SUMMARY OF THE PREDATION SURVEYS FOR THE TUNA LONGLINE CATCH IN THE INDIAN AND THE PACIFIC OCEAN BASED ON THE JAPANESE INVESTIGATION CRUISES (1954, 1958 AND 1966-81)

(complete version)(*)

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ABSTRACT

This report is a summary of the predation surveys for the longline caught tuna and billfishes, which were conducted by the Japanese longline survey cruises in 1954, 58 and 1966-82. In addition, we summarized biology, physiology and ecology of predators and also mitigation methods.

INTRODUCTION

Predation problems by killer whales and false killer whales on Japanese tuna longline fisheries have been continued to the present since the start of its fisheries in 1952. The first report was from the Palau water in1952. In the earlier years, only some catch of the longliners where the predators had passed, were damaged. But, predation problems had become expanding to the whole catch of the longliners. In serious case, predators approach to the broadsides of the boats and attack the catch.

To investigate this predation problem and to find out possible mitigation methods, Fisheries Agency of Japan had conducted a number of surveys and research in the Pacific Ocean and the Indian Ocean, using public longline vessels (high school longline training vessels and prefecture fisheries stations' longline vessels) during 1954, 1958 and 1965-81. Results of these surveys were reported in the Proceedings of the annual tuna fisheries research meetings in Japan in the past.

In recent years, predation problems in the western Indian Ocean became also serious, thus the IOTC Scientific Committee and Commissioner's meetings in 1998 and 1999 recommended to start investigating the situation of the predation. Under these circumstances, it is realized that it is a appropriate timing to provide summary of results of the above-mentioned Japanese investigations and research, which is believed to be profitable references for the IOTC's predation project.

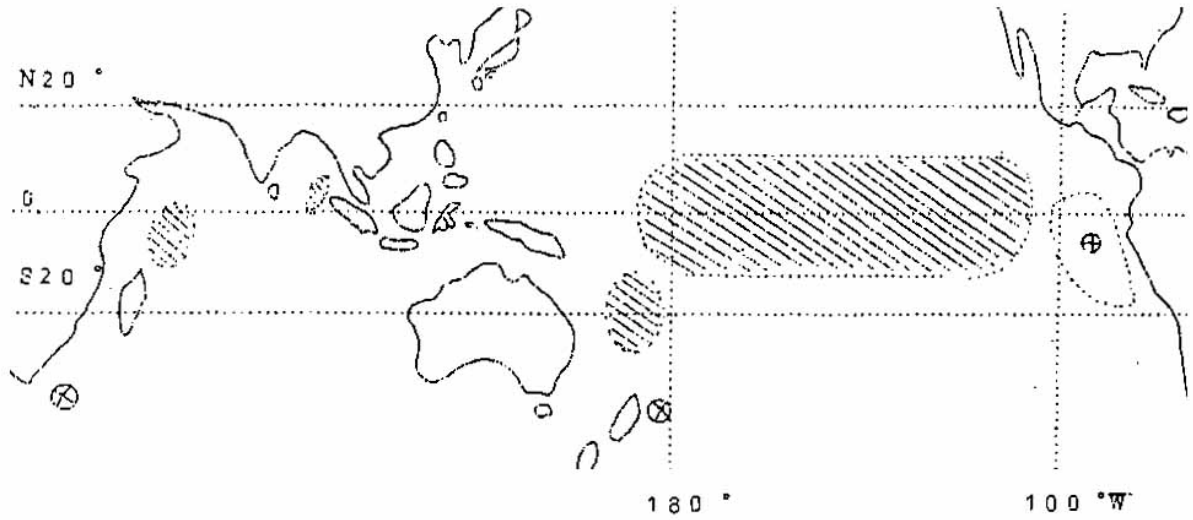
In addition to the summary of surveys, sporadic information on biology and ecology of the predators and mitigation methods were appeared in the past Proceedings with additional references, which were complied and summarized in this document.

SUMMARY OF SURVEYS

1954 and 1958

Map 1 shows areas of false killer whales observed during the 1954 and 58 surveys. Generally, many of them appear in high water temperature regions especially at latitudes 10? ~ 17? of north and south across the equator, while few appear in the low water temperature regions, to the north of latitude 28 ? or to the south of latitude 25?. Tables 1-2 and Fig. 1 shows the results of the surveys.

Map 1 Areas where false killer whales observed during the 1954 and 58 surveys.



Note: ? indicate the locations where predators were observed, but there were no damages on tuna.

Table 1 Summary of predation on tunas by Toothed Whales (killer whale and false killer whale) in 1954 and 1958 surveys

	1958	1954	1958
	Number of survey vessels	Average interval of operation for attack	Average interval of operation for attack
Eastern Pacific Ocean	20	7-9	7.6
South Pacific Ocean	15		10.0
Indian Ocean	17	18-20	7.3
Indian Ocean (south)	10	8-15	6.7
(average of above 4 Oceans)		12.8 (30 boats)	8.0 (62 boats)
Atlantic Ocean	7		15.9

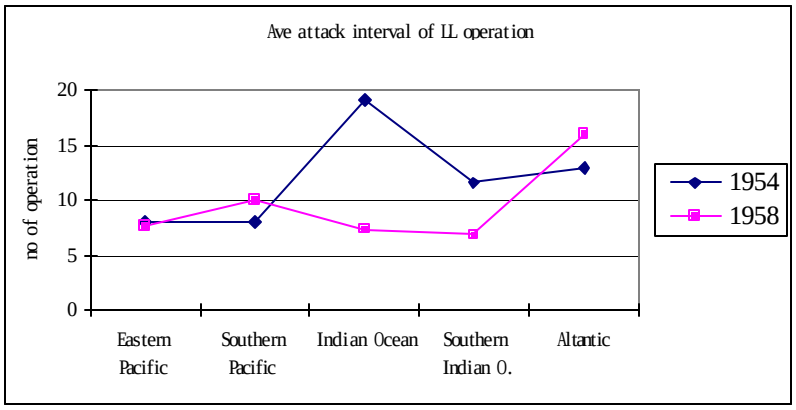


Fig 1 Average attack intervals of the LL operations in 1954 and 1958 surveys.

Table 2 Attack frequency by species (based on 1954 & 1958 surveys)

Species	Number of LL boats attacked (seriously damaged)	Number of LL boats attacked (lightly damaged)
YFT	34	0
BET	24	2
ALB	5	25
BILLFISH	2	29

1965-75 surveys

(1) Summary of public vessel surveys

Table 2 shows number of fishing trips, which had damages by killer whales during 1965-75. Although the whole number of the damage-emerging-trips is not known, we can see the general tendency if we assumed number of trips and the reporting rates were more or less constant. Based on these

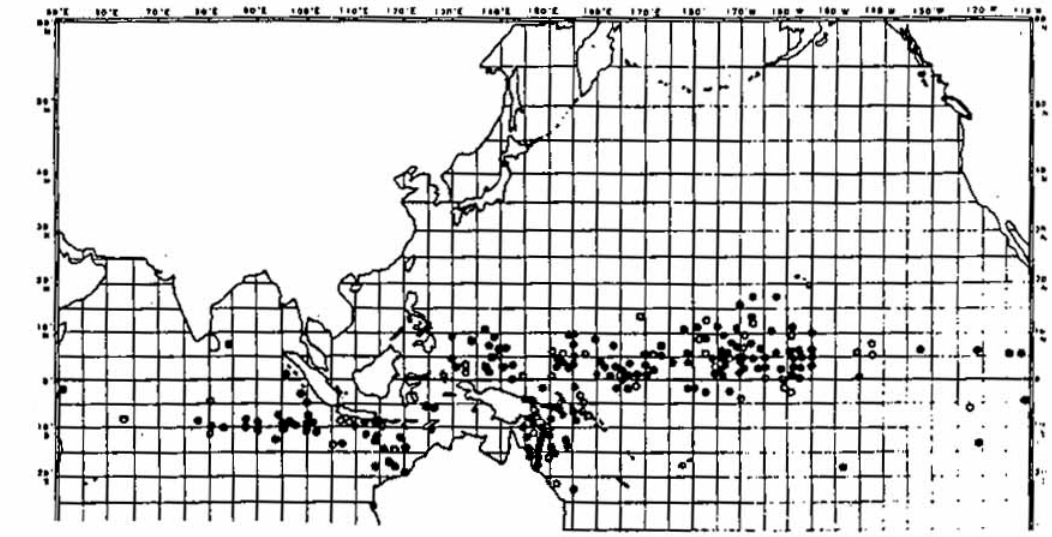
assumptions, it is resulted that damages were high in 1969 and 1975. Especially in those years, there were considerable damages in the Indian Ocean.

Table 2 Number of fishing trips, which had damages by killer whales during 1966-75.

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Total	23	17	16	38	18	15	20	26	18	32
Indian Ocean	5	2	1	10	4	3	4	3	3	14
Pacific Ocean	18	15	15	28	14	12	16	23	15	18
Coral Sea	(1)	(3)	(1)	(6)	(2)	(6)	(6)	(4)	(5)	(4)

Map2 shows the distribution of operations that had information on killer whales. Black circle shows the areas of operations, which indicate occurrences of the predation by killer whales and white circles present the affected areas by killer whales. Killer whale appeared in the wide range of the Coral Sea extending east and west. Though the operation of Public Agency longline vessels are limited, the distribution of damages concentrate on the waters off Java Island and south Sumatra in the Indian Ocean, in the Coral Sea and in the waters along 0 ° ~15 ° N in the Pacific Ocean.

