Further Developments in the Tagging of the Pacific Herring, *Clupea pallasii*[1]).

By

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A previous report in the *Journal du Conseil* (Rounsefell, and Dahlgren, 1933)[2]) described an experiment carried on at Holmes Harbor, Washington, in developing a method of tagging herring. Since the publication of that report an extensive tagging programme has been carried on in south-eastern Alaska. It is the purpose of this paper to note the results accomplished during the ensuing years, and to report a new electrical method for the recovery of the tagged individuals. Details of the method of tagging and of the method of magnetic recovery of tags were described in the former article.

These tagging experiments have had a two-fold purpose. First, by tracing the migration of the tagged individuals, to delineate the areas inhabited by each major population of herring, and to obtain thereby a measure of the degree of intermingling which occurs between stocks. The existence of these separate races had already been established (Rounsefell and Dahlgren, 1935)[3]). Second, to obtain a measure of the intensity of the fishery by considering the percentage recovery of tags.

Difficulties encountered in the use of the magnet recovery system.

The accurate tracing of migration routes by the use of magnet-recovered tags presents certain difficulties which have limited its value. First, the method of handling the raw fish often precludes an accurate statement of the area from which the tag has been returned, since the fish are conveyed from the hold of the vessel to a large tank and are

[1]) Dr. George A. Rounsefell, who had been in charge of the herring work, was transferred to another problem in July 1934. His part in the development of this tagging programme is hereby gratefully acknowledged.

[2]) Rounsefell, George A., and Edwin H. Dahlgren. 1933. Tagging experiments on the Pacific herring. Journ. du Cons. Perm. Intern. Explor. Mer., vol. VIII, no. 3, pp. 371-384, 6 figs. Copenhague.

[3]) Rounsefell, George A., and Edwin H. Dahlgren. 1935. Races of herring, *Clupea pallasii* in south eastern Alaska. Bull., U. S. Bur. Fish., vol. XLVIII, 1935, pp. 119-141, 10 figs.

stored there until sufficient fish have accumulated to begin reduction operations. Consequently, when boats from different areas return to the shore station during one "run" of the reduction unit, it is virtually impossible to state from which load, and hence from which area, the tag was taken.

Further, there is known to be a lag between the taking of the tagged individual by the fishermen and the recovery of the tag in the plant by the electromagnet. This has been demonstrated by placing fish, bearing test tags, directly in the holds of the vessels being unloaded, to find that although most of the tags were reported recovered from the magnet within two days, in occasional instances they were reported as much as three weeks later. This delay may be due to any one of several causes. One of these is "sticking" in the drier, a rotating steel drum about fifty feet long and six feet in diameter through which the damp meal is passed with an intense oil flame playing on one end so that the hot gasses surrounding the meal evaporate it to dryness. There is a tendency for meal to burn on the shell of this drum, and it is believed that tags become lodged in this material, being held there for a time before continuing through the drier. Other possible sources of delay are the conveyors which carry the dry meal to the magnet. Each of these has a "dead" end in which meal accumulates, and tags, being heavier than the dry meal, occasionally become trapped in such a place for a time before finding their way over the magnet.

In the summary of results given in the following paragraphs it is to be understood that there are discrepancies in many cases between the reported locality of recovery and the actual area from which the fish were taken, for the reasons mentioned above. In special cases, however, this error does not enter. For instance, the first fishing operations of the season for the past three years have been concentrated in the Iphigenia Bay region; the entire fleet fishes this area during the first week to ten days of the season. In 1934 eleven recoveries, and in 1935 eighty-six recoveries of tags affixed at Sitka were made at Warren Channel before the fleet had operated in any other area, giving absolute proof that the Ommaney population mingles with the Craigh population in this region. (See Figure 1). Of course, as soon as the fishing has expanded to include more than the one area, it becomes impossible to segregate the tags accurately. Consequently it is hazardous to state whether the Craig population migrates across to Cape Ommaney, although the 1935 experiment, as mentioned later, has thrown some light on this problem.

