Evaluation of Attractiveness of Angling Bait Extracts for Oriental Weatherfish Using All the Parameters of Three Logistic Curves for Different Behaviors[*1,*2]

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Attraction activities of the 12 representatives of fishing bait for oriental weatherfish *Misgurnus anguillicaudatus* were estimated by applying a logistic curve ($y=\boldsymbol{g}/\{1+\exp[-\boldsymbol{r}(x-\boldsymbol{a})]\}$) to the cumulated number polygons of the individuals entered into, left from, or retained in the baited sector, for the purpose of evaluating their attraction activities, paying attention to all the specificities, which were indicated by the respective parameters of the curves. The following conclusions were obtained:(1) The variation in the parameters was large according to the baits. (2) When a bait was chosen because of its excellent specificity in one of the parameters, the change in another specificity, which was expressed as the correlated parameters, was inevitable. (3) The following baits were chosen by the desired specificity, which differed according to the role of the bait in the respective fishing methods: the best bait for the non-return trap was the Japanese pilchard, the preferable baits for the open trap were the limpet, barnacle, Japanese river goby, Japanese pilchard, silkworm pupa, and earthworm, and the baits good for the longline and the non-return trap were the limpet, barnacle, Japanese river goby, and Japanese pilchard.

1 Introduction

Various methods have been reported on evaluation of feeding attraction of baits for fish by ethological observations.[1-18)] On the other hand, we have previously reported[11-14)] that the cumulated number of individuals entered into the sector with the test bait extract increases in accordance with the passing of the observation time following a logistic curve $y=\boldsymbol{g}/\{1+\exp[-\boldsymbol{r}(x-\boldsymbol{a})]\}$. Hereafter, to simplify the description, the cumulated frequency polygon of the entered individuals is simply expressed as the number of entered individuals. The same was true to either or both of the number of individuals left from or retained in it. In our laboratory, the activity of bait as the feeding attractant was evaluated by using parameter $\boldsymbol{a}$ of the number of retained individuals for abalone *Haliotis discus* and oriental weatherfish *Misgurnus anguillicaudatus* and using

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gr of that entered or left individuals for yellowtail *Seriola quinqueradiata*, because a good parallelism could be found between these parameters and the behavior observation during the experiment.[11-14] At the same time they have the following meaning: the parameter ***a*** corresponds to the time when the number attained to $g/2$, where ***g*** is one of the parameters of logistic curve and means the level of asymptote, and the parameter ***gr*** corresponds to 4 times the differential coefficient of the logistic curve at time ***a***.

The bait is used for various purposes, and its specificity and/or necessity differs according to its major role, even for the same bait. Abalone once entered into the baited sector and few of them left from it, the logistic curve could not be applied to its cumulative polygon of the left individuals. Accordingly, 6 parameters—3 for the entered individuals and 3 for the retained ones—could be estimated for abalone. In contrast with abalone, yellowtail once entered into the baited sector and left from it after a short stay. This behavior made the parameters for the retained individuals unable to be estimated. And the 6 parameters—3 for the entered individuals and 3 for the left ones—were estimated and used in the present series of studies.[19] Conditions were different in the oriental weatherfish from the above-mentioned 2 species of the test animals. The oriental weatherfish entered into the baited sector and some of them left but others retained in the baited sector. Accordingly, 3 parameters each could be estimated for the cumulative frequency polygons of the 3 behavior types—entered, left and retained individuals.

The above-mentioned behavior pattern threw doubt as to the presence of the correlation among the estimated parameters, as found in abalone and yellowtail.[19] This point was examined, in the present report, by using the results from 12 fishing baits for oriental weatherfish. Suggestions for choosing bait were also discussed.

2 Materials and Methods

The test tank, the preparation of bait solution, and the method of estimating the parameters of logistic curve were described in the preceding reports.[11-14, 20] The tested baits and their abbreviations were listed in Table 1.