Map 2 Distribution of survey (operational) points by Japanese official longline vessels (1966-75).



(Note) Black circle : locations of predation by killer whale

White circle: affected locations by killer whale

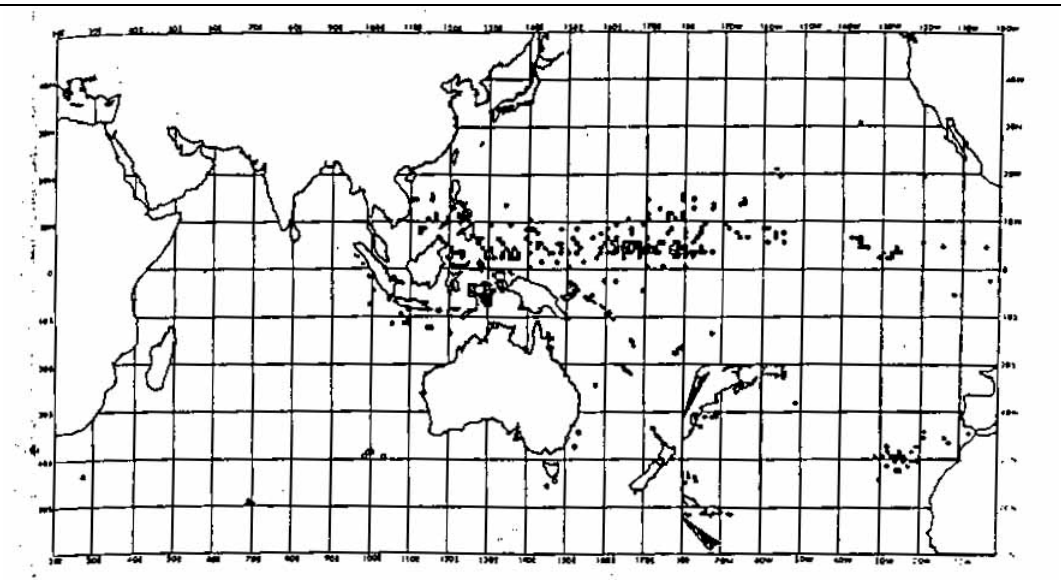
(2) Summary of fish market surveys at the Yaizu port (1974-75)

The Yaizu branch of National Research Institute of Far Seas Fisheries has been routinely conducting the hearing survey on fishing conditions as well as the biological survey from the longliners. This survey does not focus on the predation problems by killer whales. Thus, information on predation are recorded only when damages by killer whales have occurred. Using these information, we investigate areas of the predation problems and the ditribution of killer whales.

Map 3 shows the locations of predations (1x1 basis area), which are based on the information of the 682 commercial longliners' trips returned to the Yaizu port during 1974-75. Although the whole operational areas are not mapped, the coverage is much wider than that of public agency vessels and covers all three Oceans and extends from latitude 45 ? N to 50 ? S.

The distribution of locations of predations in the Pacific Ocean covers tropical areas from 0 ° to 10 ° N extending east and west, which well correspond to that of public agency vessels. But it should be noted that damages have also occurred in the South China Sea and Celebes Sea and extended to longitude 100 ° E, which were not reported by the public longline vessels. It is noteworthy that in the north Pacific (north of latitude 30 ° N), there are damages only by sharks, while there are no damages by killer whales, which are the interesting phenomena observed in the commercial longline vessels.

Map 3 Locations of predations (1x1 area) based on the information of the 682 commercial longliners' trips returned to the Yaizu port during 1974-75. Situation in the Atlantic Ocean is presented at the lower right corner.



(Note) Black circle : locations of predations

White circle: observed locations of predators

The distribution of the predation areas in the Indian Ocean concentrate on Banda Sea and Flores Sea and damages emerge also in the Java Sea and in the waters off south Sumatra. In the high-latitude fishing ground of southern bluefin tuna where public agency vessels don't operate, there are many commercial longline vessels. Nevertheless damages by killer whales had not been recorded. Locations where killer whales were observed (represented by white circles), appear off Sydney and off Tasmania in the Pacific Ocean and also the waters near 45 ° S and 100 ° E in the Indian Ocean and off South Africa.

Though data had not cover whole areas of the Atlantic Ocean, the damage distribution in the Atlantic Ocean appears in the offshore of New York and Las Paramas which are fishing grounds of bigeye tuna, where several vessels were affected. It is noted that damages in the Atlantic Ocean appear also in the high latitude waters of 30 ° N and 40 ° N, which could not be observed in the Pacific Ocean.

1976 survey

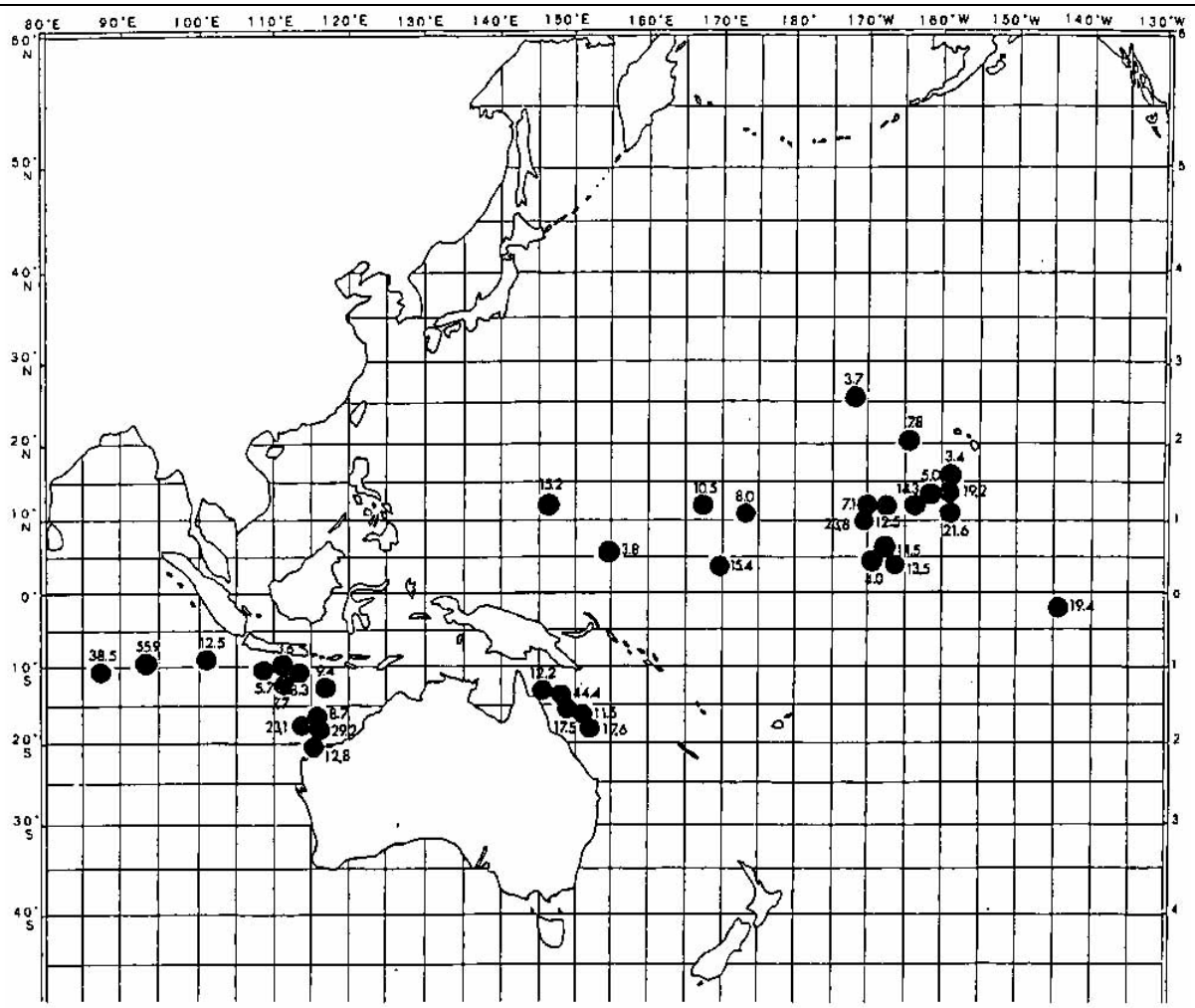
(1) Summary of the survey

In 1976, there were 57 trips by 29 public agency longline vessels. Map 4 represents the locations of predations and damage rates (number of operations with predations x100/total number of operations). The ranges of the experimental operations of public agency vessels are limited and concentrate on eastern part of the Indian Ocean, the Coral Sea and the tropical areas of the central western Pacific. The distribution is considerably scattered compared with that of commercial vessels. Therefore, it is difficult to get the whole picture of predation problems by killer whales in the Indian Ocean and the Pacific Ocean. Nevertheless, by mapping these data we can have some knowledge on the situation of the predation in each area.

The highest damage rate was 20.6% (average) in the Coral Sea, which ranged from 11.5~44.4 %. The damage rate in the tropical area of the Central Western Pacific was 11.6% in average. In that area, the lowest rate was 3 % and the highest rate was 24%, which was considerably lower than those in the Coral Sea.

