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TAGGING BRITISH COLUMBIA PILCHARDS
(*Sardinops Caerulea* (Girard)):
INSERTIONS AND RECOVERIES FOR 1938-39

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APPENDICES.

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INTRODUCTION.

The pilchard tagging and tag recovery programme was continued through its fourth season during 1938. Results for previous years (Hart, 1937; 1938) have established that there is an interchange of individuals between the sardine-fishing grounds of California and the pilchard-fishing grounds of British Columbia. The programme is being continued in an attempt to establish the degree of generalness of the movements observed and to learn more detail concerning the migrations of the fish. The present report describes the work done during the past year and recent tag recoveries. The discussion of results and the calculations based on them are in many cases to be regarded as illustrations of the use to which tagging data may be put rather than presenting final conclusions.

METHODS.

The methods used during the 1938 season were similar to those employed during the previous year, as discussed in Hart (1937; 1938). Fish from commercial purse-seines were tagged from the seine-skiff by the use of a tagging-gun (Hart and Tester, 1938; Hart, 1938). As a check on the mortality produced by placing tags in pilchards with the gun, part of the fish from some schools were tagged with a knife, as previously described (Hart, 1937).

Tags were of the same type and dimensions as used in previous years.

Recoveries, too, were made by the same method as in previous years. Electromagnets in the meal-lines (Hart, 1937) of the seven reduction plants operating removed the tags from the dried unground meal. A number of tags were found in irregularities in the conveyers or in the driers of reduction plants. Rewards of 50 cents were paid to plant employees for recovering the tags and returning them with information concerning time and place the fish were caught. The great weakness of the method is that sometimes tags are held up for a greater or shorter time in their passage through the plants. When they finally are recovered they are reported from fish captured later than the correct ones. The difficulty has been teated more fully elsewhere (Hart, 1937; 1938b).

A few tags were recovered by the induction detector installed at Nootka (Hart and Tester, 1939), but difficulty was encountered by the fish rolling down the chute instead of sliding.

Through the co-operation of the State fisheries departments of Washington, Oregon, and California, Canadian tags recovered in United States reduction plants have been returned with the pertinent data.

TAGS APPLIED.

During the 1938 season 4,982 tags were inserted in pilchards. The tags were inserted in two series. Two thousand four hundred and eighty-nine were used between July 28th and August 2nd off the coast of Washington and 2,493 were used between September 3rd and 11th in the inlets and off the coast of the north-westerly end of the west coast of Vancouver Island. The details are shown in Table I.

TABLE I.—SUMMARY OF TAGGING, GIVING REFERENCE NUMBERS, DATES, NUMBERS OF TAGS INSERTED, LOCALITY OF RELEASE OF FISH, TECHNIQUE, AND SERIAL NUMBERS OF TAGS USED.

Tagging Reference No.	Date.	No. Tags.	Place Fish released.	Tagging Technique and Serial Nos. of Tags used (P.).
	1938.			
I.	July 28	200	15 mi. S.W. Quillayute R.	Gun, 11001-11200.
II.	July 28	299	10 mi. S.W. Quillayute R.	Knife, 10701-11000.
III.	July 29	498	15 mi. S.W. Destruction Is.	Gun, 10501-10700; knife, 10201-10500.
IV.	July 29	499	12 mi. W.S.W. Destruction Is.	Gun, 10001-10200, 12401-12500; knife, 12201-12400.
V.	Aug. 1	497	10 mi. S.xE. Quillayute R.	Gun, 11301-11400, 11501-11700; knife, 11201-11300, 11401-11500.
VI.	Aug. 2	496	4 mi. S. Quillayute R.	Gun, 11701-11800, 11901-12200; knife, 11801-11900.
VII.	Sept. 3	400	Camp Bay, Nootka Sd.	Gun, 13401-13500, 13701-13800; knife, 13801-13900, 14501-14600.
VIII.	Sept. 5	500	Off Winter Har., Quatsino Sd.	Gun, 13101-13300, 14901-15000; knife, 12701-12800, 13301-13400.
IX.	Sept. 6	199	Koskeemo Har., Quatsino Sd.	Gun, 14201-14300; knife, 12601-12700.
X.	Sept. 6	198	Koprino Har., Quatsino Sd.	Gun, 13901-14000, 14401-14500.
XI.	Sept. 6	200	Kultus Cove, Quatsino Sd.	Gun, 14201-14400, 14701-14800.
XII.	Sept. 8	498	10 mi. S.W. Nootka Lt.	Gun, 12501-12600, 12801-13100, 14001-14100.
XIII.	Sept. 9	298	Off Rlgh Is., Nootka Sd.	Gun, 13601-13700, 14101-14200, 14801-14900.
XIV.	Sept. 11	200	3 mi. E.S.E. Cape Cook	Gun, 13501-13600, 14601-14700.

