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Study on the methods to mitigate the bycatch of juvenile bigeye tuna by introducing Double-FADs with light stimulus for tuna purse seine fishery in the Western and Central Pacific Ocean

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Study on the methods to mitigate the bycatch of juvenile bigeye tuna by introducing *Double-FADs* with light stimulus for tuna purse seine fishery in the Western and Central Pacific Ocean

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Abstract

In this paper, a research to mitigate bigeye tuna fishing mortality by using two separate FADs with underwater light stimulus (herein after referred to *Double-FADs*) was described. This purpose of this paper is to verify effects of decreasing bigeye tuna catch of *Double-FADs* as compared with common FADs (herein after referred to *Normal-FADs*). The total number of operation was forty eight (48) including 6-*Double-FADs*, 8-*Normal-FADs* and 34-Free school operations, which were conducted by a commercial vessel "Wakaba-Maru No.3" in November and December 2011 in exclusive economic zone of Papua New Guinea and Solomon Islands by using the assistance fund of the Fisheries Agency of Japan. Based on the onboard sampling data, the size proportion of *Double-FADs* is bigger than that of *Normal-FADs* in all species including skipjack, yellowfin and bigeye if we count number of fish which weight is bigger than 3.0kg on *Normal-FADs* compared with *Double-FADs.* The bycatch rate of bigeye tuna to total number with *Double-FADs* and *Normal-FADs* was 6.1% and 8.9% in number, and 7.2% and 14.2% in weight respectively. The number of bigeye tuna in catch of one (1) metric ton is estimated as 24 in *Double-FADs* and 45 in *Normal-FADs*. Although sample size and quality is not enough to reach conclusion and to apply appropriate statistical test, these results support that *Double-FADs* have some effect on reducing bigeye tuna bycatch as compared with *Normal-FADs*.

Introduction

Tuna Purse seine fishing operation with FADs (Fish Aggregating Devices) has been rapidly increased in the Western Central Pacific Ocean since 1990s, which resulted in increasing juvenile bigeye tuna (*Thunnus obesus*) catch. It is essential to develop a effective methods to mitigate juvenile tuna bycatch brought by purse seine fishing operation with FADs for sustainable use of tuna resources. To achieve this goal, Fishery Agency of Japan planned to conduct a research cruise and carried out experimental fishing operation by using two separate FADs with underwater light which create solid and flashing light stimulus in collaboration with a commercial fishing vessel "Wakaba Maru No.3" owned by Kyokuyo Suisan Co., Ltd of Japan.

It is well known that juvenile tuna is attracted by solid light stimulus. Actually such technologies have been introduced in commercial fishing including tuna purse seine. According to the report of Marine Fisheries Research and Development Center (JAMARC) Oshima et al 2012 [1)], skipjack tuna (*Katsuwonus pelamis*) shows clear escape behavior against a flashing light stimulus especially 0.1 cycle per second interval contrary to bigeye tuna which does not show clear escape behavior. This study aims to verify effect of decreasing bigeye tuna bycatch of *Double-FADs* as compare with *Normal-FADs*.

Materials and Methods

(1) Fishing vessel

Fig. 1 shows a commercial Tuna Purse seine fishing vessel and its associated workboats which introduced for a research cruise of this study.

(2) Research Period

Wakaba Maru No.3 left Pohnpei, Federated State of Micronesia on November 17, 2011. She started research and fishing activity on November 18 and completed it on December 27 and returned to Yamagawa Japan on January 6, 2012 for fish unloading.

(3) Area of the Research

The research area was EEZ (Exclusive Economic Zone) of Papua New Guinea and Solomon Islands. The area of experimental operation of *Double-FADs* and *Normal-FADs* is shown in Fig. 2

(4) Normal-FADs and Double-FADs

Wakaba Maru No.3 had released more than ten (10) manmade *Normal-FADs* prior to the Research period described in clause (2) above. The design of the *Normal-FADs* and the *Double-FADs* which was introduced into this research are shown in Fig. 3

(5) Fishing gear

In general, Japanese Tuna purse seiners have been introduced similar design of fishing gear composed by polyamide, polyethylene and polyester knotless mesh panels, PVC floats and sinker made by galvanized steel chain. Its scale ranging about 1,600-2,000 m in length and 200-230m in depth. In recent years, Japanese Tuna Purse seine industry is keen to introduce large mesh panels (300mm mesh size) in order to increase sinking speed of the net and anticipate increase a chance of juvenile tuna swimming out from the large mesh panel during pursing stage of fishing operation

The fishing gear for this research is mainly composed by 300mm large mesh panel and much larger panel sizing 450mm is also introduced in lower part of net body aim to increase a chance for juvenile tuna swimming out from the larger mesh panels. The basic design of the fishing gear is shown in Fig. 4.