In the eastern Indian Ocean the damage rate was 18.0% in average. High damage rates concentrated on the season between January and March. Moreover the distributions of predation areas show the tendency that the damage rate was high in the offshore waters and low in the inshore waters.

Map 4 Locations of predations and damage rates



damage rates = (number of operations that experienced predations) x100/(total no. of operations)

(2) Damage assessment

Because the damage rates, described so far, had not been analyzed by season and areas, it is difficult to estimate accurate damaged (reduced) population by killer whales. But as previously mentioned, the damage rate of 1976 was more than 10 %. So, we assumed three levels of damage rates, 10 %, 15 % and 20 % to estimate the reduced population. Since the main distribution of killer whales is at the low latitude waters in the FAO areas 71 and 77 in the Pacific Ocean and 51 and 57 in the Indian Ocean, we totaled the longline catches of yellowfin and bigeye tuna which are the main damaged species. The total annual production in these four FAO areas from 1970-74, were about 156 ~178 thousands tons. If we assume that the damage rate were 10 %, then the reduced production would be 16 ~18 thousands tons. Similarly, 15 % of damage rate indicates the reduced production of about 25 ~28 thousands tons and 20 % indicates the reduced production of about 35 ~40 thousands tons. Even in the case of reduced production of yellowfin and bigeye tunas, we can see that the great damages were caused by killer whales.

Now, we will consider the damaged amount (cost) of the production. We only consider bigeye and yellowfin tuna caught by the Japanese longliners as before. The production by Japanese longline vessels in these four FAO areas in 1976, was approximately 90 billion yen (US $ 900 million if US $ 1 = 100 yen). Now, assuming that the average damage rate would be 5 %, the amount of damaged production would be 5 billion yen (US $ 50 m.). Moreover it is presumed that the amount of damage would be much higher for those of South Korea and China (Taiwan) because they operate to catch primarily bigeye and yellowfin tuna. Hence, the global loss of the all longliners by the predation is seriously high amount.

1977-81 surveys

(1) Distribution of predation areas (Map 5)

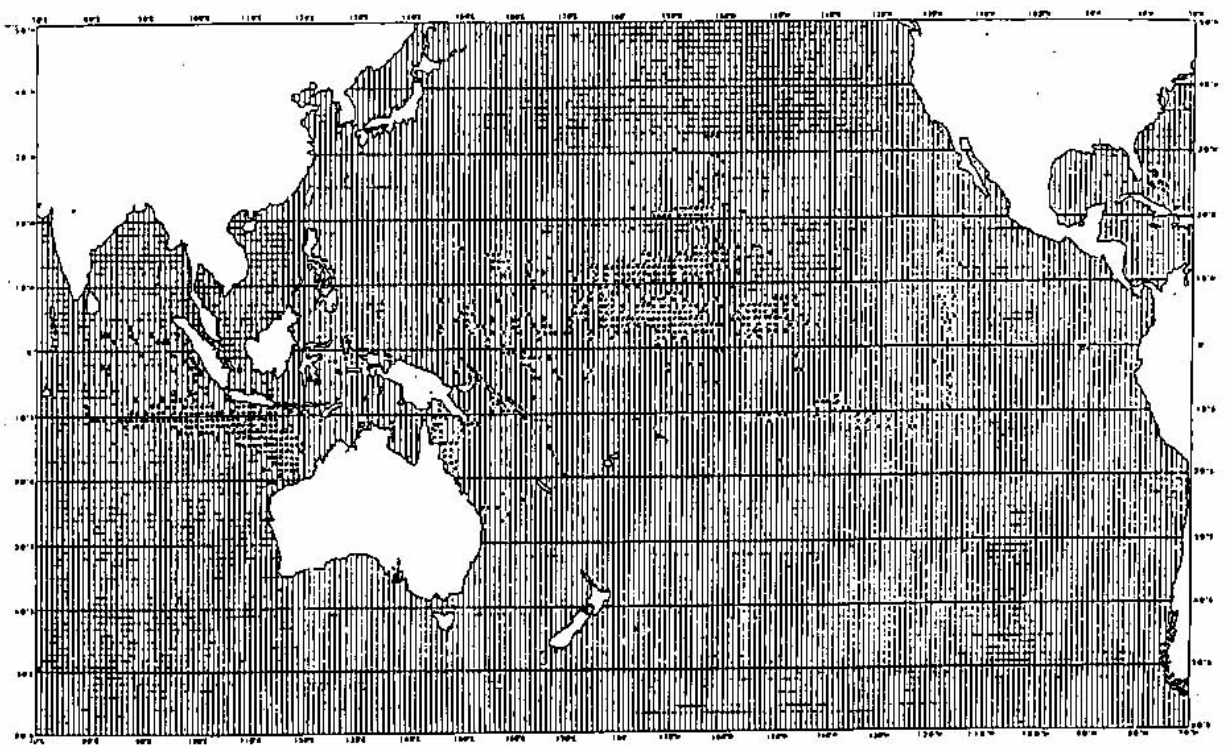
Map 5 shows the locations of predation areas (1x1 based area) during the 1977-81 survey years. Area covers almost all operational waters of the public (no-commercial) longliners. In the Indian Ocean, predation areas are concentrated in the area along 10°S, the north-western part of Australia. In the

Pacific, it occurs in Coral Seas, and along 5°N, 12°N, 20°N and 10°S.

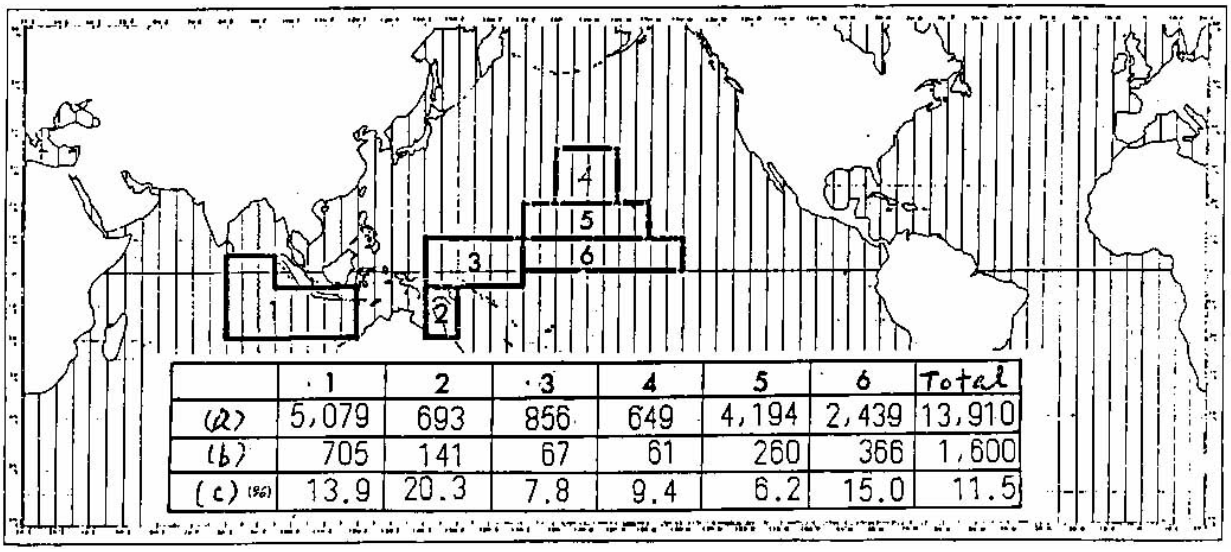
(2) Frequency of the damages by sub-area and species (Map 6, Figure 2 and Table 3)

Map 6 shows six sub-areas and predation situation by sub-area during the 1977-81 survey years. Table in Map 6 presents (a) number of longline operations, (b) frequency of predations and (c) damage rates.

Map 5 Locations of predation (1x1 area) during the 1977-81 survey.



Map 6 Situation of predation by sub-area during the 1977-81 survey



	1	2	3	4	5	6	Total
(a)	5,079	693	856	649	4,194	2,439	13,910
(b)	705	141	67	61	260	366	1,600
(c) (%)	13.9	20.3	7.8	9.4	6.2	15.0	11.5

Note: Table in the map shows (a) number of longline operations, (b) frequency of predations and (c) damage rates.

Table 3 show number of catch, number of damaged fish and damage rates by sub-area and species (1977-81). Fig. 2 shows the damage rates by sub-area and species. In the area 1 (eastern Indian Ocean), about 3 to 4.5% of the albacores, bigeye tuna or yellowfin tuna were damaged. About 2% of billfish were damaged in the same area. On the other hand, yellowfin tuna were damaged most in the area 2 to 6 in the Pacific Ocean, then bigeye and albacore follow. Predation is likely related to swimming layers of tuna.

