The R-H II Push-net and Quadrat-net, Gears for Studying Distribution Patterns of Juvenile Flatfishes along the Beach

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The designs of a twin push-net, a slight modification of the R-H push-net and a quadrat-net, a netted quadrat, to be used in the study of distribution patterns of juvenile flatfishes along sandy beaches are illustrated. Both gears proved to be effective. The width between the upper and lower 95% confidence limits (expressed as values relative to catch) of a catch of juvenile Japanese flounder by a single operation of the push-net with a sweeping area of 0.75 by 50m decreased with the increase of catch, *e. g.* 32-210% for the catch of 5 fish and 61-150% for the catch of 20 fish. Catches of juvenile Japanese flounder by the quadrat-nets along the beach fitted well a negative binomial distribution in one occasion and a Poisson series in another. The gear efficiency of the push-net was estimated to be about 30%.

Key words: sampling gears; juvenile flatfish; distribution pattern; gear efficiency; sandy beach ichthyofauna.

Shallow waters along sandy beaches are inhabited by newly-settled juveniles of flatfishes such as plaice (*Pleuronectes platessa*) and turbot (*Scophthalmus maximus*) in Europe and Japanese flounder (*Paralichthys olivaceus*) and stone flounder (*Kareius bicoloratus*) in Japan. Around a low water spring tide, the highest density of such juveniles is usually observed close to the water edge.[1-6]

In the study of flatfish juveniles along beaches, two types of sampling gears have mainly been used, a beam trawl and a push-net. The former is towed with a flat or a rubber dinghy in the waters as shallow as the draft of the vessel allows, *e. g.* 40 cm deep,[2] while the latter is pushed by a man wading along the beach. The Riley push-net[7] has been used popularly by European scientists, and we are also using the R-H push-net,[8] a slight modification of the Riley push-net.

In interpreting the results of sampling, we must take into consideration two things, the efficiency of the gear and the variability/validity in catches of single operation with the gear. The variability in catches must be related to the distribution pattern of the fish in the path of the gear.

Trials by various methods have been made to determine the efficiency of the beam trawl for juvenile flatfishes.[6,9-12] The variability in catches of gears for juvenile flatfishes, on the other hand, has little been studied, in contrast with that this topic has long been studied with plankton samplers.[13,14]

The two gears described below are for studying the variability in catches of the R-H push-net as well as the distribution pattern of juvenile flatfishes along the beach. Some preliminary results of sampling with the gears are also given.

R-H II push-net

1. Construction

The net consists of a 1.5-m beam frame, a pair of ski feet, a handle, tickler chains, and a bag net. Except for the last-named, they are made of the same materials and in the same dimensions as the R-H push-net, details of which are given in our former paper.[8]

The bag net is constructed of 1-mm mesh nylon russell netting (Nihon Bolting Cloth Co. Ltd., T-280) except for the anterior part of the bottom with 5-mm mesh (NBC, NS-4.5). The bag net, 255 cm long along the side, is two-legged in the posterior half. In the anterior half, it has a partition netting (1-mm mesh) so that the specimens present in the right half of the gear's path may enter into the right leg and those in the left half into the left (Fig. 1).

2. Operation

The net is pushed by two persons at a constant speed of about 35m per minute following Riley and Corlett[9] along 100m of beach in water within wading depths. The operation along the line of 100m is, however, once discontinued at the mid-point of the line to withdraw the catch, and then resumed for the remaining 50m. Consequently, we obtain four samples of 0.75-by-50-m sweeping area along a line, instead of one sample of 1.5-by-100-m sweeping area as we obtained before with the R-H push-net.

When sampling is made only at a low tide, we repeat the above-mentioned operation three times, parallel to each other at different depths, usually at 15, 50 and 100 cm.

In a series of samplings over a tidal cycle, the collection line is fixed along the line 15 cm deep at a low water spring tide. At any tidal phases when the depth along the fixed line exceeds wading depths, the net is pulled by hand in an anchored boat. In this case, the net with the handle removed is lowered onto the sea bottom at one end of the fixed line from a boat. The boat slowly moves along the line while the warp is paid out at the same speed as the boat's speed. When a prescribed length of the warp, either 50m or 100m, is paid out, we stop the boat and drop anchor to commence pulling the net.