(6) List of devices used in this research

The following devices are used for generating light stimulus (Fig. 5)

*Underwater LED Solid light, Type LW-2000C1, Takuyo Co., Ltd.

*Underwater LED Flash light (0.1 cycle / sec.), Type LW-2000C1, Takuyo Co., Ltd.

The following devices are used for observing fish behaviors

*Echo sounder (Wakaba Maru No.3) FCV1500L

*Echo sounder (Workboat) FCV2000BB

*Scanning sonar (Wakaba Maru No.3) FSV30, FSV84

*Scanning sonar (Workboat) CSH8L, CSH5MK2

The following devices are used for oceanography research

*XCTD (eXpendable Conductivity, Temperature and Depth, Turumi-Seiki Co., Ltd.)

*SBT (Small Bathy Thermograph, Murayama-Electronics factory Ltd.)

(7) Methods of the *Double-FADs* Research

Experimental operations of *Double-FADs* were done by the following steps;

Step 1. The vessel arrived at a *Normal-FADs* (FADs A) position which had been deployed prior to the research cruise, and investigate whether enough fish is aggregated around the FADs A. And then enough fish exist, launching the workboat A and set the solid under water light (Light A) approximately 20 m in depth nearby the FADs A.

Step 2. Launching the workboat B and set an additional FADs (FADs B) with underwater flash light (Light B) approximately 100 m in depth. Keep lighting (Light A) and start flashing (Light B)

Step 3. Moving slowly Workboat B with FADs B and Light B (Flashing) away from the Workboat A with FADs A and light A (Solid).

Step 4. Start shooting the net on the FADs A when FADs B is approximately 350-400 m away from FADs B. It usually took 30-45 minutes to keep enough distance between FADs A and FADs B. Outline of *Double-FADs* operation is shown in Fig. 6

(8) Method of onboard sampling and estimation of weight

During brailing process of each operation on *Double-FADs* and *Normal-FADs* operation, a part of fish were sorted randomly and measured its fork length by caliper up to 150 individuals per one operation regardless of species. Each weight of sampled fish by species were calculated by the following formula developed by previous studies on relationship between fork length and weight.

skipjack $W\,(kg) = 0.86388\times10^{-5}L^{3.2174}$ [2)]

yellowfin $W\,(kg) = 2.512\times10^{-5}L^{2.9396}$ [3)]

bigeye $W\,(kg) = 3.661\times10^{-5}L^{2.90182}$ [4)]

Results and Discussion

This is an innovative challenge in collaboration with government, research institutions and industries in order to achieve the same objective for sustainable use of tuna resources. This research aims to seek a clue to reduce a fishing mortality of bigeye tuna juvenile on fishing operation with FADs. To contribute this objective, we tried to examine the difference between *Normal-FADs* and *Double-FADs* in particular species and size composition of fish harvested by each operation in order to verify effect of *Double-FADs* with light stimulus for reduction of bigeye tuna bycatch.

(1) Outline of the research cruise

Throughout the research, forty eight (48) times fishing operations were carried out by Wakaba Maru No. 3 which composed of 6-*Double-FADs*, 8-*Normal-FADs* and 34-Free school operation during the research cruise and total catch of this cruise was 730 ton in catch logsheet as shown in Table 1. After the research cruise all catch were delivered to Yamagawa Japan and sorted out by species and sizes by the Yamagawa Fisheries Cooperative. The total unloaded weight of fish was 727,995 kg composed of 389,878 kg of skipjack, 302,031 kg of yellowfin and 36,086 kg of bigeye as shown in Table 2.

(2) Difference of size proportion between *Double-FADs* and *Normal-FADs*.