Table 3 Sumamry of predation on tuna longline survey catch by sub-area and species (1977-81)

Sub-area	Item	SBT	ALB	BET	YFT	SWO	MLS	BUM	BLM	SAI	SKJ	OTH	Total
1	Catch	46	3,537	10,880	6,946	649	2,041	631	1,262	233	171	5,123	31,519
Eastern	damage	8	903	3,719	2,026	64	284	65	198	27	15	115	7,424
IO	Rate(%)	17.39	25.53	34.18	29.17	9.86	13.91	10.3	15.69	11.59	8.77	13.04	23.55
2	Catch	0	539	105	3,143	34	17	51	832	79	19	1,680	6,494
Coral	Damage	0	150	24	1,197	3	1	5	279	9	1	100	1,769
Sea	Rate (%)	0	27.83	22.86	38.08	8.82	5.88	9.80	33.53	11.39	5.26	11.74	27.24
3	Catch	0	8	291	3,150	18	3	100	15	97	22	663	4,367
W tropical	Damage	0	0	50	800	0	1	12	0	20	3	4	890
PO	Rate (%)	0	0	17.18	25.40	0	33.33	12.0	0	20.62	13.64	6.35	20.38
4	Catch	0	1,185	57	533	28	494	194	2	167	66	789	3,515
Hawaii	Damage	0	239	24	151	3	77	13	0	26	9	40	582
	Rate (%)	0	20.17	42.11	28.33	10.71	15.59	6.70	0	15.57	13.64	18.18	16.56
5	Catch	0	440	3,259	1,481	133	571	587	21	210	39	4,059	10,900
Mid sub-	Damage	0	136	1,285	621	36	121	117	2	19	21	124	2,482
Trop. PO	Rate (%)	0	30.91	39.43	41.93	27.07	21.19	19.93	9.52	9.05	15.11	16.54	22.77
6	Catch	0	34	2,758	5,545	108	117	637	16	65	25	3,569	13,274
Central	Damage	0	3	2,753	1,458	13	15	174	2	9	41	59	2527
Equat. PO	Rate (%)	0	8.82	27.30	26.29	12.04	12.82	27.32	12.5	13.85	9.65	9.98	19.04
	Catch	46	5,743	17,350	20,798	970	3,243	2,200	2,148	851	42	15,878	70,069
Total	Damage	8	1,431	5,855	6,253	119	499	386	481	110	90	442	15,674
	Rate (%)	17.39	24.92	33.75	30.07	12.27	15.39	17.55	22.39	5.12	10.69	13.02	22.34

SBT: Southern bluefintuna, ALB: Albacore, tuna BET: Bigeye tuna YFT: Yellowfin tuna, SWO: Swordfish,

MLS: Striped marlin, BUM: Blue marlin, BLM: Black marlin, SAI: Sailfish, SKJ: Skipjack, OTH: Others

In total, 30 to 34% of the bigeye tuna or yellowfin tuna were damaged, which mean that as much as one third of them were damaged, and 25% of the albacore, 17% of the southern bluefin tuna were also damaged. Compared to tuna, the black marlin was damaged the most in all kinds of billfish, but less damaged than the tunas (Table 3). Finally, the estimated amounts of the damaged tunas was 7,000 in tons in 1979 and the damage looks so serious.

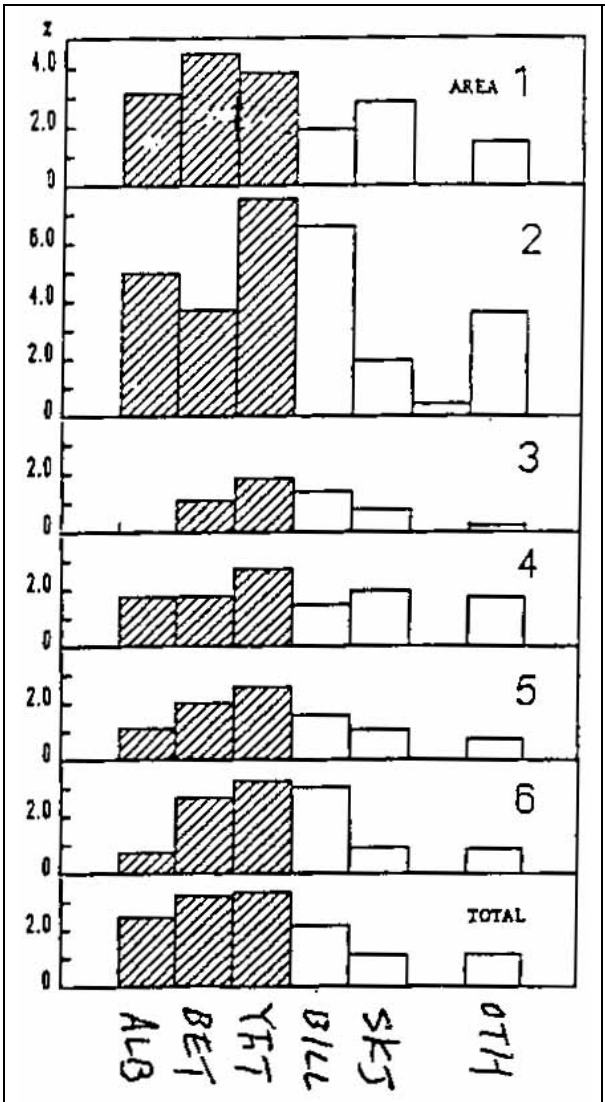


Fig. 2 The average damage rates by sub-area and species during the 1977-81 surveys. Refer to Map 6 on sub-areas.

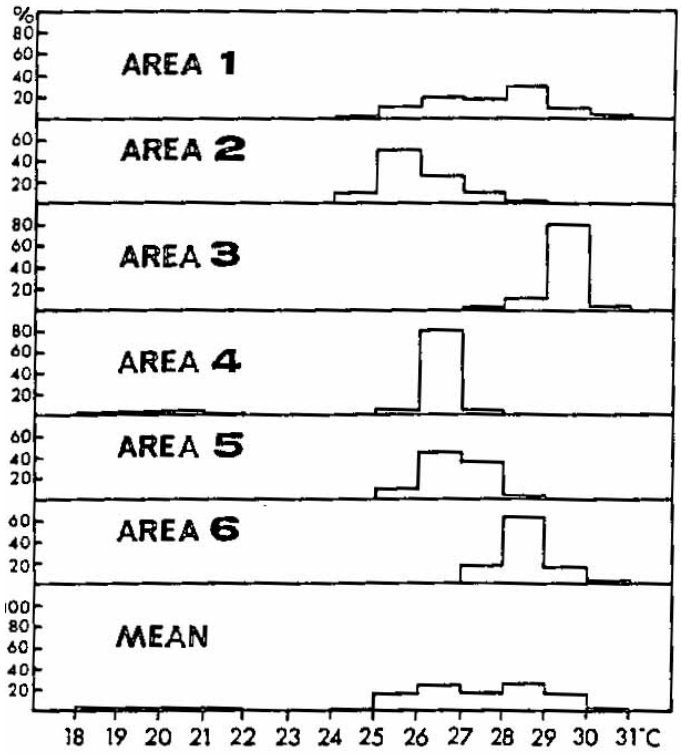


Fig. 3 Damage rates of the longline catch by sub-area and sea temperature during the 1977-81 surveys. Refer to Map 6 on sub-areas.

(3) Frequency of the damage rates by sub-area and temperature (Figs. 3-4)

Fig. 3 shows damage rates by water temperature based on the 1978 survey. Based on the survey results, the most damaged-frequent temperatures in each area were 28? , 25? , 29? , 26? , 26? and 28? from sub-area 1 to are 6, respectively. The highest temperature was in area 3 (29?). The surface temperature in the sub-area 4 is highly changeable through the year compared with the 5 other sub-areas. It is noteworthy that damages occurred in the wide rage of 18~22? in the sub-area 5.

(4) Timing of predation

Occurrence of predation is deeply related with the time when longliners were being recovered according to the 1958 survey. Oldness or freshness of the damaged fish heads indicates their irregular time for predation.

BIOLOGY, PHYSIOLOGY AND ECOLOGY OF PREDATORS

Biology

(1) Species

There are two major predators for the longline caught tuna and billfish, i.e., killer whale (*Orcinus orca)* (Linnaeus, 1758) and false killer whale (*Pseudorca crassidens*) (Owen, 1846) also known as false pilot whale, which are the family of the toothed whales (Fig. 4). As false killer whale is smaller in its size, it is often called as 'small toothed whales'. There are also other predator species of small toothed whales. Different species has its own body color. Sharks are also predators for longline caught tuna, while they are also exploited by the longliners and predated by killer whales or false killer whale. Further detail description on predator species are provided in

Appendix A. Table 4 shows species names found during the 1954 & 1958 surveys. Judging from the teeth marks, predator species can be identified

Table 4 Predator species and frequencies of attacks (from 1954 & 1958 survey)

	1954	1958
Killer whale	8	16
False killer whale	22	7
Both	8	7
Northern right whale dolphin (5m)	1	0

(2) Identification features

Killer whale

The killer whale is the largest of the ocean dolphins and probably the best known of all whales. It is easily recognized by its great tall dorsal fin and its black and white colors.

False killer whale

This little whale may be separated from all other whales by the presence of a hump or elbow- like prominence on the curved outer margin of its flippers. The large teeth are also distinctive.