RECOVERIES.

This report covers the recovery of 344 tags. If the first series of taggings off the Washington coast is considered separately from the second series off Vancouver Island the returns may be summarized in the following way:—

Recoveries of Canadian tags used off the Washington coast in 1938:—

Returns from off the Washington and Oregon coasts—

By Vancouver Island plants	19
By Washington plants	23
By Oregon plants	6

Returns from off the British Columbia coast, all by Canadian plants..... 5

Returns from the California coast by California plants..... 2

Recoveries of Canadian tags used off the coast of Vancouver Island in 1938:—

Returns from off Vancouver Island, all by Canadian plants..... 215

Returns from off the California coast by California plants..... 15

Recoveries of Canadian tags used off the Washington coast in 1937:—

Returns from off Vancouver Island, all by Canadian plants..... 7

Returns from off the Washington and Oregon coasts—

By Vancouver Island plants	3
By Washington plants	1
By Oregon plants	1

Returns from off the California coast by California plants..... 2

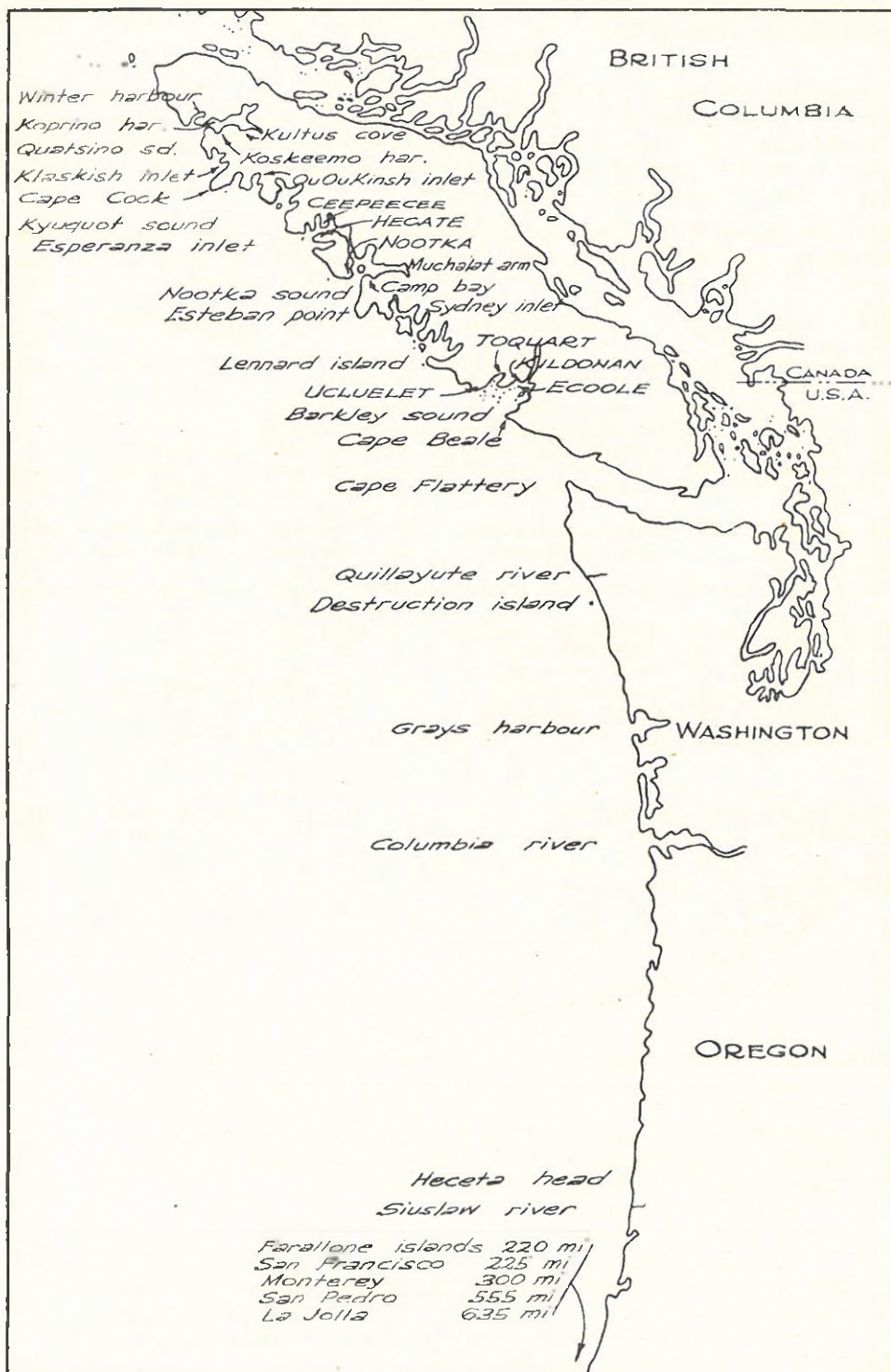
Recoveries of Canadian tags used off the coast of Vancouver Island in 1936:—