Fig. 7 shows differences of size proportion between *Double-FADs* and *Normal-FADs* by species. If we look at the total including skipjack, yellowfin and bigeye, it is observed the share of bigger sized fish which weight is more than 3.0 kg of *Double-FADs* was higher than that of *Normal-FADs.* Especially in case of skipjack, the share of bigger sized fish was only 2% in *Normal-FADs* whereas that of *Double-FADs* was 13% respectively. The similar trends are also observed in yellowfin and bigeye as shown in Fig. 7. These results suggest a possibility that flashing light stimulus influence the behavior of fish attracted by FADs in particular small sized tuna might swim away from the area of operation by the effect of flashing light stimulus.

(3) Difference of bigeye composition

Onboard sampling and was carried out by the researcher onboard to measure a fork length of sampled fish on the following twelve (12) operations;

Operation No. 1, 2, 4, 5, 6 and 7	*Double-FADs* operation
Operation No. 32, 33, 35, 36, 37 and 48	*Normal-FADs* operation

Table 3 shows species composition of onboard sampling. Total number of sampled fish on the *Double-FADs* operation is 724 composed by 424-skipjack, 256-Yellowfine and 44-bigeye respectively. Thus bigeye bycatch ratio in number is 6.1% (=44/724). On the other hand, 689 fishes were collected on *Normal-FADs* operation composed by 499-skipjack, 129 yellowfin and 61-bigeye, thus bigeye bycatch ratio is 8.9% (=61/689) accordingly. In terms of total weight of sampled fish on the *Double-FADs* operation is 2,845 kg composed by 828 kg of skipjack, 1,812 kg of yellowfin and 205 kg of bigeye respectively. Thus bigeye bycatch ratio in weight is 7.2% (=205/2,845). On the other hand, total weight of sampled fish on *Normal-FADs* operation is 2,227 kg composed by 869 kg of skipjack, 1,043 kg of yellowfin and 315 kg of bigeye, thus bigeye bycatch ratio is 14.2% (=315/2,227) accordingly.

(4) Estimation of number of bigeye tuna per ton between *Double-FADs* and *Normal-FADs*

Table 4 shows that number of bigeye tuna fished per unit catch (one metric ton) on both *Double-FADs* and *Normal-FADs* based on the corrected catch logsheet data by species composition of onboard sampling data. For example, if we look at the operation No.6, total catch was reported as 40 tons and its bigeye composition is 16% by sampling data, so its bigeye catch is estimated as 6,571 kg. On the other hand average bigeye weight is also estimated as 5.7 kg by sampling data, thus total number of bigeye in operation No.6 is calculated as 1,143. As a result, 29 (=1,143/40 tons) -bigeye was existed per unit catch (one ton) in the operation No.6. If we aggregate data of *Double-FADs* (No.1, 2, 4, 5, 6, 7) and *Normal-FADs* (No. 32, 33, 35, 36, 37, 48), average number of bigeye per unit catch is 24 in *Double-FADs* and 45 in *Normal-FADs*. (Table 4)

So far we have outlined to verify effects of decreasing bigeye tuna bycatch of *Double-FADs* as compared with *Normal-FADs.* Although sample size as well as quality is not enough to reach conclusion and to apply appropriate statistical test, aforementioned results support that *Double-FADs* with light stimulus have some effect on reducing bigeye tuna catch as compared with *Normal-FADs*. We need to incorporate more data from further studies focusing on *Double-FADs* and/or light stimulus to verify this result.

Although we also have introduced a new design fishing gear with 450mm large mesh panel aim to increase a chance to escape small sized tuna from the mesh interval and attempt to analyze effect of large mesh panel, remarkable achievement was not obtained in this research. However, it is also essential to have further studies focusing on selectivity of large mesh panel to reduce fishing mortality of small sized tuna for sustainable use of tuna resources in WCPO.

Acknowledgements

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Reference

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4) Nakamura, E.L. and J.H. Uchiyama. 1966. Length weight relations of Pacific tunas. In Manar, T.A. (ed.), Proceedings of the Governor's Conference on Central Pacific Fishery Resources. State of Hawaii, Honolulu. 197-201 pp.