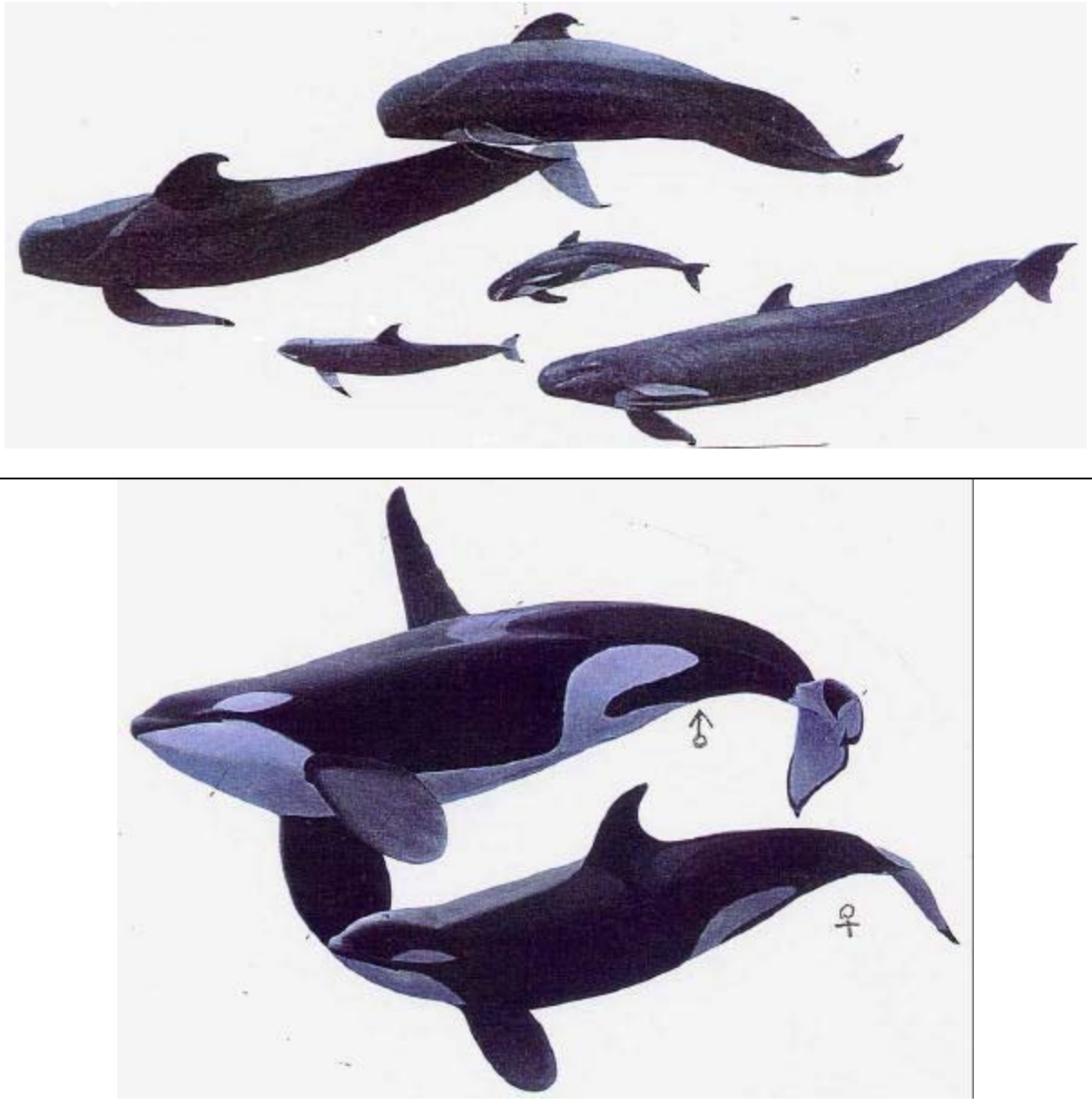


Fig. 4 Two major predators for longline caught tuna (upper : false killer whale, lower: killer whale)

(3) Size and shape

killer whale

The body of the killer whale is very broad, robust, and spindle-shaped. Large adult males will reach a length of 9.5 meters (31 ft.), but most are much smaller. Large adult females will reach a length of 7 to 8.2 meters (23 to 27 ft.), but most will measure nearer 6 meters (20 ft.). Some documents have said male killer whales are much larger than female ones, i.e., average males grow as long as 9.5 to 11.4 m, but females, even the biggest ones, are at most 5.7 m long. However, the Japanese predation survey data show that males are just a little bigger, not so different from females. The dorsal and pectoral fins are small in their childhood and they become great when they grow up. Big pectoral and dorsal fins are unique features for adults.

False killer whale

The body of this whale is long and slender and males will reach a maximum length of about 6 meters (19.7 ft.). The females will reach a maximum of about 5 meters (16.4 ft.). The head is bulbous and flattened and tapers forward from the blowhole to the snout. The upper jaw is longer than the lower jaw and overhangs it a short distance. The mouth opening is large and long. The skull has a flat, broad rostrum, but the beak is visible externally. The males will measure from 2 to 3 feet longer than the females.

(4) Color

killer whale

In this species, the body color is black with a large white area extending along the lower side from the chin to the anus; this white area gives off a lateral, upward, posteriorly-directed extension on each side just anterior to the anus. A large, distinctive white spot is located just behind the eye. The flippers and tail flukes are black above and white below. In addition, a light saddle-shaped area of various shapes and colors is often present on the back just posterior to the dorsal fin. In Antarctic Seas, the white areas are yellowish in color. In newborn calves, these light colored areas are of a yellowish hue; they become white as they grow older. Some whales of this species have been seen in the wild which were completely black or completely white.

False killer whale

Black is the predominant color of the body and covers its entire surface except for a gray area on the belly between the flippers and occasional whitish dapplings on the leading edge of the flippers. The body is often marked with scars.

Physiology

There are also many reports on the special physiological characteristics of predators, which are described as below:

Phonating (communication) ability of small-size toothed whales

They have abilities to communicate within the same families what they had learned. They can imitate human languages. It is possible to record their voice through the microphone by luring them with bait from the ship; situation with little swell and noise is desirable. There have been research activities to collect voices of the approaching small whales to the boat using the echo sounder (fish finder).

Ability to recognize and measure the target (prey)

They phonate for safe actions and food hunting. As they can clearly detect objects such as the girth of tuna longline, it is presumed that they should use 200 kHz of ultrasonic waves. Sometimes the groups of false killer whales or dolphin have mass-stranding. This is the similar situation that echo sounder with high frequencies cannot easily record the steep slope of the seabed.

Learning ability

During some period at the beginning of the longline fishing, damages had been consistently increased due to their learning ability, which are understood from following facts:

Indian Ocean in 1950's➔ predation were mainly by sharks, but from the 1960's predation by killer whales and false killer whale have increased. This might be caused by the possible fact that they learned longline have baits (tunas), so that they can easily feed.

Indian Ocean (1954) and Atlantic Ocean (1957)

longliners saw some killer whales but there was no damage.

1958 survey (whole Ocean) ➔ attack toward boats

1964 survey (whole Ocean) ➔ attack in close distance from the gunwale

From the facts above, it is considered that killer whales have the strong learning ability. The reasons are as follows: The increase of their attacks is supposed to come from their learning

ability that longliners have baits (tunas). Whales that are sensitive to sound and light may have found it easy to get foods when they approach to the longline ships which make big noises by diesel engine in the water and the frequent on-off light. As whales (like bottlenosed dolphin) have higher intelligence than dogs, it is assumed that killer whales or the false killer whales also have high standard learning abilities.

Ecology

(1) Distribution

killer whales

The killer whale has been described as the most widely distributed mammal on earth because it inhabits the polar, temperate, and tropical seas of the globe. It is commonest in the eastern and western Pacific Ocean, the northeastern Atlantic Ocean, and Antarctic Seas. It appears to stay within 800 km (500 mi.) of the shoreline and will enter inland seas, bays, and estuaries, Its preference for coastlines is doubtless due to the presence of more food in these areas. Killer whales distribute in large scope from the Arctic to the Antarctic Ocean, which are mainly concentrated in the lower latitude

waters. Regarding the distribution in the Indian Ocean and the Pacific Ocean.

False killer whale

The false killer whale is a warm water species which is distributed world–wide in the open oceans of the tropics, the sub-tropics, and the warmer waters of the temperate zones. It is an oceanic species and does not frequent coastal waters In the North Pacific it is distributed from Alaska to Panama; it occurs in the Sea of Japan and in the South China Sea; it is also widely distributed in the South Pacific, Indian, and Atlantic Oceans and in the Mediterranean Sea.

MIGRATION

killer whales

These whales move northward and southward with the seasons, possibly following the migrations of their various sources of food.

False killer whale

This is a non-migratory species, although it may shifts its position a few degrees with the changing seasons and currents.

(2) Reproductive ecology

killer whale

Many documents report that killer whales mate at the end of the year and have one-year pregnancy, but this needs a still more survey on embryo development. Schaeffer (1948) reported that killer whales in Washington State, mate from April to July, which is the same season as for false killer whales. The body length of an embryo at birth is estimated 210 cm long.

(3) Feeding ecology

killer whale

Killer whales rather prefer blood than be flesh-eating. We don't know without any experiment which sense of taste, smell, and sight they use to recognize blood, however, the present anatomy does not take account of smell. Killer whale eat the whole body of tuna except heads. All longline baits are eaten sometimes.

It has been reported that killer whales eat variety of aquatic resources., i.e., fin whales, humpback whales, gray whales, blue whales, dolphins, seals, sea lions, sea elephants, sea otters, sea fowls, fish and squid. A killer whale with 10 m long and 10 tons weight needs 1 ton of foods a day. Choosing food is likely to be needless for such a big eater. Table 5 shows stomach contents based on the 1954 and 58 survey.

Table 5 Stomach contents from the 1954 & 58 surveys

Stomach contents of false killer whales	Number of whales investigated
Empty (*)	12
Tuna flesh	5
Liquid	3
Small fish	2
Whole tuna	1 YFT (30kg) and 1 BET (50kg)
Shark flesh	1
Guts of fish	1
Small fish bones	1
Total	27

(*) Many empty stomachs may occur because when captured, they vomited.