It became evident that a more satisfactory means of recovering the tags would have to be developed before the success of this tagging method could be assured. The most desirable recovery, of course, would be the isolation of the individual bearing the tag as it was being discharged from the vessel. With upward of fifty million fish taken each year from a single plant, visual examination is obviously impossible, even if a visible tag (such as the opercle tag described in a former article) were to be used. Since the belly tag is far superior to

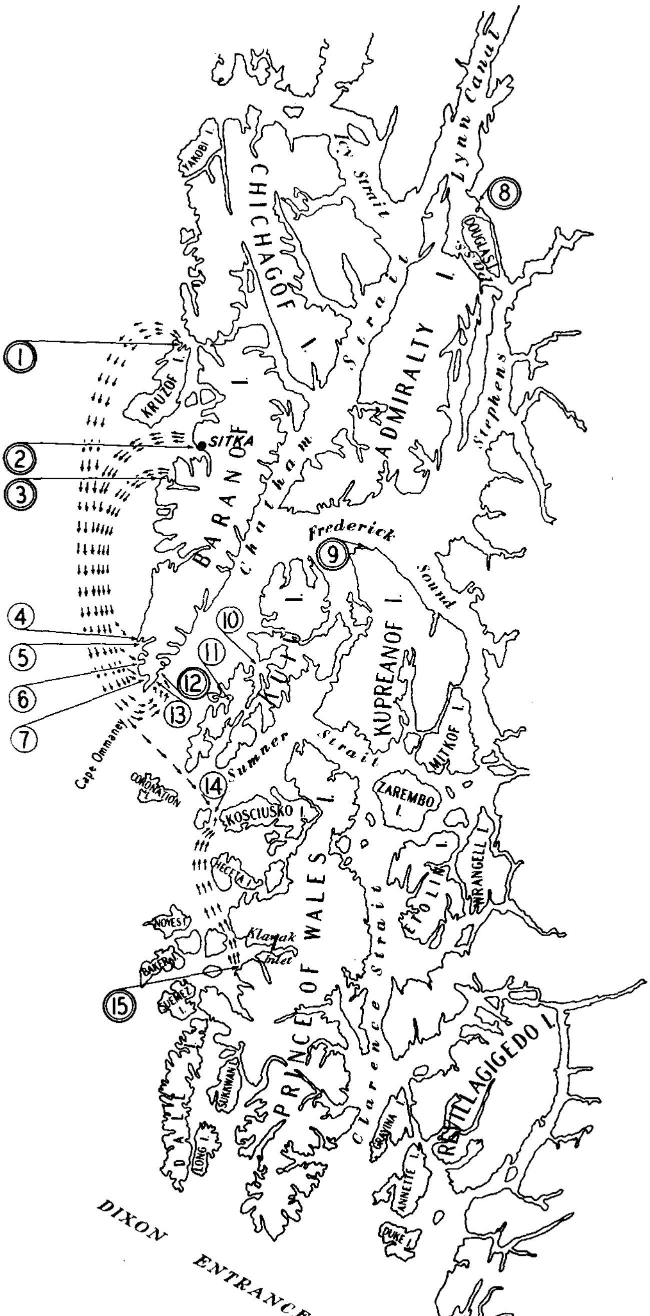

Figure 1.
Map of south-eastern Alaska, with arrows showing migration routes traced by tagging experiments. Double circles indicate tagging locations.

1. Kalinin Bay
2. Jamestown Bay
3. Redoubt Bay
4. Redfish Bay
5. Big Branch Bay
6. Puffin Bay
7. Larch Bay
8. Auke Bay
9. Cape Bendel
10. Tebenkof Bay
11. Port Malmesbury
12. Port Conclusion
13. Port Alexander
14. Warren Channel
15. Craig

the opercle type, as the experiments described below demonstrate, it became necessary to evolve some method for detecting the belly tag while still in the body cavity of the fish.

Development of electronic detector.

The problem of developing an electrical device capable of detecting the presence of a piece of metal as small as a tag was presented to Doctor C. E. Magnusson, Professor of Electrical Engineering at the University of Washington. On his recommendation, two graduate students were engaged to develop a device capable of accomplishing this. With the cooperation of Doctor Magnusson as well as other members of the faculty and with the use of University equipment, these men have designed and developed the instrument to its present form. Before describing the device and its operation, however, the results of the tagging to date will be briefly summarized.

Procedure used in tagging.

Certain changes in the technique of tagging have been made since the publication of the first report. The livebox, as used in the field, measures ten feet in width by twenty feet in length, with a three-foot depth, being partitioned off so as to leave two-thirds of the volume in one end. The fish, which are obtained either by beach or purse seine, are permitted to swim into the large end of the box by holding the cork line over the submerged edge, and "rolling" the fish into it. The smaller end of the box is used to hold the tagged individuals, so that they may be released in schools instead of singly.