Returns from off the Washington and Oregon coasts by Oregon plants..... 1

California tags recovered by Canadian plants..... 41

Oregon tags recovered by Canadian plants..... 3

Total..... 344



RETURNS FROM THE TAGGINGS OF 1938.

The recovery of tags from the tagging of 1938 is shown in detail in Table II.

TABLE II.—RECOVERIES OF CANADIAN 1938 TAGS ACCORDING TO TAGGING AND POLITICAL DIVISION OF RECOVERY.

Tagging No.	British Columbia.	Washington.	Oregon.	California.	Total.	Tags used.	Returns per 1,000 Tags.
First Series—							
I.....	7	3	0	1	11	200	55
II.....	2	0	1	0	3	299	10
III.....	2	4	1	1	8	498	16
IV.....	5	6	1	0	12	499	24
V.....	5	4	3	0	12	497	24
VI.....	3	6	0	0	9	496	18
Second Series—							
VII.....	30	—	—	0	30	400	75
VIII.....	35	—	—	1	36	500	72
IX.....	21	—	—	1	22	199	111
X.....	11	—	—	1	12	198	61
XI.....	22	—	—	1	23	200	115
XII.....	19	—	—	5	24	498	48
XIII.....	48	—	—	4	52	298	174
XIV.....	29	—	—	2	31	200	155
Totals.....	239	23	6	17	285	4,982	—

It is evident from the table and the summary that a much higher proportion of the tags used were returned from the second series of taggings. Several explanations may be offered for this observation. It is possible that the difference is due to some more or less unconscious change in technique, and it has been suggested that a smaller loss in tagging fish in the Vancouver Island inlets as compared with tagging in the unprotected waters off the Washington coast may have led to the difference. Two taggings were completed in outside waters in the second series. One of these did in fact give a very low return (48 per thousand tags), almost comparable with the average for the first series (22 tags per thousand), but the other yielded 155 tags per thousand; so it appears that the difference in mortality resulting from tagging in inlets and open water cannot be held entirely responsible for the difference.