(1) Sea temperature vs. feedings

Like dolphin, amount of feed of killer whale likely vary by temperature.

(2) Schooling, swimming depth and diving duration

killer whale

This whale is a very good swimmer and is reported to be able to swim at a speed of 25 knots (28.8mph). It travels in groups of 2 or 3, sometimes as many as 20 to 30, and is occasionally seen in great groups which might include as many as 150 or more individuals.

False killer whale

This whale is a sociable species and travels in small groups; however, it is not uncommon to see groups of 100 individuals and, in a few instances, large groups have been observed which included an estimated 1,000 individuals. These whales have been observed to leap above the water and to approach ships, where they will ride the bow waves. They occasionally associate with schools of tuna fishes and are captured in the seines of the tuna fishermen. There are records in which these whales were known to dive to a depth of 1,000 feet. The most amazing habit of these whales is that of beaching themselves in great groups of as many as 100 to 300 individuals and to resist any attempts to return them to the sea. These whales set an all-time record for swimming ashore and beaching themselves. It is reported that in 1946, 835 of these whales beached themselves near the city of Mar del Planta in Argentina.

Other observation

There are various reports and views on swimming depth and diving duration in the past Proceedings. However, in general, diving time of toothed whales with a long beak (bill) is short (1-2 minutes), while the one with longer beak is longer. Several reports are introduced as follows:

The Second Satsuma Seiun Maru (June 1, 1976) recorded the image of killer whale appeared in the fish finder when it was at anchor at the point of 12 ° 27' N and 164 ° 38' W (Fig. 5). Judging from this image they seemed to have been swimming between 30 and 55 meter depth.

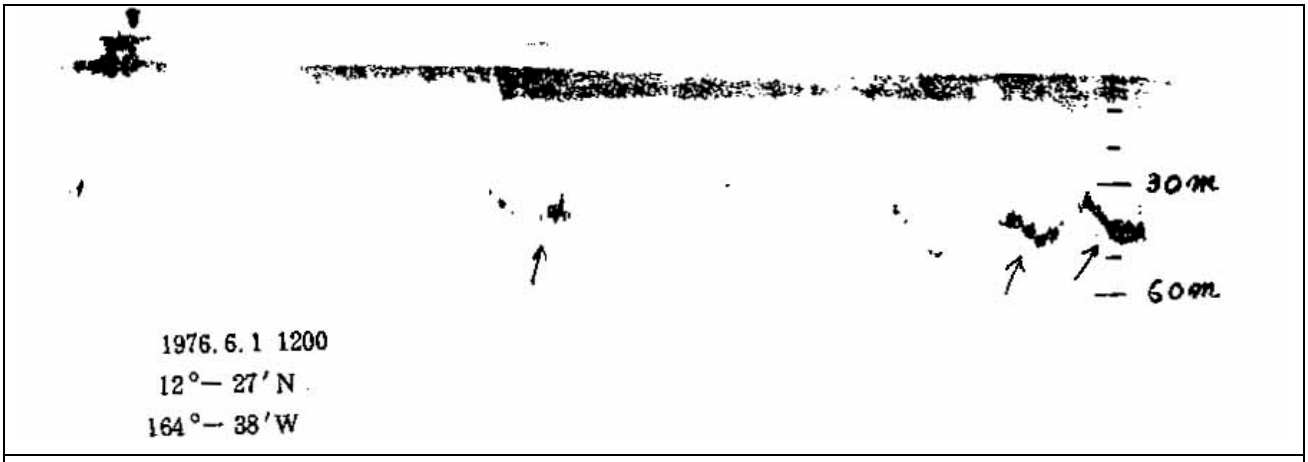


Fig. 5 Echo images of killer whale appeared in the fish finder Second Satsuma-seiun Maru

Moreover by analyzing the relationship between time and depth, it was calculated that they moved downwards at a speed of 24~37 cm/sec and upward at a speed of 17~70 cm/sec. When they descend, images were caught in the shape of concave toward downhill line. (Downhill line: we assumed the straight line, which extend from the center of the maximum point to the center of the minimum point in the image). On the other hand when they ascend, the image was recorded in the shape of convex toward uphill line.

For the regular or shallow longliners, the most deep hook is set at as deep as about 120 m. The images of killer whale also appeared in the fish finder indicates 120 m. Thus, it is evident that they can easily attack tuna at that depth.

The assumption that regards the intervals of their breathing as for about 2 minutes, the speed of sailing at diving as 10 knots, and the time of predation as 10 seconds makes it possible for them to dive down to the 225 meters deep.

Optimum diving depth can be considered to be about 80 m when fixing the breathing intervals for about 30 seconds, and the submerged speed for 15 knots.

In the albacore fishing grounds in the Atlantic Ocean, when the hook depth of longliners is 250~300 meters, the damages by killer whales did not show the normal form (i.e., eat whole tuna except heads), but only some part of the fish body was damaged. Considering that they did not have enough time to damage and breath at about two minuets intervals, the limit of their diving depth can be estimated.

(6) Evolutional view

It is considered that all kinds of animals should be differentiated from "insectivore" so called "Creodonta". But it seems odd that toothed whales had been separately evolved from as same position as "even-toed ungulate", differently from that as Baleen Whale. But the fact is known that cows supply plenty of milk when they listen to beautiful melody of chord. They might have something close ecologically with toothed whales being very sensitive to sounds.

Furthermore dolphin often appear in the Greek myths and they are treated as if they are familiar with humans. There are no clear reasons why it was considered that humans were more familiar with such aquatic animals having fish style rather than land animals. Is it possibly presumed that humans would have communicated with dolphin by means of signal sounds, before they have obtained their own languages?

MITIGATION

Various mitigation measures of predations have been reported, which are listed as below:

(1) Avoid to throw tuna's guts into the sea after getting them on board to keep away predators.

(2) Make big sounds using guns or trumpet speakers to scare them.

(3) It has been reported that there are no damages at all by predators if tuna are caught by up-side-down (means that tails are hooked by the longline) (see Fig. 6). It will be worthwhile if we consider to develop the fishing methods to catch tuna in that way. From another source, it has been also known since 1959 that the tail-tied fishes tend not to be damaged by killer whales. Judging from the intelligence of killer whales, it is assumed that they regard the reversed fishes as abnormal ones and they don't eat them.

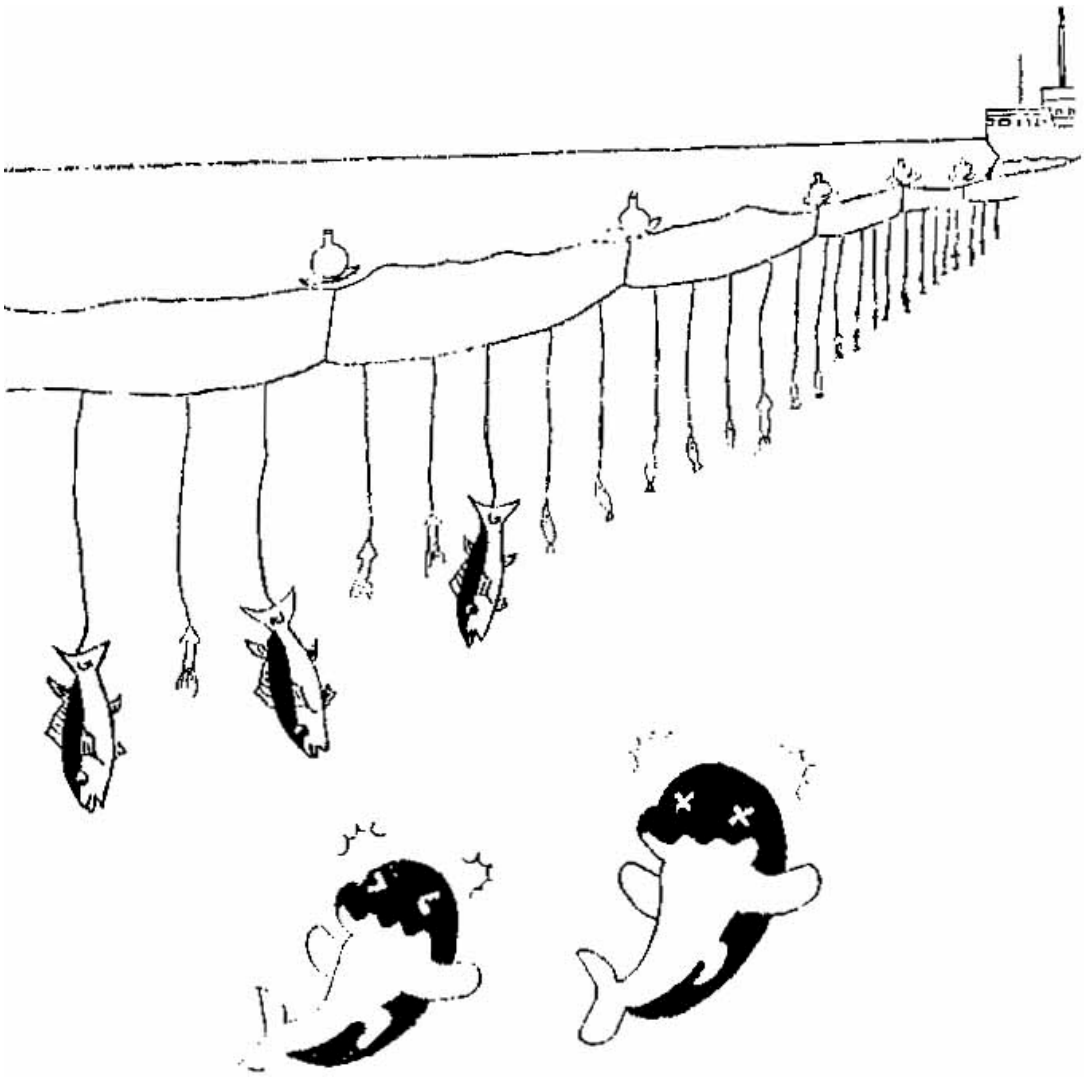


Fig. 6 Tail-tied hooked tuna longline fishing might be the best mitigation method to prevent the predation by killer whale.