In tagging, fish are dipped from the livebox into a large galvanized tub, kept filled with frequently changed water. Two men are employed at the tagging. The one man grasps a fish from the tub, and holds it firmly in his two hands while the second operator makes the incision and inserts the tag. The tagged fish is then dropped back into the box. By this method it is possible for two operators to tag three hundred to four hundred fish in an hour.

Summary of tagging experiments.

As stated in the previous report, out of a total of 3,487 herring tagged and released in 1932 (see Table 1), the recovery of ten tags from the 1,034 individuals tagged and released July 27 at Port Conclusion, gave the first real promise of success in tagging the herring. This experiment proved conclusively not only that the fish would survive the tagging, but that tag recovery by means of magnets was possible. It also gave evidence that the "inside" fish, i. e., fish taken inside Cape Ommaney, are of the same population as those taken outside the Cape. This tentatively answered the question of the homogeneity of the populations in the Cape Ommaney region.

In the same year 824 opercle tags and 996 belly tags were affixed to herring at Cape Bendel, 65 miles north of Cape Ommaney, in

Table 1.

1932 Tagging and recoveries.

Location of Tagging	Type of Tag	Number Tagged	Date	Number of tags recovered with reported locality of recapture: Inside Cape Ommaney	Outside Cape Ommaney	Total Recoveries	Percentage Recovery
Port Conclusion	Pure nickel opercle type	1,034	7/27/32	1	9	10	1.0
		633	8/ 3/32	0	0	0	
	Total	1,667					
Cape Bendel	Pure nickel opercle type	824	8/17/32	0	0	0	
	Pure nickel belly type	996	8/17/32	0	0	0	
	Total	1,820					

Table 2.

1933 Tagging and recoveries.

(Including those recovered in 1934).

Location of Tagging	Type of Tag	Number Tagged	Date	Number of tags recovered with reported locality of recapture: Vicinity Cape Ommaney		Unknown		Total Recoveries		Percentage Recovery	
				1933	1934	1933	1934	1933	1934	1933	1934
Sitka	Pure nickel belly type	2,499	4/21-25/33	81	2	20	4[1])	101	6	4.0	0.2
	Pure nickel opercle type	1,470	4/22-23/33	7	0	0	0	7	0	0.5	0.0
Juneau	Pure nickel belly type	800	5/3-5/33	0	0	0	0	0	0		
	Pure nickel opercle type	772	5/4-5/33	0	0	0	0	0	0		

Frederick Sound. None of these tags was recovered. This negative evidence indicates that there was no intermingling betweeen this and the Cape Ommaney populations.

Encouraged by the success of the Port Conclusion experiment, tagging was continued in the spring of 1933. Tags were affixed to spawners at Jamestown Bay (near Sitka, west coast of Baranof Island) and at Auke Bay (Juneau spawning area). The recovery of 4 % of the belly tags, and ½ or 1 % of the opercle tags affixed at Jamestown Bay (see Table 2), gave the first absolute evidence of migration between the spring spawning area and the summer feeding grounds. These fish were taken at Cape Ommaney, approximately seventy miles from Sitka. This experiment proved conclusively that the belly

[1]) Three of these tags were recovered during first day's operation, indicating that they were held over in the plant from the previous year.

tag was superior to the opercle type. No recoveries were made of the previous year's tags, nor were any of those from the Juneau experiment retaken. The latter was to be expected, in the light of the racial findings made by biometrical methods (Rounsefell and Dahlgren, 1935).

Economic conditions had caused a decrease in the number of boats operating in 1933. The resulting lack of competition between gear led to a concentration of the entire fleet in the lower Chatham Strait (Cape Ommaney, Iphigenia Bay) region. Very few fish were taken from upper Chatham Strait, Icy Strait, or Stephens Passage, which are within range of Auke Bay. The negative evidence given by lack of recovery from the Cape Bendel experiment in 1932, or from the Juneau tagging in 1933, assumes added significance in the light of the large recovery of tags from later experiments, and it may be

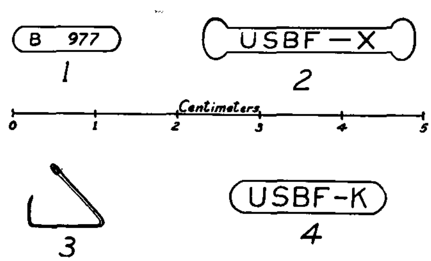

Figure 2. Types of tags used in the experiments, drawn to scale: (1) Pure nickel belly type, (2) Dumb-bell-shaped nickel-plated steel belly type, (3) Opercle type, (4) Nickel-plated steel belly type.

stated definitely that no mixture of either the Juneau or Cape Bendel populations and those of Cape Ommaney took place.