To make it possible to compare the attractivity of the 12 baits by using the 4 channel test tank, the 12 baits were randomly classified into 4 groups. And the numbers of individuals entered into, left from and retained in the baited sector of the respective channels were counted at every 1 min intervals for 10 min, sharing one channel for control (=dummy gauze ball only). From the results of each group, the parameters, ***r, g*** and ***a***, for the 3 baits and a dummy gauze were estimated. Then, they were divided by the corresponding parameters of dummy gauze ball, for the purpose of making it possible to compare the estimated parameters among the different groups of experiments one another. The parameters thus standardized were expressed as ξ_{ijk}, where the respective suffixes were defined as follows: The suffix i was to express the behavior type, namely E being for the number of individuals entered into the baited sector, L being that left from it, and R being that retained therein. The suffix j was for the parameter of logistic curve shown above, and k was the abbreviation of the bait, which was shown in Table 1. However, the suffix k was not described for expressing the variable name.

3 Results and Discussion

3.1 Outline

The standardized parameters, ξ_{ijk}, were listed in Table 1. The parameters shown in

Table 1. Attraction index ξ_{ijk} of the baits

Baits	Abbreviation	Entered				Left				Retained			
		r	*g*	*a*	*gr*	*r*	*g*	*a*	*gr*	*r*	*g*	*a*	*gr*
Japanese pilchard*1	JP	1.545	2.323	1.018	3.591	0.752	2.649	1.152	1.993	1.415	2.912	2.068	4.121
Squid*2	SQ	1.103	0.997	0.906	1.100	0.442	1.336	1.151	0.590	1.576	0.963	1.489	1.519
Whiskered velvet shrimp*3	WS	1.005	1.534	0.939	1.543	0.457	1.856	1.215	0.848	1.207	1.844	1.431	2.226
Japanese river goby*4	JG	1.191	1.758	1.224	2.093	2.471	1.152	0.916	2.847	0.311	3.192	2.495	0.992
Sea cucumber*5	SC	0.550	1.805	1.846	0.992	0.485	2.100	1.937	1.018	0.336	1.446	1.636	0.486
Barnacle*6	BN	0.997	1.530	1.166	1.525	1.226	1.234	0.972	1.514	0.220	3.421	3.648	0.753
Sea cockroach*7	SR	0.810	1.845	1.553	1.494	0.759	1.781	1.653	1.352	0.945	2.233	1.562	2.111
Mask crab*8	MC	0.895	1.185	1.299	1.060	0.810	1.176	1.300	0.953	1.072	1.225	1.461	1.313
Silkworm pupa*9	SP	1.036	1.605	1.303	1.663	0.758	1.365	1.486	1.034	1.540	2.690	1.465	4.143
Limpet*10	LP	0.525	1.675	1.581	0.879	1.273	1.199	1.096	1.527	0.073	4.153	4.031	0.302
Brown alga*11	BA	0.781	1.128	1.208	0.881	0.912	1.021	1.126	0.932	0.377	1.467	1.361	0.554
Earth worm*12	EW	0.889	1.723	1.273	1.532	1.318	1.418	1.132	1.869	0.272	2.616	1.469	0.711

*1 *Sardinops melanosticta*; *2 *Todarodes pacificus*; *3 *Metapenaeopsis barbata*; *4 *Acanthogobius flavimanus*; *5 *Stichopus japonicus*; *6 *Mitella mitella*; *7 *Ligia (Megaligia) exotica*; *8 *Dorippe japonica*; *9 *Bombyx mori*; *10 *Cellana grata*; *11 *Endarachne binghamiae*; *12 *Pheretima communissima*. ***gr*** was added in this table, because of the reason shown in section 3.4.

this table were not the estimated ones themselves but the standardized ones, using the corresponding ones for the control as the denominators. Accordingly, preceding the further analysis, it is necessary to certify that the parameters for the control were estimated from not the extremely small cumulative frequency at the final time, because this frequency was the result of incidental entering or leaving or retaining. All of the cumulative frequency polygons were shown in Fig.1. This figure showed that the parameters for the control were estimated from sufficiently large frequencies especially in ξ_{Ej} and ξ_{Lj}. Low frequency in retained number is inevitable, because left number took similar value to entered one. However, the range of ξ_{Rj} was similar to that of ξ_{Ej} and ξ_{Lj}. The parameters for the bait, which were apart from 1, were due to the specificity of the behavior pattern relating to the bait examined. Namely, ξ_{ijk} shown in Table 1 could be used for the further analysis.