Table and Figure

Table 1 : Fishing Operation record of Wakaba Maru No.3

Operation No	Date	Set time	Lat.	Long.	Aera	School type	Catch in Ton (Logsheet) Total	On board sampling Number of fish measured
1	**2011/11/19**	**2:41**	**0.26 S**	**152.58 E**	**PNG**	**WFADs**	**50.0**	**150**
2	**2011/11/20**	**3:10**	**0.54 S**	**152.10 E**	**PNG**	**WFADs**	**25.0**	**150**
3	2011/11/20	10:08	1.17 S	151.49 E	PNG	Free school	20.0	×
4	**2011/11/21**	**3:11**	**0.46 S**	**152.56 E**	**PNG**	**WFADs**	**50.0**	**156**
5	**2011/11/22**	**3:17**	**0.51 S**	**152.59 E**	**PNG**	**WFADs**	**5.0**	**73**
6	**2011/11/23**	**3:24**	**1.04 S**	**152.15 E**	**PNG**	**WFADs**	**40.0**	**103**
7	**2011/11/24**	**3:22**	**1.10 S**	**152.15 E**	**PNG**	**WFADs**	**10.0**	**93**
8	2011/11/27	5:13	2.44 S	162.15 E	PNG	Free school	5.0	×
9	2011/11/27	14:48	2.06 S	161.12 E	PNG	Free school	0.0	×
10	2011/11/28	5:51	2.04 S	161.08 E	PNG	Free school	0.0	
11	2011/11/30	9:34	6.02 S	156.14 E	PNG	Free school	5.0	×
12	2011/12/1	4:55	6.02 S	155.55 E	PNG	Free school	0.0	
13	2011/12/2	9:14	2.22 S	159.01 E	PNG	Free school	0.0	
14	2011/12/2	11:42	2.22 S	159.01 E	PNG	Free school	10.0	
15	2011/12/3	6:48	2.43 S	160.05 E	PNG	Free school	20.0	×
16	2011/12/5	4:38	2.47 S	160.34 E	PNG	Free school	0.0	
17	2011/12/5	15:07	3.23 S	159.31 E	PNG	Free school	1.0	×
18	2011/12/6	7:27	3.26 S	159.27 E	PNG	Free school	9.0	×
19	2011/12/6	12:07	3.28 S	159.27 E	PNG	Free school	0.0	
20	2011/12/9	4:49	6.20 S	160.12 E	Solomon Is.	Free school	1.0	×
21	2011/12/9	12:17	6.23 S	160.15 E	Solomon Is.	Free school	20.0	×
22	2011/12/10	5:27	6.37 S	160.13 E	Solomon Is.	Free school	2.0	×
23	2011/12/10	10:14	6.36 S	160.10 E	Solomon Is.	Free school	0.0	×
24	2011/12/10	13:01	6.39 S	160.09 E	Solomon Is.	Free school	25.0	×
25	2011/12/11	4:58	6.54 S	160.12 E	Solomon Is.	Free school	0.0	
26	2011/12/11	8:06	6.50 S	160.07 E	Solomon Is.	Free school	0.0	
27	2011/12/11	13:41	6.54 S	160.08 E	Solomon Is.	Free school	12.0	×
28	2011/12/12	4:53	7.00 S	160.08 E	Solomon Is.	Free school	0.0	
29	2011/12/12	8:43	6.56 S	160.07 E	Solomon Is.	Free school	2.0	×
30	2011/12/12	14:24	7.00 S	160.08 E	Solomon Is.	Free school	0.0	
31	2011/12/14	13:26	6.57 S	160.43 E	Solomon Is.	Free school	0.0	
32	***2011/12/17***	***3:03***	***0.45 S***	***153.18 E***	***PNG***	***FADs***	***30.0***	***150***
33	***2011/12/19***	***3:16***	***0.16 S***	***152.34 E***	***PNG***	***FADs***	***50.0***	***20***
34	2011/12/19	9:17	0.40 S	152.33 E	PNG	Free school	23.0	×
35	***2011/12/20***	***3:30***	***0.19 S***	***152.17 E***	***PNG***	***FADs***	***35.0***	***69***
36	***2011/12/22***	***4:03***	***0.23 S***	***145.49 E***	***PNG***	***FADs***	***55.0***	***150***
37	***2011/12/23***	***4:17***	***0.01 S***	***143.09 E***	***PNG***	***FADs***	***45.0***	***150***
38	2011/12/23	10:00	0.15 S	143.00 E	PNG	Free school	5.0	×
39	2011/12/23	12:36	0.16 S	143.00 E	PNG	Free school	5.0	×
40	2011/12/24	4:36	0.16 S	142.56 E	PNG	FADs	0.0	
41	2011/12/24	7:25	0.14 S	142.53 E	PNG	Free school	10.0	×
42	2011/12/24	11:20	0.09 S	142.53 E	PNG	Free school	5.0	×
43	2011/12/24	14:57	0.07 S	142.53 E	PNG	Free school	30.0	×
44	2011/12/25	9:01	0.11 S	142.59 E	PNG	Free school	0.0	
45	2011/12/25	15:15	0.00 N	142.23 E	PNG	Free school	0.0	
46	2011/12/26	4:34	0.04 N	142.37 E	PNG	FADs	10.0	×
47	2011/12/26	8:51	0.06 N	142.40 E	PNG	Free school	90.0	×
48	***2011/12/27***	***4:55***	***1.31 S***	***144.13 E***	***PNG***	***FADs***	***25.0***	***150***
						Total	**730.0**	**1,414**