During the 1934 season, seven tags affixed in 1933 were recovered. Of these, three were taken during the first "run" of one plant, indicating that they were not taken by the fishermen during the 1934 season, but had been held over from the previous year in the machinery. The significance of this small recovery will be discussed later.

In 1934 the tagging experiments were expanded. In order to obtain a more adequate sample from which to calculate percentage recoveries, 13,167 individuals were tagged at Jamestown Bay, Sitka. In addition, an experiment was started at Klawak Inlet, Craig, on the west coast of Prince of Wales Island, in which 8,394 individuals were tagged.

A new type of tag was used for the first time in these experiments, i. e., a nickel-plated steel tag measuring 19 mm. in length, 4 mm. in width, and 1 mm. in thickness. (See Figure 2.) In the previous experiments a smaller non-corrosive pure nickel tag had been used, which measured 13 mm. by 3 mm. by 0.7 mm. Nickel, in addition to being expensive, has the disadvantage of possessing only a fraction of the magnetic properties of iron or steel. On account of the lack of oxygen, it was concluded that the ferrous metal would not corrode

Table 3.

1934 Tagging and recoveries.

(Including those recovered in 1935).

Location of Tagging	Type of Tag	Series	Number Tagged	Date	Number of tags recovered with reported locality of recapture: Warren Channel 1934	Warren Channel 1935	Warren Channel or Cape Ommaney 1934	Warren Channel or Cape Ommaney 1935	Cape Ommaney 1934	Cape Ommaney 1935	Tebenkof or Cape Ommaney 1934	Tebenkof or Cape Ommaney 1935	Tebenkof[2]) Bay 1934	Tebenkof[2]) Bay 1935	Unknown 1934	Unknown 1935	Totals Recoveries 1934	Totals Recoveries 1935	Percentage Recovery 1934	Percentage Recovery 1935
	Nickel-plated steel belly type	A	2,484	3/24/34	28	7	1	3	18	6	2	0	0	0	0	10	49	26	2.0	1.0
		B	2,467	3/24/34	27	6	2	5	24	9	0	0	0	0	0	6	53	26	2.1	1.1
		C	2,488	3/26/34	23	11	2	5	20	3	1	0	1	0	0	11	47	30	1.9	1.2
Craig		Totals	7,399		78	24	5	13	62	18	3	0	1	0	0	27	149	82	2.0	1.1
	Pure nickel belly type		995	3/25/34	4	0	0	0	2	0	0	0	0	0	0	0	6	0	0.6	0.0
	Nickel-plated steel belly type	D	2,432	4/2/34	5	2	0	5	117	18	6	0	2	0	2	26	132	51	5.4	2.1
		E[1])	2,439	4/7-9/34	3	4	0	2	78	12	4	0	2	0	2	15	89	33	3.6	1.4
		H	2,425	4/5/34	1	1	4	2	103	16	8	0	1	0	0	14	117	33	4.8	1.4
		J	2,441	4/7/34	4	2	0	4	95	15	5	0	2	0	0	32	106	53	4.3	2.2
Sitka		K	1,232	4/9/34	1	2	0	1	35	5	1	0	0	0	1	20	38	28	3.1	2.3
		Totals	10,969		14	11	4	14	428	66	24	0	7	0	5	107	482	198	4.4	1.8
	Pure nickel belly type		2,198	4/7-9/34	0	0	1	0	35	3	1	0	0	0	1	3	38	6	1.7	0.3

[1]) Not nickel-plated.
[2]) Recoveries from this area considered doubtful, since the Cape Ommaney region was being fished at the same time, and the tags reported probably were held over in the machinery.

within the body cavity of the fish. All except one series of these steel tags were nickel-plated, however, in order to reduce any possibility of corrosion, and because the process of plating insures a clean tag, and renders the distinguishing characters more legible.