The following two characteristics in the outline of the parameters were found in Table 1. One was that the variation according to the baits was large in ξ_{Er}, ξ_{Lr} and ξ_{Rr}. The other was that (1) ξ_{Eg} and ξ_{Lg}, (2) ξ_{Ea} and ξ_{La}, and (3) ξ_{Rg} and ξ_{Ra} for the respective baits took the similar values one another. The former fact meant that the number of retained individuals showed a large difference in the estimated parameters, in spite of the fact that the large difference was not found in ξ_{ig} and ξ_{ia} of the number of entered and left individuals. And large variation in ξ_{Er} and ξ_{Rr} meant that the competition in bait taking was probable to be severe for some baits. The latter fact had the two meanings. One was that the pair of similar value in ξ_{ij} of different behavior i supported the validity of the estimated ξ_{ij}, because the parameters ξ_{ij} of the different i were estimated by using the different data series. The other was that some of the ξ_{ij} varied keeping correlation to one another.

3.2 Correlation Coefficient Matrix

The correlation coefficients among ξ_{ij} were examined because of the following two reasons. One is that attention should be paid to the correlated ξ_{ij}, when a given bait was chosen in respect of a high or low

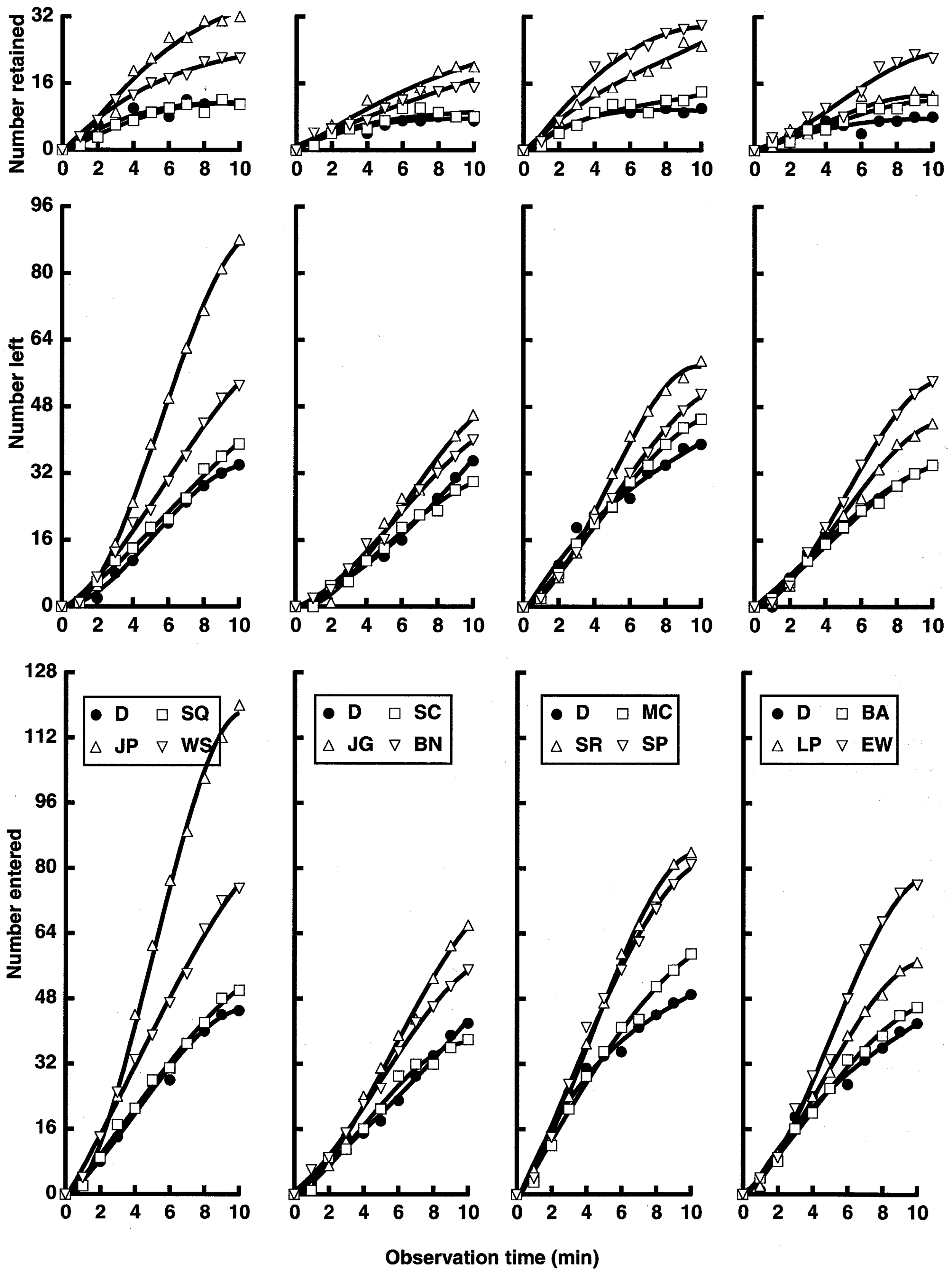

Fig. 1. Comparison of bait water extracts with a dummy gauze ball with respect to the cumulative number (each point) and the estimated curve (line). Abbreviations of bait names are shown in Table 1. "D" in bait name means the dummy gauze ball only.