Table 2 : Fish unloading data of the Research cruise by species and sizes in Yamagawa Japan

Species	Size	Weight (kg)
SKJ	More than 6.0kg	7,505
	4.5-6.0kg	2,104
	2.5-4.5kg	15,780
	1.8-2.5kg	45,702
	1.0-1.8kg	288,024
	1.0kg or less	20,333
	Rejected	10,430
	Sub total	**389,878**
YFT	More than 10kg	183,367
	3.0-10kg	101,482
	1.5-3.0kg	6,282
	1.5kg or less	10,900
	Sub total	**302,031**
BET	More than 10kg	218
	2.5-10kg	21,053
	2.5kg or less	14,815
	Sub total	**36,086**
Grand Total		**727,995**

Remarks: Sorted out by Yamagawa Fisheries Cooperative

Table 3 : Species composition of onboard sampling

		Unit: number of fish				Unit: weight (kg)			
	Operation No	SKJ	YFT	BET	Total	SKJ	YFT	BET	Total
Double-FADs	1	105	44	1	150	192	468	3	663
	2	86	60	4	150	119	437	10	566
	4	94	56	5	155	235	493	27	755
	5	45	20	8	73	65	76	41	181
	6	41	50	12	103	57	294	69	420
	7	53	26	14	93	161	45	54	260
Total		424	256	44	724	828	1,812	205	2,845
Species Ratio		58.6%	35.4%	6.1%	100.0%	29.1%	63.7%	7.2%	100.0%
Normal-FADs	32	124	26	0	150	204	349		553
	33	8	4	8	20	12	76	50	137
	35	21	23	25	69	38	315	123	476
	36	114	34	2	150	182	37	4	223
	37	116	18	16	150	168	120	61	349
	48	116	24	10	150	265	147	77	489
Total		499	129	61	689	869	1,043	315	2,227
Species Ratio		72.4%	18.7%	8.9%	100.0%	39.0%	46.8%	14.2%	100.0%

Table 4 : Estimation of number of bigeye per ton between *Double-FADs* and *Normal-FADs*

Operation No	School type	Catch logsheet data in ton	Species composition by onboard sampling				Estimated catch by species by sampling data (kg)				Number of BET per unit catch(1MT)		
			SKJ	YFT	BET	Total	SKJ	YFT	BET	Total	BET Av. Weight	Number of fish	Number of fish/1MT
1	Double-FADs	50	29%	71%	0%	100%	14,513	35,290	197	50,000	2.6	76	2
2	Double-FADs	25	21%	77%	2%	100%	5,263	19,280	457	25,000	2.6	176	7
4	Double-FADs	50	31%	65%	4%	100%	15,550	32,647	1,803	50,000	5.4	334	7
5	Double-FADs	5	36%	42%	23%	100%	1,778	2,093	1,129	5,000	5.1	221	44
6	Double-FADs	40	14%	70%	16%	100%	5,419	28,010	6,571	40,000	5.7	1,153	29
7	Double-FADs	10	62%	17%	21%	100%	6,185	1,719	2,097	10,000	3.9	538	54
	WFADs total	180					48,708	119,039	12,252	180,000		2,497	24
32	Normal-FADs	30	37%	63%	0%	100%	11,054	18,946	0	30,000	4.9	0	0
33	Normal-FADs	50	8%	55%	36%	100%	4,222	27,714	18,064	50,000	2.2	8,211	164
35	Normal-FADs	35	8%	66%	26%	100%	2,828	23,147	9,024	35,000	3.8	2,375	68
36	Normal-FADs	55	81%	17%	2%	100%	44,745	9,171	1,084	55,000	7.7	141	3
37	Normal-FADs	45	48%	34%	17%	100%	21,687	15,445	7,867	45,000	5.0	1,573	35
48	Normal-FADs	25	54%	30%	16%	100%	13,557	7,485	3,958	25,000	0.0	0	0
	FADs total	240					98,094	101,909	39,997	240,000		12,300	45