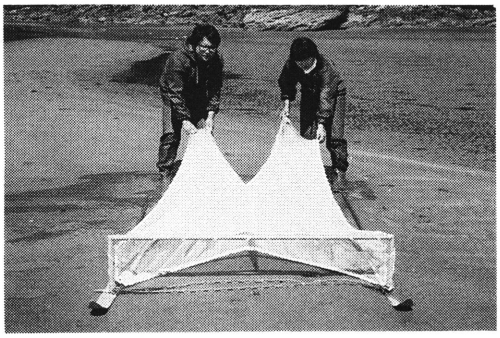

Fig. 1. The R-H II push-net. The anterior part of the bag net is also separated into right and left by a partition net.

3. Examples of the results of collections

Several series of experiments were carried out at a sandy beach of Yanagihama near Nagasaki in April and May 1990. Among several beaches on the western coast of Kyushu surveyed by us, juvenile Japanese flounder just after settlement was most abundant in this beach, with the peak of occurrence in the middle of April.[15] The highest catch by a single operation with the R-H push-net obtained in the past was 131 juveniles, sweeping area being 1.5 by 100m.

Table 1 shows the result of collections with the R-H II push-net made on April 18 and 19, 1990. Since the collection dates fell on a neap tide of March 23 and 24 in the lunar calender, the net was pulled along the low water line of spring tide from an anchored boat.

To find the appropriate transformation of catch (x), the followings were calculated in turn: 1) the mean and variance of catches for each sampling time, 2) the parameters a and b of $\sigma^2 = a\,\mu^b$, and 3) $p = 1-b/2$. As we obtain $b = 0.847$ and $p = 0.577$ from the data listed in Table 1, each of the catches may be appropriately replaced by $x^{0.577}$ for further statistical treatments (Elliot,[16] p. 71). For simplicity we adopted the square root transformation, $y = (x+0.5)^{0.5}$.

Table 2 shows the analysis of variance for the transformed data from Table 1. The mean square for times is highly singificant when tested against that for the second order interaction, with $F_T = 11.13$ and $F^5_5\ (0.01) = 10.97$. None of the mean squares from the other sources is significant, and we can consider that the catches neither of the first and second hauls nor of the right and left sides differ significantly from each other.

Table 1. Record of collections of juvenile Japanese flounder with the R-H II push-net along 100m of Yanagihama beach on April 18-19, 1990. As the collection dates fell on a neap tide, the net was towed in an anchored boat. Each haul was once discontinued at mid-point of the 100-m line to withdraw the catch, and then resumed for the remaining 50m

Time of collection				1st haul of 50m		2nd haul of 50m		Total
Day	h	Tide	Dep.(m)	Sea side	Land side	Sea side	Land side	
18	1545	Ebb	1.5	2	0	2	0	4
	2000	Low	0.9	8	7	17	9	41
19	0004	Fld	1.6	7	5	5	7	24
	0635	Ebb	1.8	3	2	1	1	7
	0900	Low	1.7	1	6	3	2	12
	1200	Fld	1.8	0	1	4	1	6
Total				21	21	32	20	94

Table 2. Analysis of variance of the catches shown in Table 1. The square root transformation, $y = (x+0.5)^{0.5}$, was applied before the calculation

Source of variation	Degree of freedom	Sum of squares	Mean square
Time (T)	5	13.120	2.624**
Haul (H)	1	0.120	0.120
Side (S)	1	0.295	0.295
First order interaction			
TxH	5	1.306	0.261
TxS	5	1.202	0.240
HxS	1	0.344	0.344
Second order interaction			
TxHxS	5	1.178	0.236
Total	23	17.565	

** probability less than 1%.

Table 3. Reformation of Table 2 by putting together the sources of variation of which the variances are insignificant when tested against the variance of the second order interraction

Source of variation	Degree of freedom	Sum of squares	Mean square
Time	5	13.120	2.624
Remainder	18	4.445	0.247
Total	23	17.565	

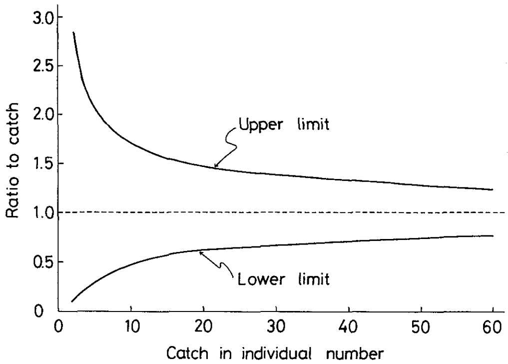

Fig. 2. The change in the 95% confidence limits of the catch of the juvenile Japanese flounder by a single haul of the push-net with a sweeping area of 0.75 by 50m. The upper and lower confidence limits are expressed in terms of the ratio to the catch in number of fish.

