binomial series, that in the 34 strings out of the 39 ones

was agreeable to the negative binomial series, and the distribution in the strings unable to be regarded to be agreeable to this series was more strongly contagious than this theoretical series.

5. The frequency distribution of the rockfish by a skate in the 15 strings was compared with the negative binomial series, but it was difficult to compare that in the other strings with this theoretical series because of insufficient number of catch classes of higher frequency than 5 due to low rate of catch. That in the 11 strings out of these 15 ones was agreeable to the negative binomial series but that in the other strings was more strongly contagious than this theoretical series.
6. The catch of sablefish showed a convex relation to the depth sounded during setting the line with the maximum at 600-800 m zone especially 600-700 m zone (the quadratic regression coefficient was significantly negative in the 25 strings and insignificantly negative in the 9 strings out of the 39 ones).
7. The boat fished mainly in the 6 favorable spots, shifting one to another. With progress of repetitious shootings, the bathymetric distribution of catch of sablefish changed along the following pattern : when the strings were settled consecutively at insufficient unfished time-intervals covering the similar depth zones in the same spot, the catch from the zone supplied a good catch to the preceding string declined, but that from the zone of poor catch increased. When a part of string was stretched over the different depth zones, where were left unfished by the preceding strings, a good catch was supplied from these zones. When a spot was left unfished sufficient time-intervals, the catch recovered. But the interval necessary to recover the catch and the level of recovery differed according to the spot and according to the depth zones. These facts modified the deduced pattern, and the results became unclear.
8. The regression of catch of sablefish on the depth estimated from the echogram during hauling showed similar but less clear results than those from the regression on the depth sounded during setting the line. The major changes from the regression on the depth sounded during setting to that on the depth estimated from the echogram during hauling were the decrease in the number of strings showing the significantly negative cubic regression and the increase in that showing the insignificantly positive one. The same was true of the quadratic regression. The trend of the linear regression coefficient taking the negative value became less clear.
9. The catch of idiot showed the negative quadratic regression on the depth sounded during setting (significantly in the 20 strings but insignificantly in the 15 ones) and the negative linear one (significantly in the 24 strings but insignificantly in the 11 ones).
10. The depths of maximum catch of idiot estimated from the regression on the depth during setting were concentrated into the zone a little shallower than those of the sablefish —— from 500 m to 700 m deep, showing areal difference.
11. The regression of catch of idiot on the depth estimated from the echogram during hauling showed the similar but less clear results than the regression on the depth during setting the line : clear negative quadratic regression on the depth found in that on the depth sounded during setting disappeared. And only the trend of negative linear regression remained in that on the depth estimated from the echogram during hauling.
12. The rockfish showed negative cubic regression, positive quadratic one, and negative linear one, on the depth sounded during setting, all showing the sharp increase of catch near the shallowest extreme. The similar but less clear results were found in the regression of the

catch of this species on the depth estimated from the echogram during hauling.

13. The detailed discussions were given to the sources of error in the catch mainly relating to the accidental skates due to technical miss and those in the depth estimation. And the most influential source of error making the results less clear may be involved in the graphical method of depth estimation from the echogram during hauling, especially the estimation from the shallowing phase. This is the reason why the regression on the depth estimated from the echogram during hauling ended in less clear results than that on the depth sounded during setting the line.
14. The validity of the method adopted here, i.e. that of the estimated pattern, was checked by examining the difference in the deduced pattern of the same species due to the different way of depth estimation and that in the pattern of the different species deduced from same method. It was found out that the possibility of uncorrect estimation of the settled depth from the echogram during hauling could be pointed out in a few strings near the extreme depths. And it may be said that the above-mentioned pattern, especially that deduced from the regression on the depth sounded during setting the line, was valid.

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