*Name of Vessel: Wakaba Maru No.3

*Length Overall: 57.8 m

*Gross tonnage : 1,096 ton

*Main engine : Niigata 2,206KW

*Work boat A
(LOA 8m, M/E output 294kw,
equip underwater Solid light)

*Work boat B
(LOA 8m, M/E output 294kw,
equip underwater Flash light)

Fig. 1 Fishing vessel introduced for a research cruise

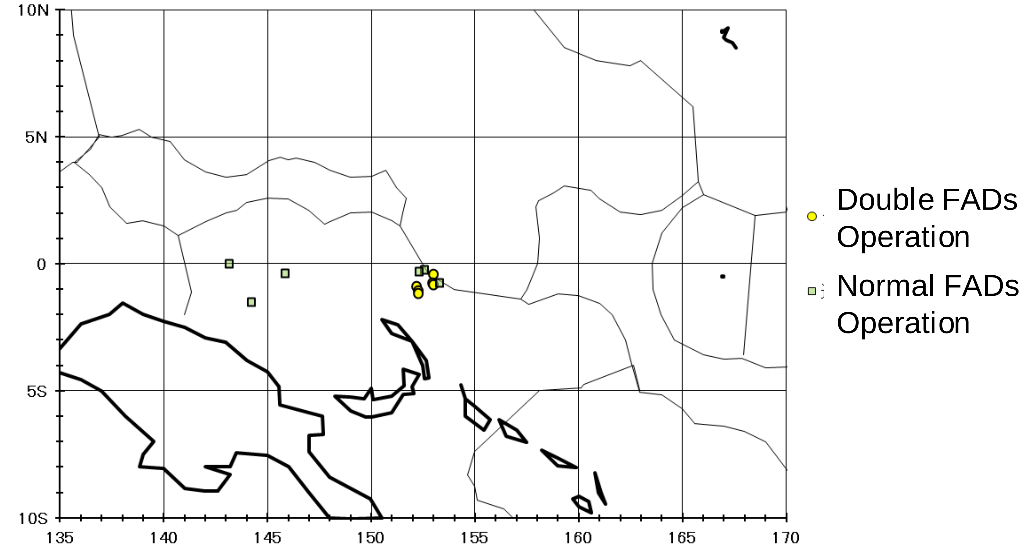