From the above results, we may put together the sources of variation other than times of Table 2, and we get Table 3. The 95% confidence limits of the catch x by a single haul of 0.75 by 50m are calculated as $(x^{0.5} \pm 1.96 \cdot 0.247^{0.5})^2$. Fig. 2 illustrates how the values of the 95% confidence limits change with x.

Quadrat-net

1. Construction and operation

The net is practically a quadrate riddle, 70.7 cm along a side, *viz*. 0.5 m² in area, and 10 cm in depth (Fig. 3). The mesh of the netting is 3 mm, and the quadrate frames of the upper edge and of the bottom are made of galvanized iron rods 5 mm thick. Two small pieces of stylofoam are used as marker buoys for a quadrat-net, each tied at each corner on a diagonal line of the upper edge with a short string so that the marker buoy will come out on the surface of water when the depth of water above the quadrat-net becomes less than about 50 cm.

At first, we made ten quadrat-nets to test if we can catch juvenile Japanese flounder with this gear. A line of 100m was set on the exposed part of the tidal flat a little above and parallel to the low water line of a spring tide. The position of each of the ten quadrat-nets to be placed along this line was determined by using a random number table. A shallow hollow about 5 cm deep was made at each position by removing the sand, a quadrat-net was placed there with the side nettings folded and covered with sand so that the upper edges did not show (Fig. 3).

A little before the second low tide after setting, when the quadrat-nets were still under water of 30 to 40 cm thickness, we recovered them. Two persons, each holding the opposite side of the upper edge, lifted the quadrat-net and shaked it keeping its lower half in water to sift out the sand. If any juvenile fishes were caught, they were picked up and put in a specimen bottle.

Encouraged with a promising result of the first trial with ten quadrat-nets, we made additional twenty quadrat-nets of the same construction. This time we set three lines of 100m length, 5 to 10m apart from each other, close and parallel to the low water line of a spring tide. Ten quadrat-nets each were allocated for each of the three lines. Otherwise the method of operation was the same as before.

2. Examples of the results of collection

The results of the collections with ten and thirty quadrat-nets made on April 10-11 and April 25-26, 1990, respectively, are summarized in Table 4. The quadrat-nets were set at the low tide in the afternoon of the first day and recovered 22 to 24 h after that.

In the first trial eight quadrat-nets out of ten caught at least one juvenile Japanese flounder, giving a total catch of 21 fish and an average of 2.1 fish per quadrat-net or 4.2 fish/m². In the second trial with 30 quadrat-nets only nine caught the juveniles of Japanese flounder. The total