(4) Using some killer whales or false killer whales in aquariums, observe their behaviors in details, and record the cries they make when clubbed or thrust on tape. Then, attach the tapes to buoys making them begin to play when they approach to and see if they go away or not.

(5) Put bleaching powder, insulin or lime powders in the sea, for instance, is considered to be the effective method to keep the predators away because their ultrasonic waves might be diffused and disturbed.

There are a few reports on the effects such materials as follows:

Mass suicides of whales tend to occur in the flat and long beaches, which are more frequent in the beaches where there are algae and babbles. As examples of Japan and foreign countries, there are only a few reports that a few whales were stranded on rocky seashores. It was reported that a school of small-sized toothed whales was stranded when lime powders transitively flowed into the Sacramento beach. This seems to be one of the proofs that small-sized toothed whales do direction findings by using sonar. That is why inflows of fine powders or suspended matters put millimeter-wave radar out of order and they consider them something big, so that we would be able to prevent damages.

(6) Reduce population of predators

(7) Mitigation methods during fishing operations

- Make sure of the direction of the killer whale school sailing, then get away from it.
- Change deployment angle of the longline to 90 degrees (right angle) in some stage.
- Go toward the low temperature water region apart from the school's sailing direction
- Stop the engine, then change the course and go sailing the ship.

- Cut the line off and wash away with radio buoy. After 3 or 4 hours sailing, throw the

lines again to the same place or to the opposite direction away from the cut-off lines.

- Sail or drift with no lights.

There are many effective methods, but predators easily learn the characteristics of some of mitigationmethods. Combining these methods seem to be the most effective approach. However, if we can find the fishing method to hook the tail (refer to (3)), it is likely the best solution.

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APPENDIX A: WHALES AS PREDATORS ON TUNA (WHALES AS PREDATORS OF TUNA ;ARTICLE BY OHSUMI, 1976)

1. INTRODUCTION

As shown in Table A1, whales have relation to fisheries in various aspects and predations by whales occur in various fisheries and there were various features of the damages as shown in Table A1.

Table A1. Relationship between whale and fishery

? . Whale will can be an object of fishery.
? . Whale is useful for fishery because..
1. Whale can be an index to find a shoal of fishes.
2. Whale aggregate schools.
? .Whale damages fishery because…
1. Whale preys high-valued commercial fishes in nature.
2. Whale scatters a shoal and reduce catchability.
3. Whale damages fishing gears.
4. Whale robs baits.
4. Whale damages exploited fishes.

In tuna longline fisheries, twenty years have passed since in 1956 when predation problems became serious that precious catches had been damaged not only by sharks but also by whales and the damage-prevention measures were realized to be necessary. Though various researches had been attempted to now (1976), no effective measures of damage prevention have been succeeded. But the damage cases have not decreased and even the actual situations are not well understood.

As Yamaguchi (1964) explains, damages by "Killer Whales" are not scattered unlike the damages by sharks, but they are consecutive and, what is worse, in most cases all the eatable parts are lost completely except the heads, compared with the shark's case in that some parts of fish body are left. Once fish are attacked by "Killer Whales" the damages are extremely great compared with the cases of sharks.

It is also reported that the damages by Killer Whales range over three Oceans where are fishing grounds of tuna longline fisheries. Damage frequency is considerable and it is assumed that the damages would amount to 4~5 billion yen at least. It is regrettable that precious fishes which were hooked with a lot of effort, are robbed helplessly. As the efficient use of fishery resources is essential, the research activities to prevent the eating damages including by sharks should be established.

When we design prevention measures, we must survey and research the ecology of attackers. Then, understanding their features we have a possibility to solve the problems. Therefore ecological research should be made systematically as part of the measures of the damage prevention.

2. WHALES THAT PREY TUNAS

As fishers often call it "damage by Killer Whales", it had been assumed that the kinds of whales which preys tunas is Killer Whales or species close to this. But it had been discussed for a long time whether or not so called "Killer Whale" is taxonomically *Orcinusorca*. And through efforts of Ishibashi *et al.* (1966), it became to be known that the principal offender is False Killer Whale (*Pseudorca crassidens*). In addition to False Killer Whales and Killer Whales, Ishibashi suggested the possibility of the existences of other kinds of whales which attack tunas. Nevertheless after that no systematic survey has been made and it remains not to be confirmed other species to present.

The identification of predator species and the accurate recognition of the time-spatial and quantitative distribution are the basis for planning of prevention measures. Therefore the systematic survey and research is necessary and at least in the survey operations by public agency vessels (Japan) they should prepare the field books which are helpful to identify whales species in observing whales and the crew should try to take the precise records as a routine work.

At present there are about 80 species of whales. But among those, the whales which possibly to prey tunas are limited. As the distinction standard, the form of mouth, the variety of foods, the style of feeding, and their distribution areas are given. (Table A 2).

All species of whales have same tendency to feed on animals and types of their baits are divided roughly into five groups, i.e., animal planktons, cephalopods, bottom fishes and small and large pelagic fish. Their favorite tastes of baits are different by species. The animal-eating whales should be the kinds which are possible to eat large pelagic fishes like tunas. As they damage tunas hooked in longliners and are never caught in hooks, we believe that they should have a big and broad mouth with tooth and should catch foods by biting off instead of swallowing. Furthermore, as the damages by "Killer Whales" occur mainly in a warm core ring centering on the tropical sea areas even in a whole year. Therefore it is limited to some specific species of whales that distribute in such sea areas throughout a year.

Table A2 Possible whale species that predate tuna

Classification	Numbers of kinds	Mouth	Variety of baits	Style of feeding	Distribution	Synthesis
Baleen Whale (sub order)	10	-	-	-	++	-
	67	+++	+++	+++	+++	+++
Toothed Whale (sub order)	5	-	-	-	-	-
Chinese lake Dolphin (family)	3	-	+	-	+++	-
Sperm Whale (family)	18	-	+	-	+++	-
Goose-back Whale (family)	2	-	-	-	-	-
Narwhal (family)	25	-	-	-	+++	-
Common dolphin (family)	1	-	+	-	+++	-
Risso's Dolphin (family)	1	+	-	-	++	-
Irrawaddy Dolphin (family)	6	-	-	-	-	-
Harbor Porpoise (family)	6	+++	+++	+++	-	+++
(Blackfin Whale)		+++	++	+++	+++	+
Pilot Whale		+++	++	+++	+	++
Short-finned Pilot Whale		+++	+++	+++	+++	+++
False Killer Whale		+++	+++	+++	+++	+++
Killer Whale		+++	++	+++	+++	++
Melon-headed Whale		++	++	+++	+++	++
Pygmy Killer Whale		++				

Note: - + ++ +++ represents orders of adaptabilty to predate tunas from the lowest (-) to highest (+++)

Through these basic knowledge, whale species that have a possibility to prey tunas are focused on five kinds that belong to Blackfin Whales, as mentioned in Table A2. Ishibashi suggested in 1966 that some species of dolphins that belong to Pacific-Right Whales and Striped Dolphins should have a possibility to damage tunas. However, some species of whales that belong to the Common Dolphins should have the linear and small mouths and can never hold a big tuna body in the mouth and never bite it off. Normally they do not eat a bigger fish body and have very little chance to damage tunas that are caught in the longliners. As the school of dolphins happened to be found in the waters where the damages occurred, it should be supposed to have related to such damages. It is necessary anyhow to confirm whether or not dolphins can prey tunas.

3. IDENTIFICATION OF WHALE SPECIES TO PR EY TUNAS

In the previous section, it was presumed that the whales which have a possibility to prey tunas would be some kinds belonging to Blackfin Whales. To confirm the actual conditions of eating damages, nothing could be better than observing those of damages by hydro-camera, for instance. Or, if possible, it is ideal to inspect their stomach contents, or, to inspect bites marks of tooth remained on the tuna, so that whale species can be judged.

3.1 Identification (outlook)

Figure A1 shows four kinds of lateral views, which belong to Blackfin whales. At first sight, Killer Whales can be distinguished from other kinds of whales by characteristic white marks that are recognized on the abdominal region and behind the eyes. False Killer Whales have the features on short pectoral fins and big leading edges. It is possible to make a misjudgment between Short-Finned pilot whales and Pilot whales, but Short-Finned Pilot whales, as its naming, have a short pectoral fin and one sixth of length in comparison with Pilot whales. Pygmy whales have a long oval white spot on the back abdominal region, though they are similar to False Killer Whales. Melon-headed whales are very similar to Pygmy whales to all appearance, but if you would count their tooth, you could distinguish either of them easily.