Approximately three times as much pilchards were caught off the west coast of Vancouver Island as were caught off the Washington coast and this might be regarded as an explanation of the returns. However, it must be borne in mind that the Washington coast fish were tagged first and were liable to recapture during the whole season instead of during just the latter part of it as was the case for the Vancouver Island fish. Evidently the difference in the amounts of fish caught in the two main fishing areas cannot in itself account for the differences in the proportions of the tags returned.

A third explanation of the returns is possible. In tagging investigations the number of returns can be expected to be large when the number of fish is small, and small when the number of fish is large. It may be, therefore, that fish were more abundant off the Washington coast than they were in British Columbia waters. The reference to abundance is not to be confused with availability. It is suggested that during the first weeks of August reasonably large amounts of pilchards were off the Washington coast, even although they were comparatively difficult to observe or catch. In September and October, off Vancouver Island, it is suggested that although fish were comparatively easy to observe and catch (i.e., available) they were not present in very large amounts. The abundance of pilchards off the west coast of Vancouver Island is dealt with further in regard to intensity of fishing.

RETURNS FROM TAGGINGS OF 1937 AND 1936.

Fourteen tags from the 1937 tagging were recovered during the 1938 season. Of these, ten were recovered by Canadian plants, one each by Washington and Oregon plants, and two by California plants. The return of year-old tags is in considerable excess of that for former years, as is indicated in Table III. As the ten tags were recovered by plants having a

composite efficiency lower than that of former years it is believed that the increase is real. The catch figures given in the table show that part but not all of the difference between 1938 and the previous year may be accounted for by the larger number of tags used in 1937 and the greater tonnage of fish processed in 1938.

TABLE III.—DATA CONCERNING THE RECOVERIES OF CANADIAN TAGS OUT FOR A YEAR OR MORE.

Season of Tagging.	Season of Recovery.	No. of Tags used.	No. of Canadian Recoveries.	Approximate Canadian catch in Recovery Year.	Total Recoveries.
1935	1936	978	2	38,000	2
1936	1937	2,535	2	48,000	3
1937	1938	6,936	10	52,000	14
1936	1938	2,535	1	52,000	1

During the 1938 season a tag put out in 1936 was recovered. This is the first time a Canadian tag which has been out for two years has been recovered.

All three returns of tags put in by the Oregon Fish Commission were of fish which had been tagged approximately a year ago off Heceta Head and the Siuslaw River.

MOVEMENTS OF PILCHARDS.

BETWEEN CALIFORNIA AND WASHINGTON AND BRITISH COLUMBIA.

Again proof is offered of the movement of pilchards from the waters of southern and central California, where they are called sardines, to the fishing-grounds exploited by Canadian fishermen. Forty-one California tags (Janssen (1939)) were recovered from fish released at various points between the Farallon Islands and La Jolla. All of them had been out for more than six months, many for more than a year, and one for two and one-half years. Of the forty-one tags, fifteen were recovered from fish caught off the Washington coast and twenty-six from the west end of Vancouver Island. Consideration of the efficiencies of the various plants and the amount of fish processed by each does not indicate any significant difference between the concentrations of tags in the fish on the two fishing-grounds.

In the report for the previous year attention was called to the speeds of travel of pilchards on northward and southward migrations. The speed of the fastest movement southward was calculated as 3.5 miles per day, as compared with a northward migration rate of 9.2 miles and an average of 5 miles per day (from Janssen, 1938, data). These data suggested a rapid northward migration in spring and early summer followed by a slower return trip in autumn and winter. This year the southward migration rate for the quickest returns may be calculated as around 7.3 miles per day. Considering this as a minimum estimate it is quite comparable with the 9.2 rate as established for the northward migration in a previous year.

Magnets in California reduction plants were instrumental in recovering seventeen Canadian tags used during 1938 and two tags from the previous season. Two of the seventeen tags originated from fish tagged off the Washington coast as compared with fifteen from fish tagged off the Canadian coast. The difference is greater than would be expected on the basis of chance if the tagged fish from the two northern fishing-grounds were represented in the California waters in numbers proportionate to the number of tags used.