Fig. 2 : The area of *Double-FADs* and *Normal-FADs* experimental operation

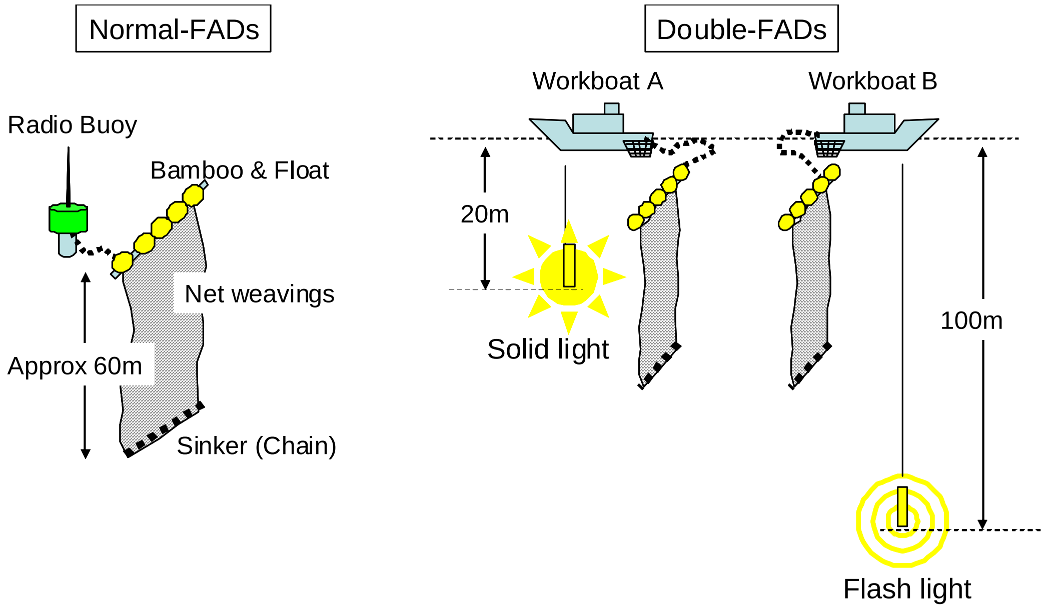

Fig. 3 : The design of the *Normal-FADs* and *Double-FADs*

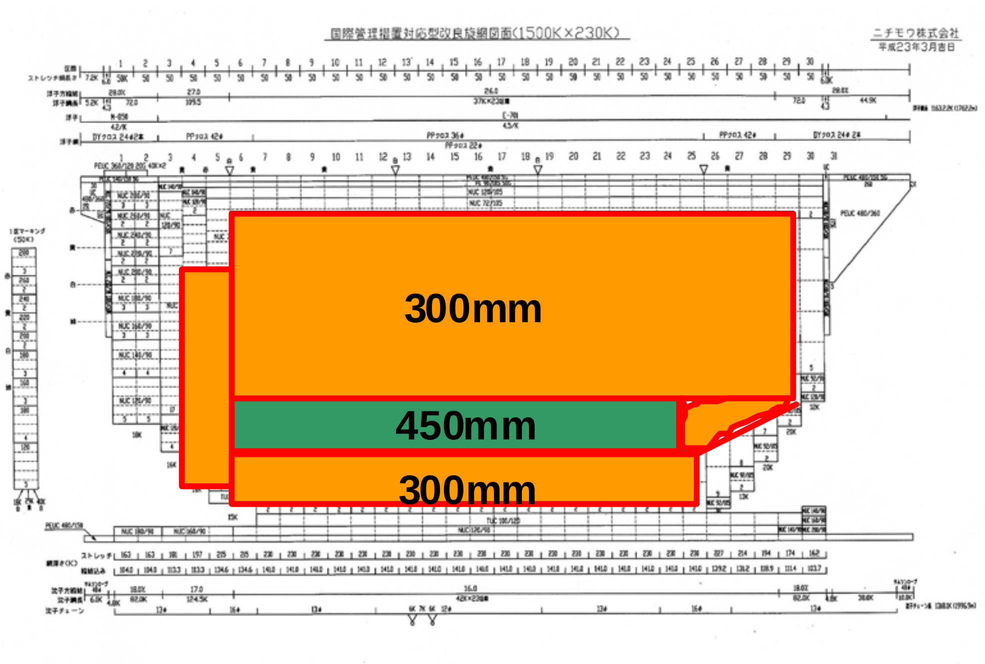

Fig. 4 : Basic design of fishing gear introduced for the research cruise

Fig. 5 : The LED Underwater light producing solid and flashing light stimulus.