Table 2. Correlation coefficient matrix among ξ_{ij}

Behavior		Entered			Left			Retained		
		r	*g*	*a*	*r*	*g*	*a*	*r*	*g*	*a*
Entered										
	r	1.000	0.248	-0.752**	0.122	0.354	-0.433	0.570	0.061	-0.144
	g	0.248	1.000	0.298	0.207	0.704**	0.198	-0.109	0.567	0.224
	a	-0.752**	0.298	1.000	0.041	0.032	0.667*	-0.513	0.142	0.167
Left										
	r	0.122	0.207	0.041	1.000	-0.437	-0.570	-0.574	0.603*	0.467
	g	0.354	0.704**	0.032	-0.437	1.000	0.434	0.361	-0.056	-0.208
	a	-0.433	0.198	0.667*	-0.570	0.434	1.000	0.180	-0.415	-0.441
Retained										
	r	0.570	-0.109	-0.513	-0.574	0.361	0.180	1.000	-0.438	-0.548
	g	0.061	0.567	0.142	0.603*	-0.056	-0.415	-0.438	1.000	0.816**
	a	-0.144	0.224	0.167	0.467	-0.208	-0.441	-0.548	0.816**	1.000

**,Significant at 0.01 level ; *,Significant at 0.05 level.

Table 3. The estimated multiple linear regression equations of the ξ_{ij} on the other ξ_{ij} of the same behavior pattern (i) $\Psi = c_0 + c_1x_1 + c_2x_2 + c_3x_3$

Behavior	$j^\dagger$	Const. $c_0{}^\dagger$	$j=r$ $c_1{}^\dagger$	g $c_2{}^\dagger$	a $c_3{}^\dagger$	*R*	n_1	n_2	AIC
Entered									
	r	1.430	–	0.459	-0.946	0.888**	2	9	-46.548
	g	-1.373	1.255	–	1.383	0.793*	2	9	-34.466
	a	1.362	-0.819	0.437	–	0.896**	2	9	-48.282
Left									
	r	2.345	–		-1.089	0.570	1	10	-17.593
	g	0.162		–	1.014	0.434	1	10	-14.332
	a	1.552	-0.299		–	0.570	1	10	-33.110
Retained									
	r	1.461	–		-0.339	0.548	1	10	-16.857
	g	0.589		–	0.875	0.816**	1	10	-12.541
	a	0.226		0.760	–	0.816**	1	10	-14.229