Six Canadian 1938 tags were recovered in San Francisco, five in Monterey, and six in the San Pedro area. Both 1937 tags were returned from San Francisco.

WASHINGTON TO VANCOUVER ISLAND.

Five tags inserted off the Washington coast were reported as being recovered off the west coast of Vancouver Island. It is possible that some of these represent tags which are wrongly reported because of being held up in passing through the reduction machinery. One recovery is probably and another quite possibly explained in this way. However, one return was made by a plant which did not operate on fish caught off the Washington coast

and two other returns give every indication of being valid. These returns taken together provide absolute proof of a movement of pilchards from the Washington coast fishing-grounds to the west end of Vancouver Island during August, in spite of the fact that such a movement was not observed by the fishermen. It is suggested that the north-westerly movement took place too far offshore to be noticed by boats plying between Destruction Island and Vancouver Island reduction plants.

Considering the number of tags returned from each series of taggings from fish captured in the British Columbia grounds, it is apparent that only part of the pilchards which were off the Washington coast moved north to the west coast of Vancouver Island. Certainly not more than five Washington coast tags and possibly not more than three were recovered from Vancouver Island fish. This, compared with the 215 returns from the Vancouver Island taggings, presents a strong case for believing that a comparatively small part of the Washington coast fish moved to the westward. In this connection attention may be drawn to the returns by California plants of the two series of taggings. It is obvious that if the difference in the numbers of returns is to be credited to a splitting of the population in migration the explanation must be extended to account for the presence on California fishing-grounds of more Vancouver Island pilchards than Washington coast fish.

ALONG THE COAST OF VANCOUVER ISLAND.

The movements of pilchards around the coast of Vancouver Island has already been dealt with in a Progress Report (Hart, 1938c). The results are repeated as follows: Several recoveries which are believed to be authentic have been made of tags used in Nootka Sound in each of the following places—Sydney Inlet, Estevan Point, Nootka Sound, Esperanza Inlet, and Kyuquot Sound. Tags inserted off Nootka Light were recovered in considerable numbers in Nootka and Kyuquot Sounds and, to a less extent, at Cape Cook. Tags used at Cape Cook were returned in seven cases from Kyuquot Sound and in smaller numbers from Sydney Inlet, Nootka Sound, Esperanza Inlet, and Klaskish Inlet. Tags applied to pilchards in Quatsino Sound were returned most frequently from Esperanza Inlet and Kyuquot Sound, but other returns believed to be authentic were reported from Lennard Island, Sydney Inlet, Estevan Point, Nootka Sound, Oucoukinsh Inlet, Cape Cook, and Quatsino Sound. Even although in a few cases the apparent diversity of returns may have arisen from the deficiencies of the recovery method, it is evident that movements around the Vancouver Island coast were very general.

Examination of tag returns for days on which five or more tags were recovered by the same plant showed a tendency for the tags to come from one or two taggings. Since many of these tags had been out for two weeks or more, and the fish were recaptured far from the place of tagging, it seems apparent that in spite of the evident mixing of pilchards off the west coast there is a tendency for small groups of fish to stay together.

Although small groups tend to remain together, it is patent that schools break up and the fish in them reach widely separated points. This is amply illustrated by the returns for west coast reduction plants during the 1938 season and possibly even better by the returns of five tags applied at the Muchalat Arm. On January 7th two tags were recovered from pilchards caught at the locality where the fish were originally tagged. On each of January 1st, 12th, and 13th one of these tags was recovered from sardines delivered to California reduction plants.

INTENSITY OF THE FISHERY.

Tag returns may be used to obtain general impressions of the extent of exploited fish populations and of fishing intensity. In general, estimates of populations are likely to be too high and those of fishing intensity correspondingly low, because most of the potential errors tend in that direction.

WASHINGTON COAST FISHERY.