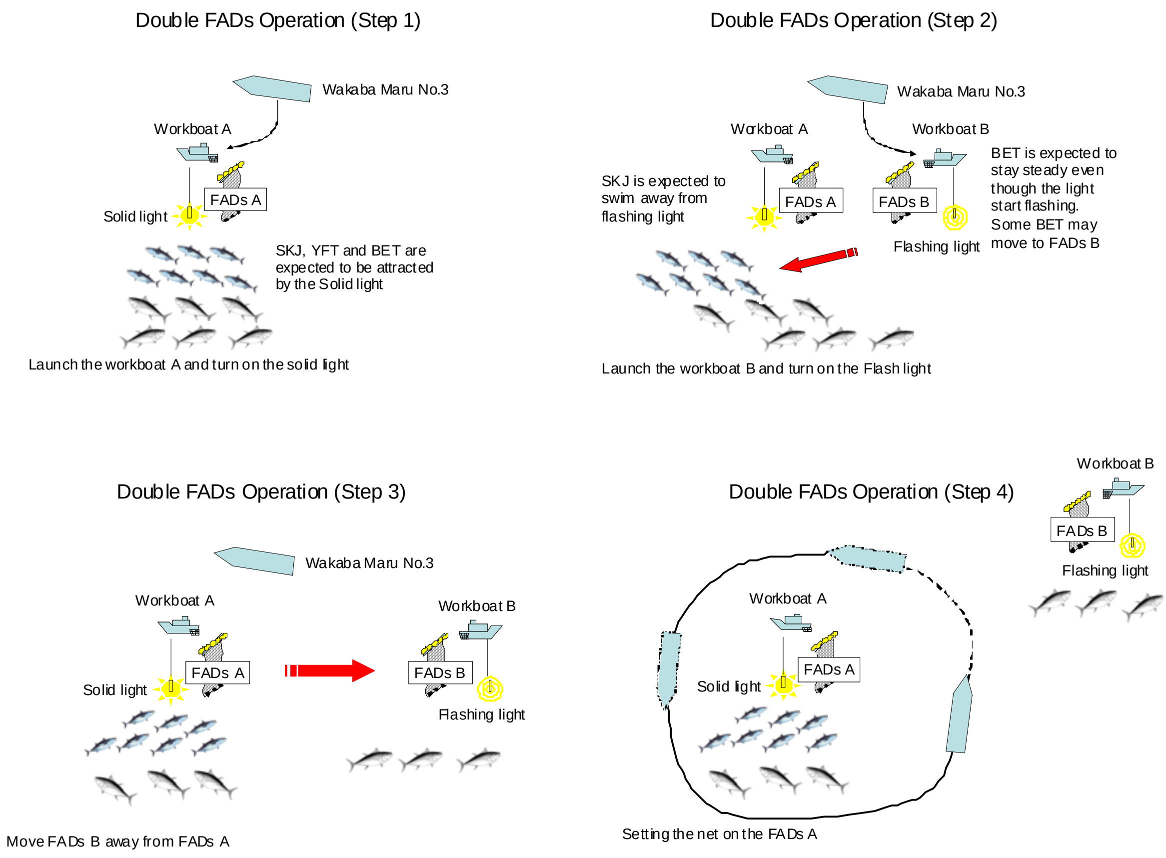

Fig. 6 : Outline of the *Double-FADs* operation

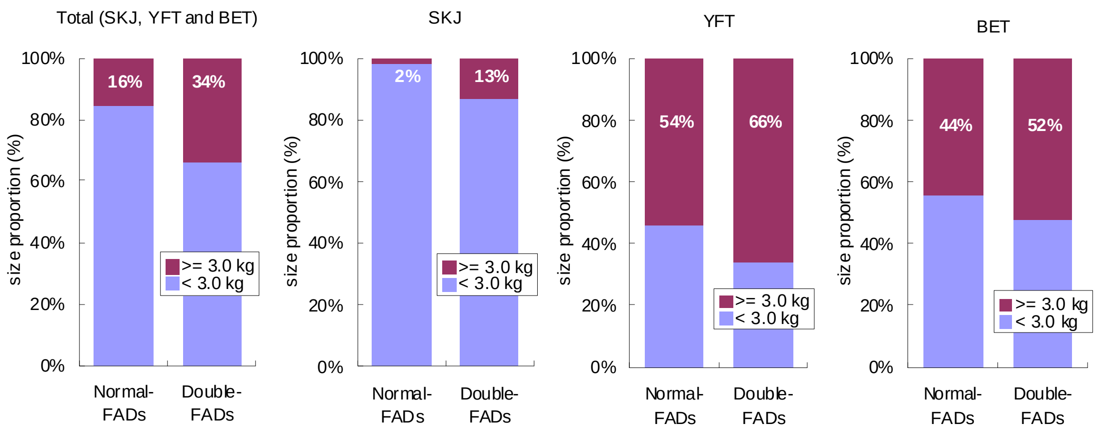

Fig. 7 : Difference of size proportion between *Double-FADs* and *Normal-FADs*