†, ***R***, multiple correlation coefficient with n_1 and n_2 degrees of freedom. x_1 is ξ_{irk}, x_2 ξ_{igk}, and x_3 ξ_{iak}.
**, Significant at 0.01 level; *, Significant at 0.05 level.

value of parameter, which represents the needed specificity. The other is expected that the pairs of ξ_{ij} showed significantly positive or negative correlation, because of the definition of ξ_{ij} or from the results of the experiments for other test animals. However, the correlation coefficient was actually insignificant or sometimes its sign was contrary to expectation. Such phenomenon sometimes includes the clue of finding preferable bait.

Correlation coefficient matrix among ξ_{ij} was shown in Table 2. The sign of the correlation coefficient between ξ_{Lj} and ξ_{Rj} was contrary to those of other combinations. This result was acceptable, because ξ_{Lj} represents the specificity of left individuals and ξ_{Rj} that of retained ones. These combinations could not be examined for the other 2 test animals. Significant correlation was found in the following 5 pairs out of 36 ones: $\mathbf{c}_{Er\text{-}Ea}$, $\mathbf{c}_{Eg\text{-}Lg}$, $\mathbf{c}_{Ea\text{-}La}$, $\mathbf{c}_{Lr\text{-}Rg}$, and $\mathbf{c}_{Rg\text{-}Ra}$ (where **c** means correlation coefficient). The same results, except for $\mathbf{c}_{Lr\text{-}Rg}$, were

Table 4. The estimated multiple linear regression equations ξ_{ij} on the other ξ_{ij} of the different behavior types (i) $\Psi = c_0 + c_1x_1 + c_2x_2 + c_3x_3$

$j^{\dagger}$	Behavior	Const.	i=Entered	Left	Retained	R	n_1	n_2	AIC
		$c_0^{\dagger}$	$c_1^{\dagger}$	$c_2^{\dagger}$	$c_3^{\dagger}$				
r									
	Entered	0.261	—	0.330	0.465	0.791*	2	9	-39.66
	Left	0.431	1.350	—	-0.942	0.791*	2	9	-22.76
	Retained	0.162	1.335	-0.662	—	0.863**	2	9	-27.00
g									
	Entered	0.392	—	0.417	0.252	0.914**	2	9	-44.18
	Left	-0.289	1.817	—	-0.489	0.876**	2	9	-26.50
	Retained	-0.458	2.973	-1.322	—	0.872**	2	9	-14.58
a									
	Entered	-0.119	—	0.839	0.171	0.849**	2	9	-44.07
	Left	0.547	0.849	—	-0.186	0.876**	2	9	-43.92
	Retained	2.227	2.921	-3.140	—	0.772*	2	9	-9.98

†, R, multiple correlation coefficient with n_1 and n_2 degrees of freedom. x_1 is ξ_{Ejk}, x_2 ξ_{Ljk}, and x_3 ξ_{Rjk}.
**, Significant at 0.01 level; *, Significant at 0.05 level.

found in the parameters of algae for abalone and angling baits for yellowtail.[19] When a bait was chosen because of excellent specificity expressed by one of the above-mentioned variables, the change in other specificity, which was expressed as the correlated variables, was inevitable. For example, a bait was chosen because of many individuals retained around it (*i.e.*, large ξ_{Rg}), then it took long time for the chosen bait to attain a half of its theoretical maximum (*i.e.*, large ξ_{Ra}).

3.3 Multiple Correlation

The significantly positive correlation between ξ_{ij} of the different behavior i but the same parameter j and significantly negative correlation between ξ_{ir} and ξ_{ij} were found as the general trend in the parameters for abalone and yellowtail.[19] The reason why the correlation coefficient between these variables was insignificant in this test animal was examined in this section.