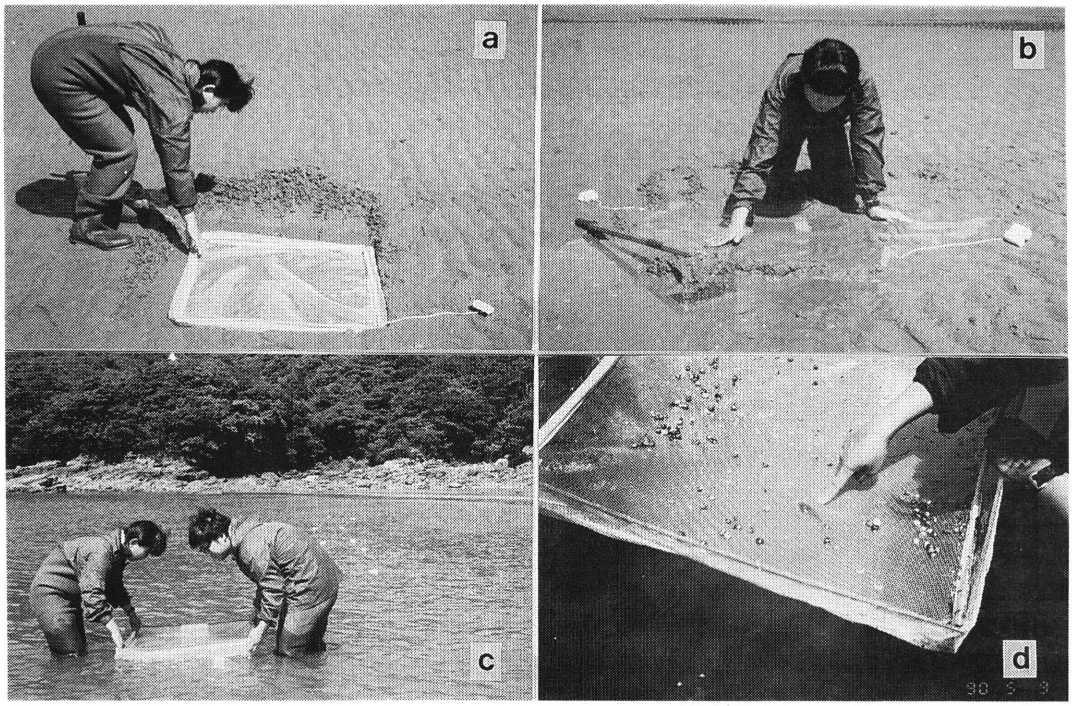

Fig. 3. The operation of the quadrat-net. a) Placing a quadrat-net in a shallow hollow on the tidal flat. b) Covering the quadrat-net with sand. c) Two persons sifting out the sand on recovering the quadrat-net a little before the next day low tide. Marker buoys for other quadrat-nets are seen behind the person on the right. d) Pointing at a juvenile Japanese flounder collected.

Table 4. Two records of collections of juvenile Japanese flounder with the quadrat-nets at Yanagihama beach in April 1990. The quadrat-nets were set at the low tide and recovered before the low tide next day. The expected frequencies by catches were calculated assuming that catches on April 10-11 may fit a negative binomial distribution and those on April 25-26 a Poisson seris

a. April 10-11, with ten quadrat-nets

Catch x	Observed f	fx	Expected m	x^2 $(f-m)^2/m$
0	2	0	3.3	0.512
1	3	3	2.2	0.291
2	3	6	1.5	1.500
3	1	3	1.0	0.000
4	0	0	0.7	
5	0	0	0.5	
6	0	0	0.3	
7	0	0	0.2	0.500
8	0	0	0.1	
9	1	9	0.1	
10～	0	0	0.1	
Σ	10	21	10.0	2.803

b. April 25-26, with 30 quadrat-nets

Catch x	Observed f	fx	Expected m	x^2 $(f-m)^2/m$
0	21	0	20.1	0.040
1	6	6	8.0	0.500
2	2	4	1.6	0.100
3	1	3	0.2	1.633
4～	0	0	0.1	
Σ	30	13	30.0	2.273

Note: $x^2(\nu = 2, p = 0.05) = 5.990$.

catch was 13 fish, and the mean 0.43 fish per quadrat-net or 0.86 fish/m².

The variance of the distribution of catches in the first trial was calculated as 6.767 and is much greater than the mean, while that in the second trial was 0.599 and the null hypothesis that the variance and mean ratio is unity is not rejected (Elliot,[16] p. 40-42). This suggests that the catches by the quadrat-nets in the first trial may follow a negative binomial distribution and those in the seccond a Poisson series.

The expected frequency in terms of the number of the quadrat-nets obtaining a certain number of juvenile Japanese flounder was calculated following Elliot (p. 18-29), and added in the fourth column of Table 4. The parameters used are $\bar{x} = 2.10$ and $\hat{k} = 0.945$ for the first trial and $\bar{x} = 0.43$ for the second trial, respectively.

The χ^2s were calculated for the test of "goodness-of-fit" in the fifth column of Table 4. The total χ^2s of 2.803 for the first trial and 2.273 for the second are well below the 5% point of 5.991 ($\nu = 2$ in both). The agreement with a negative binomial distribution and a Poisson series, respectively, of the results of these collections is accepted at the 95% probability level.