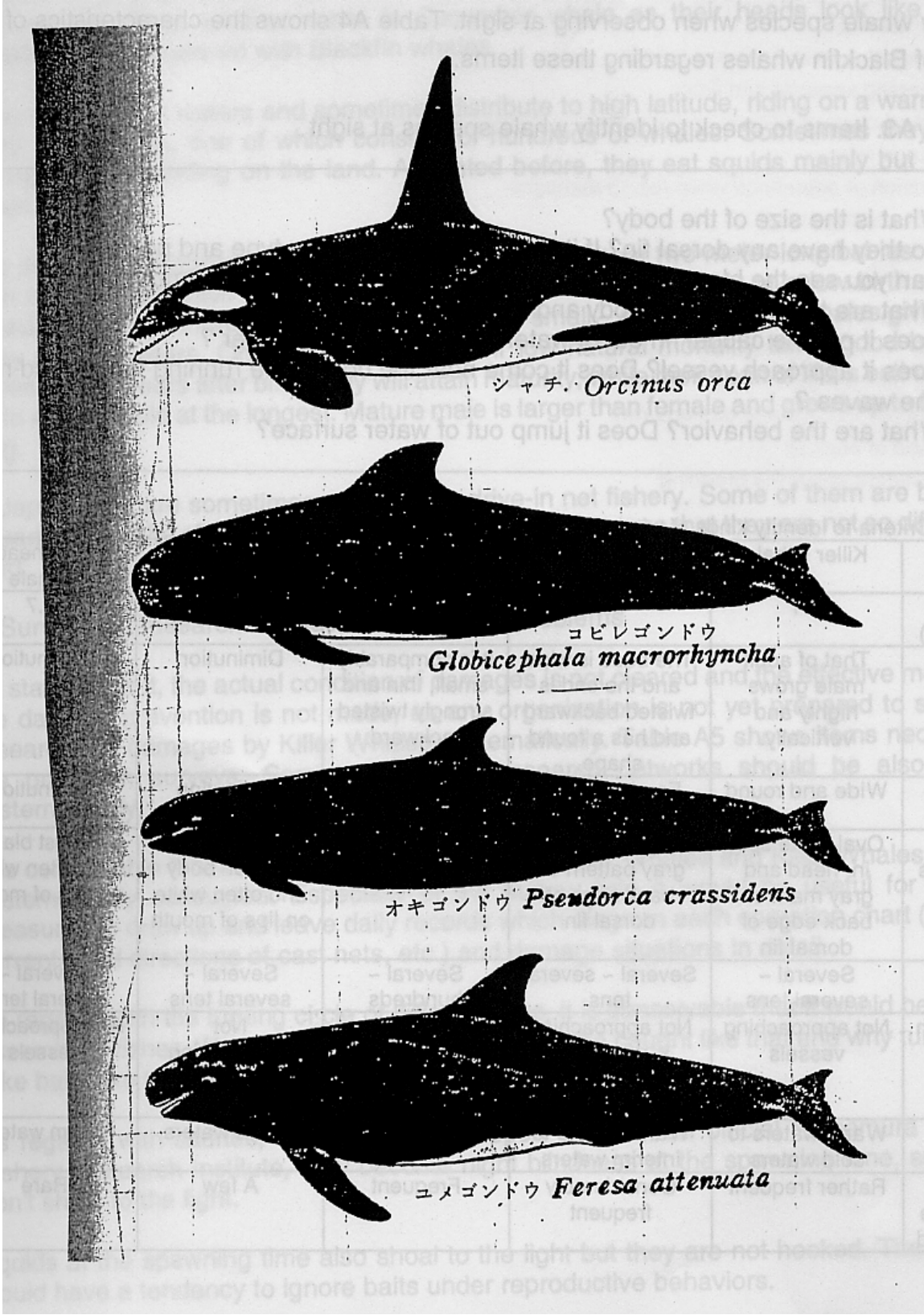

Fig. A1 Four pieces of toothed whale that predate tunas

3.2 Identification (from vessel when swimming)

Since it is impossible for commercial longliners to catch whales, visual observation from vessels is the most effective method to identify whale species. Generally, few whales appear their whole bodies to the surface of the sea, when they are swimming. Therefore, the identifications of the whale species are difficult when swimming. Table A3 lists items to check to identify whale species when observing at sight. Table A4 shows the characteristics of five species of Blackfin whales regarding these items.

Table A3. Items to check to identify whale species at sight

1. What is the size of the body?
2. Do they have any dorsal fin? If it have, what are its size, type and position?
3. Can you see the blow? If you can, what is its height, type and number?
4. What are the color of the body and its mark?
5. Does it put the caudal fin out of water when it dives into water ?
6. Does it approach vessel? Does it come near the bow of the running vessel and ride the waves ?
7. What are the behavior? Does it jump out of water surface?

Table A4. Criteria to identify kinds of whales at site which possibly attack tunas

Distinction Index	Killer Whale	Short-finned Pilot Whale	False Killer Whale	Pygmy Killer Whale	Melon-headed Whale
Body length (adult, meter)	9.1	5.3	5.5	2.7	2.7
Dorsal fin	That of adult male grows highly and vertically.	The base is wide and the end is twisted backward and has a round shape.	It is comparably small, thin and strongly twisted backward.	Diminution	Diminution
Head shape	Wide and round	Forehead type	Diminution like a rugby ball	Diminution	Diminution
Coloration and markings	Oval white spot in head and gray mark on back edge of dorsal fin	Black and having gray pattern on back edge of dorsal fin	Black completely	Gray mark on side of body and often white on lips of mouth	Almost black and often white on lips of mouth
Shoal composition	Several ~ several tens	Several ~ several tens	Several ~ hundreds	Several ~ several tens	Several ~ several tens
Relation with vessel	Not approaching vessels	Not approaching vessels	Approaching vessels and riding surf by the bow	Not approaching vessels	Not approaching vessels
Distribution areas	Warm waters to cold waters	Warm waters to interim waters	Warm waters	Warm waters	Warm waters
Encounter chance in the fishing ground	Rather frequent	Considerably frequent	Frequent	A few	Rare

3.3 Identification of False Killer Whales

As Ishibashi reported in 1966, it is certain that False Killer Whales would be the principal offender that prey tunas caught by longliners. It is well known from old times in Japan that False Killer Whales, or Big Fish Killers as their nicknames, attack big fishes sometimes, and this character is noted broadly in the world. Additionally, False Killer Whales, which is an English name originally, are also called Imitating Killer Whales and similar to Killer Whales in their figures. Their another name is Cucumber whale as their heads look like lanky as cucumbers, if compared with Blackfin whales.

They live in warm waters and sometimes distribute to high latitude, riding on a warm current. They form shoals, one of which consists of hundreds of whales. Sometimes they die after having mass stranding on the land. As stated before, they eat squids mainly but attack big fishes at times. The duration of pregnancy is about one year, and they bear two-meter-long babies. They give birth to one baby each time. The multiple conception is extremely at a low birth rate. Their breeding period is three years and its rate is very small – sexual mature females give only one baby in three years. On the other hand, their low natural mortality takes good balance. In seven to nine years after birth, they will attain maturity, while their span of life is estimated to be 40 to 45 years old at the longest. Mature male is larger than female and grows up to 5.5 meters long.

In Japan, they are sometimes captured by drive-in net fishery. Some of them are bred in the aquarium. In spite of the environment is not oceanic, it seems that they are not so difficult to be bred.

4. SURVEY AND RESEARCH METHODS FOR PREDATION PROBLEMS

As stated at first, the actual condition of damages is not cleared and the effective measures of the damage prevention is not made, as any organization is not yet prepared to survey and research the damages by Killer Whales systematically. Table A5 shows items necessary for the predation surveys. Some survey and research networks should be also prepared systematically.

It is conceivable that survey of damages by False Killer Whales and Killer Whales should be systematically conducted. Especially in the survey lists it would be useful for the future measures to draw up and leave daily records which diagram each operation chart (about tidal currents and directions of cast nets, etc.) and damage situations in detail.

As regards with the turning circle of Killer Whales, it is conceivable that it would be an act for assembling fishes. We want to know how fishes can be caught like that and why tunas should take baits like that with death approaching.

As regards with sauries , according to the report of technical official Yamamura of Tohoku Fishery Research Institute, they become night blindness at the spawning time, so that they don't shoal to the light.

Squids at the spawning time also shoal to the light but they are not hooked. Therefore they would have a tendency to ignore baits under reproductive behaviors.

In the eastern tropical Pacific, there exist tunas and dolphins and it is said that catching tunas by round haul nets is also to search dolphins.

Table A5 Survey items of "Killer Whales" predations

1. Confirmation of attacker whale
a. Identification of the kinds by the visual observation
b. Identification of the kinds by the capture and the investigation of the gastric contents
c. Identification of the kinds of whales by the tooth mark of damaged fishes
d. Experiment and observation in the aquarium
2. Record of damages
a. Damaged area and the water depth
b. Damaging seasons and times
c. Kinds of damaged fishes and condition of damaged fishes
d. Damage rate
e. Condition of operations when taking damages
3. Ecology of attacker whale
a. Distribution and transfer
b. Stock number
c. Assumption of biological attributes
d. Observation of behavior by breeding
4. Method of damage prevention
a. Operation method and damage rate
b. Method of capture
c. Experiment under the breeding