The most probable factor, which made the single correlation between these ξ_{ij} not attaining the significant level, was that ξ_{ij} varied depending on the other 2 ξ_{ij} of the same i but different j. These ξ_{ij} were estimated together from the same cumulative frequency polygon. As shown in Table 3, however, the fact supporting this possibility was found only for ξ_{Ej}.

The next point to be examined was the influence of ξ_{ij} of the different i but the same j. For example, the number of retained individuals in the baited sector (*i.e.*, ξ_{Eg}) may be influenced by the number of individuals entered in it (*i.e.*, ξ_{Rg}). If the number of left individuals from the baited sector is set to be negative expression of the attraction activity of the bait, then ξ_{Lg} also may be influential on other ξ_{ig}. The relation like this may be found between other ξ_{ij} of the same j. Table 4 supports the influence of ξ_{ij} of the same j. And the probable influence of the adopted explanation variables could be deduced from their partial regression coefficients. For example, the equation for ξ_{Lg} suggested that many individuals entered into and few individuals retained in the baited sector, then many individuals left from the baited sector. The equation for ξ_{Rg} meant that

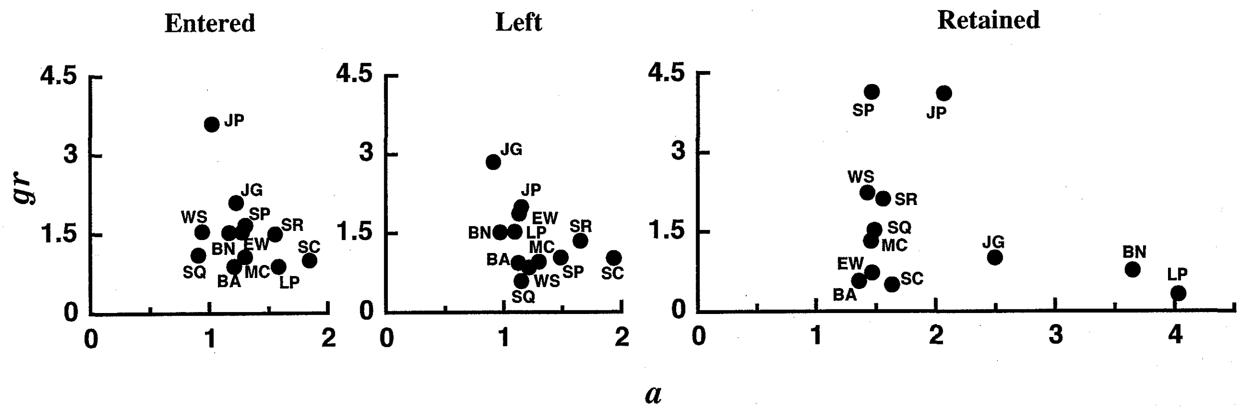

Fig. 2. The ***gr-a*** scattered diagram. Abbreviations of bait names are shown in Table 1.

many individuals entered and few individuals left, then many individuals retained in the baited sector.

As shown in Table 4, two of ξ_{ij} of the same j were actually adopted in the respective equations. For abalone and yellowtail[19], each 1 of other ξ_{ij} of the same j could be estimated. For oriental weatherfish, each two of other ξ_{ij} of the same j could be estimated. This difference may be the reason of making the single correlation coefficients less frequently attained the level of being regarded to be significant in this fish.

3.4 Suggestion for Choosing Baits

As above-mentioned, the significant single correlation was observed less frequently in the correlation coefficient matrix. Accordingly, the preferable bait could be chosen from Table 1. And notice should be added, if the chosen bait showed discontinuously large or small value in other parameters. In regard to the parameter ***r***, description for ***gr*** was given here because more easily understandable image was given from ***gr*** than from ***r***.

gr : This parameter is equal to 4 times the differential coefficient at time ***a***. Whether the bait of large ***gr*** is preferable or not differed, according to the case. When a bait is chosen because of preferable specificity in ***gr***, its relation to ***a*** has to be taken into account together, if it is easy to do so. The ***gr-a*** scattered diagram is helpful for this purpose. Those for the 3 behavior types were shown in Fig.2.