Of the tags used off the Washington coast, nineteen were recovered in British Columbia reduction plants. These may be considered as being recovered from the fish captured off the Washington coast after half the tags were applied; that is, from approximately 11,000 tons. Calculations based upon the efficiencies of the different reduction plants in recovering tags and upon the tonnages handled by each show that the number of tags actually recovered is rather less than 80 per cent. of the number entering the plant. In other words, not nineteen

but twenty-four or twenty-five tagged fish were caught by the fishermen. If the tagged fish do not behave differently from other fish this means that Canadian fishermen caught 24.5/2,489 or about 1 per cent. of the fish on the grounds, and that the total amount of fish would be in the neighbourhood of 1,100,000 tons. British Columbia and Washington boats together caught some 40,000 tons of pilchards off the Washington coast, which, according to these calculations, constitutes some 3½ per cent. of the fish on the grounds. This does not take into consideration the take by Oregon fishermen who fished the same grounds to a considerable extent.

Similar calculations based on the recovery of Canadian tags by reduction plants in the State of Washington give results which are in remarkably close agreement with those based upon British Columbia recoveries. The Washington calculations (Shuman, 1939) are based upon twenty-three tags recovered by magnets having a composite recovery efficiency of 43.4 per cent. The fishermen may, accordingly, be calculated to have taken fifty-three tags in their 26,500 (*circa.*) tons of fish. This indicates a population of $26,500 \times 2,489/53$, or between 1,200,000 and 1,300,000 tons.

VANCOUVER ISLAND FISHERY.

Some 30,000 tons of pilchards were caught after half of the tags of the second series had been inserted. From these fish 215 tags were recovered during the season by British Columbia reduction plants. Consideration of the efficiencies of and tonnages handled by the various plants indicates a composite efficiency for the recovery of these tags of somewhat less than 60 per cent. In other words, between 372 and 373 tagged fish entered the reduction plants to lead to the recovery of the 215 tags. From this the total population off Vancouver Island may be calculated as $30,000 \times 2,493/372$, or 200,000 tons. This value is calculated from the returns of all the Canadian plants and is, consequently, affected unduly by any error which might apply to one plant only. To avoid affecting the results by error of this kind a "median" value was obtained by averaging the total populations as calculated from the two plants which gave the least extreme values. This gave a result of approximately 225,000 tons. Using this last figure as a basis for calculation and considering the total catch of pilchards off Vancouver Island as 38,000 tons, the intensity of the fishery may be calculated as $38,000 \times 100/225,000$, or 17 per cent. That is, Canadian pilchard fishermen took 17 per cent. of the fish on the grounds. As already pointed out, this is a minimum estimate.

In foregoing discussions it has been assumed that because some of the fish from the Washington coast are known to have moved to Vancouver Island waters that all of the Vancouver Island fish originated from that source. The number of Washington coast tags (one to five, probably three or four) as compared with Vancouver Island tags is too small to allow that explanation without qualification. It would appear that either the movement of fish from the Washington coast to Vancouver Island started before tagging was begun, or that a comparatively few migrants were joined by a larger body of untagged fish before the Vancouver Island fishery started.

RECOVERY OF CALIFORNIA TAGS.

In the report on pilchard-tagging in the 1937 season (Hart, 1938) a calculation was made of the number of California tags recovered per 1,000 tons of pilchards handled by each plant, and this was compared with a corresponding figure calculated for Californian recoveries of their own tags. It was found that on the average 0.44 California tags were recovered from each 1,000 tons of pilchards during the 1937 season. A corresponding calculation for the 1938 season yields the result 0.79 tags per 1,000 tons of fish processed. This figure is directly comparable with that of the previous year and the significance of the difference is attested by the fact that when the individual plants are considered separately the returns in 1938 are higher in all cases. (When these figures are corrected for plant efficiencies they give the results—1937, 0.69; 1938, 1.2.) A complete explanation of the change is not readily obtained. No doubt the increased number of California insertions is largely responsible for much of the change, since twenty-four of the forty-one California recoveries (0.46 tags per 1,000 tons uncorrected, 0.68 corrected) were tags available for capture during the previous year and the remainder consists of new tags.