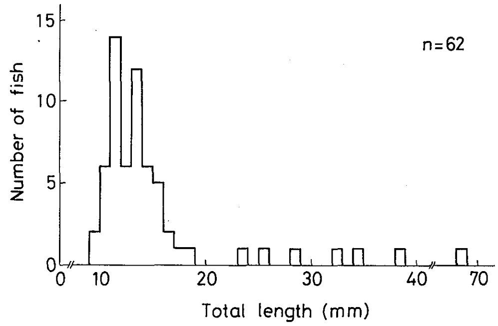

Fig. 4. Total length composition of juvenile Japanese flounder collected with the quadrat-nets along the beach of Yanagihama in April and May, 1990.

3. Size of juveniles collected

In addition to the two trials explained above, we operated the quadret-nets nine more times in April and May with little success. The total number of juvenile Japanese flounder collected amounted to 61 fish.

Most of the jeveniles collected were between 10 and 16 mm TL, while some juveniles exceeding 30 mm TL were also caught (Fig. 4).

4. Comparison of the catches of the R-H II push-net and quadrat-nets

Collections with the R-H II push-net were also made on April 26. Just before the quadrat-nets were recovered in the second trial, we repeated the operation with the push-net for 50 m twice between rows of quadrat-nets. A total of 44 juveniles of Japanese flounder were caught, giving an apparent density of 0.29 fish/m².

It may be reasonable to assume that the earlier-stated density of 0.86 fish/m² based on the collections with the quadrat-nets represents the actual density of the juveniles much better than the above-mentioned apparent density. If this is accepted, the gear efficiency of the R-H II push-net is considered as about 30%.

Supplementary remarks

The main purpose of the present paper is to describe the gears for studying the distribution pattern of the juvenile Japanese flounder along the beach. In addition, the catches of the juveniles with the R-H II push-net in April this year were generally lower compared with those in 1988 and 1989 when we used the R-H push-net. More detailed results and discussion on the distribution pattern will appear after we will be able to collect more data in the next season.

A similar idea as our quadrat-nets to estimate the density of juvenile Japanese flounder was adopted by Fujii et al.[6] However, they placed 1-by-1-m quadrats on the sea bottom, and counted the juveniles present in each quadrat by SCUBA-diving, without catching specimens. They compared the densities of the juveniles assessed by "SCUBA-equipped quadrat method" and by experimental tows with the Kuipers beam trawl, and estimated the gear efficiency of the beam trawl to range from 25.0 to 30.8%, which are close to the gear efficiency of the R-H II push-net obtained by us.

A sampling device resembling our quadrat-net, but only by name, is the drop-net quadrat reported by Hellier.[17] This device is for studies of fish population in shallow marine bays and much larger than ours, being either 15.9 by 15.9m or 31.8 by 31.8m. The quadrat consists of a steel cable suspended above surface of the water from eight pilings. A small mesh net supported by the cable is kept rigged for several hours and dropped by trigger mechanism to isolate the quadrat. The fish trapped in the quadrat are then caught with a bag seine.

Acknowledgements

Our heartfelt thanks go to Yasuyuki Tamamoto of the Municipal Office of Ooseto Town and Motofumi Kimura of our laboratory who helped us in the field work during the present studies. A part of this study was executed with a subsidy from the Japan Shipbuilding Industry Foundation to the third author.

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(* In Japanese with English Summary)

カレイ目着底稚魚の分布様式研究のための採集具，R-H II Push-net および Quadrat-net

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砂浜海岸の汀線付近におけるカレイ目着底稚魚の分布様式を研究するため，特殊な押し網とコドラート網を製作した。押し網は R-H push-net の網の部分を左右ふたつに仕切ったもので，従来の1.5x100m の1サンプルの代わりに0.75x50m の4サンプルをとるようにした。コドラート網は70.7cm四方（面積0.5m²）の一対の枠に3㎜目の網を張って深さ10cmの篩状にしたもので，干潮時に大潮低潮線付近の海底に浅く埋めておいて翌日の干潮で干出する前に取り上げる。

押し網による掃底面積0.75x50m の1サンプルに得られたヒラメ稚魚数の95%信頼区間は，採集数が多くなるほど相対的に狭くなり，例えば採集数5個体のとき0.32〜2.1倍，20個体のとき0.61〜1.5倍と計算された。

コドラート網を使った2回のヒラメ稚魚採集結果は，それぞれ負の2項分布とポアソン分布に適合した。

押し網とコドラート網の採集結果の比較から，前者の漁獲効率はほぼ30%と推定された。