The following information was easily found from this figure. If the bait of large ***gr*** in the number of individuals entered into the baited sector is preferable, Japanese pilchard fits for this condition. The subfigure for the entered individuals showed that this bait does not cause delay in entering. However, if this bait is chosen, then large value of this coefficient (sharp increase) for the number of retained individuals is unavoidable. If the gradual increase in the retained individuals is set to be preferable for escaping from the competition in bait taking, this accompanied characteristic is serious in Japanese pilchard. The same was true to silkworm pupa. If large value of ***gr*** in the number of individuals retained in the baited sector is unfavorable, the third choice is Japanese river goby, although this bait is large in ***gr*** of the individuals left from the baited sector.

On the contrary, if the bait of small value in ***gr*** for entered individuals is preferably expecting gradual increase, squid, sea cucumber, mask crab, limpet, and brown alga fit for this condition as shown in Table 1.

g : This parameter shows the level of asymptote of the logistic curve. The 12 baits tested were differentiated into the 2 groups in this parameter. If the baits of large ***g*** for entered individuals are preferable — for example as the bait for non-return trap —, Japanese pilchard fits for this condition (Table 1). And the baits other than squid, mask crab, and brown alga succeed to it. It is hard to consider that the bait of large ***g*** for left individuals is preferable. If the bait of large ***g*** for the retained individuals is preferable — for example as the bait for open trap, limpet, barnacle, Japanese river goby, Japanese pilchard, silkworm pupa, and earth worm fit for this condition (Table 1).

a : This parameter means the time of attaining the individuals of the respective behavior types at a half of level of its asymptote, and shows the delay in the number of individuals showing the respective behavior types. Small value of this coefficient for the entered individuals is the favorable specificity for various purposes. Practically there is no large difference of the baits in this parameter for the entered individuals or the left ones, except for the large value of sea cucumber, sea cockroach, and limpet for entered individuals (Table 1). If limpet, barnacle, Japanese river goby, or Japanese pilchard is chosen because of large value of ***g*** for retained individuals, delay in attaining a half of the level of asymptote is not avoidable (Table 1). This specificity, ***a***, is serious when the bait is chosen by the importance in the short time effect, and is out of the problem as the bait for longline and non-return trap.

The above descriptions were the outline. The notice for choosing the bait should be drawn by taking attention to all the 9 parameters of the same bait as well as to the relation to all the 9×11 ones of other baits. The notice to choose Japanese pilchard was described here as an example. Many individuals entered into the baited sector with a sharp increasing curve, many individuals left from it with a slightly sharp increasing curve, and the retained individuals increased with a sharp increasing curve over long time, in consequence, many individuals retained in the baited sector.

The consideration like this should be done on each bait by drawing some of the scattered diagrams of any two parameters. The detailed descriptions in this respect were omitted in this paper, because the specificity of importance differs according to the major role of bait, which differs according to the fishing methods.

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試料区画に出入りする個体数の経時変化に関するロジスティック曲線の全係数を用いたドジョウに対する釣餌の誘引効果の評価

宮崎泰幸・原田勝彦・前田 弘

釣り餌素材の水抽出液をしみ込ませたガーゼのある区画に出入りする累積個体数にロジスティック曲線をあてはめ，求められた曲線の係数の各々が表す意味からドジョウに対する摂餌誘引効果を多角的に評価した。係数の間には有意とみなせる相関を示す組み合わせがあり，目的とする特性以外にも注意しなければならないことが分かった。一度入ると出られないトラップ用の餌料として最もふさわしいと考えられた素材はマイワシであった。自由に出入りできるトラップ用としてはベッコウカサガイ，カメノテ，マハゼ，マイワシ，カイコサナギおよびミミズが挙げられたが，ベッコウカサガイ，カメノテ，マハゼおよびマイワシは，延縄や一度入ると出られないトラップのような長時間にわたる効果を必要とする餌としてもふさわしいことが明らかとなった。