In view of the number of unknown factors involved, the comparison between British Columbia and California returns does not now appear in order.

TECHNIQUE.

Experiments have been made to test the efficiency of some of the operations involved in tagging programmes and some of the recoveries appear suggestive in this connection.

The general procedure in making an attempt to assess the relative mortalities caused by tagging-gun and tagging-knife has been described under "Methods." The results are shown in Table IV. The figures in the last row indicate a somewhat higher efficiency for the technique involving use of the gun, but it is evident from a more detailed examination of the table comparing only taggings in which both techniques were used that the difference is not real. An examination of the return from California shows the following:—

	Gun.	Knife.
First series.....	1	1
Second series.....	14	1

which superficially appears significant. However, examination of the results shows that of the fourteen second series gun-inserted tags only one was of a fish tagged at a time when the knife was used. It is believed that no significant differences result from the employment of the two tagging methods and, consequently, the more convenient method may be employed.

TABLE IV.—COMPARISON OF ALL RETURNS FROM 1938 TAGGINGS BY GUN AND KNIFE.

FIRST SERIES.					SECOND SERIES.				
Tagging No.	Gun.		Knife.		Tagging No.	Gun.		Knife.	
	Tags used.	Tags recovered.	Tags used.	Tags recovered.		Tags used.	Tags recovered.	Tags used.	Tags recovered.
I.	200	11	0	—	VII.	200	17	200	13
II.	0	—	299	3	VIII.	300	22	200	14
III.	198	1	300	7	IX.	99	7	100	15
IV.	299	9	200	3	X.	198	12	0	—
V.	297	5	200	7	XI.	200	23	0	—
VI.	396	7	100	2	XII.	498	24	0	—
					XIII.	298	52	0	—
					XIV.	200	31	0	—
Totals.....	1,390	33	1,099	22	.....	1,993	188	500	42
Tags recovered per 1,000 used	.....	24	.....	20	.....	.....	94	.....	84

Two pilchards tagged by gun on September 9th were recovered on November 30th by Dr. A. L. Tester, operating an induction detector at Nootka. They showed no sign of permanent injury and the wounds through which the tag had been inserted were completely healed, distinguishable only as very small scars.

The tags used in 1937 were inserted in twenty-two lots, of which four yielded no recoveries. Of the fourteen 1937 tags recovered during the current year none came from those four taggings. This result is not of high significance, but it may indicate that certain taggings are not productive of returns owing to unperceived peculiarities of the conditions under which tagging is carried out.

The results of an examination into the efficiency of different British Columbia plants in recovering pilchard tags has been published elsewhere (Hart, 1938a). They showed that efficiencies ranged from 34 to 89 per cent. and that tags might be recovered as late as forty-five days after entering the plant, although 78 per cent. of the tags recovered were recorded within two days of that time. In some cases when two tests were made there was considerable difference in the results of tests on the same plant. It may be noted here that a late tag recovered from the Ceepeecee plant raises the figure for its efficiency in tag recovery to 62 per cent.

ACKNOWLEDGMENTS.

Once again the pilchard-tagging work has enjoyed the hearty co-operation of many of those connected with the fishing industry. Firms operating reduction plants have facilitated

the installation of recovery magnets in their plants and the crews have been active in recovering tags and returning them for identification.

Mr. L. Quickenden again has carried out the work of tagging. Grateful acknowledgment is made of his help and that of the seine-boat and tender skippers with whom he worked—Captains John Kasulandish, V. Mercer, John Dale, and Gordon Wilks.

The co-operation of officials in California, Oregon, and Washington in exchanging tagging information and in returning tags is much appreciated.

The research has been carried out under a joint arrangement between the Fisheries Research Board of Canada and the Provincial Fisheries Department of British Columbia. Acknowledgment is made of the financial assistance of both and of the interest and support of the respective executive officers concerned, Dr. W. A. Clemens and Mr. George J. Alexander.

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