In order further to reduce the cost of the tags, they were stamped with identifying characters instead of serial numbering, each lot of 2,500 bearing the same series letter or number. Since 2,500 can be applied in a day, such a system does not confuse the interpretation of the data.

Along with the 7,399 steel tags, 995 of the pure nickel tags were affixed at Craig; 10,969 steel tags and 2,198 of pure nickel were applied at Sitka. The percentage recovery of these two types of tags has given a measure of their relative efficiencies.

As expected, there was no corrosion of these steel tags, even those taken a year and a half later appearing as bright as when first made. Those of the series "E", which were not nickel-plated, discoloured, showing a greyish-black appearance which, however, was not to be confused with ordinary rust.

The recovery of 0.6 % of the pure nickel tags affixed at Craig, compared to 2.0 % of the nickel-plated iron tags from this same experiment, and the recovery of 1.7 % of the pure nickel tags from Sitka, compared to 4.4 % of the nickel-plated iron tags from this experiment, (see Table 3) definitely proved the latter to be much more efficient. The reason for the greater recovery of the iron tags probably lies in the greater permeability of steel, which has approximately ten times the magnetic properties possessed by nickel, and in the increased size, which not only makes their attraction to the magnet more positive, but makes for greater visibility to the operator who removes them from the magnet.

The recovery, during the 1935 season, of 82 (1.1 %) of the steel tags applied at Craig in 1934, and, during 1935, of 198 (1.8 %) of the steel tags affixed at Sitka in 1934, was not as high a percentage recovery as might be expected in view of the much higher percentage recovery of the 1935 tags. The difference in the percentage recovery between two seasons, taking into consideration the percentage taken of the second year's tags, gives an estimate of the natural mortality which occurs during that time. Until more reliable recovery data are available, however, no attempt will be made to evaluate the natural mortality.

In 1935, tagging was again carried on at Craig and at Sitka. As in the 1934 experiment, a large number of individuals were tagged, in order to obtain more reliable data on mortality. In this experiment, 13,008 herring were tagged at Klawak Inlet, off Craig, and 20,157 at Jamestown Bay, Sitka. In addition, 5,141 individuals were tagged at Kalinin Bay, Salisbury Sound, about 25 miles north, and 2,613 at Redoubt Bay, 15 miles south of Sitka.

Again a new type of tag was used, a steel tag with a "dumb-bell" shape, measuring 26 mm. in legth, 1 mm. in thickness, having a shank

1935 Tagging and recoveries.

Location of Tagging	Type of Tag	Series	Number Tagged	Date	Number of tags recovered with reported locality of capture: Warren Channel	Warren Channel or Cape Ommaney	Cape Ommaney	Tenakee[3]) or Cape Ommaney	Unknown	Total Recoveries	Percentage Recovery
Craig	Nickel-plated steel belly type	1	2,505	3/19/35	17	10	4	0	17	48	1.9
		2	2,508	3/20/35	18	8	6	0	18	50	2.0
		3	2,500	3/22/35	18	20	10	0	31	79	3.2
		4	2,449	3/23/35	7	13	5	0	31	56	2.3
		Totals	9,962		60	51	25	0	97	233	2.3
	Dumb-bell-shaped nickel-plated steel belly type	1	1,027	3/20/35	2	2	2	0	2	8	0.8
		2	1,019	3/22/35	9	4	3	0	8	24	2.4
		3	1,000	3/23/35	3	4	1	0	10	18	1.8
		Totals	3,046		14	10	6	0	20	50	1.6
Sitka	Nickel-plated steel belly type	5	2,471	3/28/35	5	12	98	3	96	214	8.7
		6	2,473	3/29/35	12	10	99	1	80	202	8.2
		7	2,484	3/30/35	3	4	44	2	34	87	3.5
		8	2,550	3/30/35	5	11	63	4	78	161	6.3
		0	2,552	3/31/35	12	17	102	7	90	228	8.9
		Z	2,594	4/1/35	11	14	96	1	101	223	8.6
		S[1])	2,525	4/3/35	4	8	66	3	74	155	6.1
		T[2])	2,616	4/4/35	2	3	64	4	63	136	5.2
		U[3])	2,613	4/5/35	10	10	105	4	103	232	8.9
		Totals	22,878		64	89	737	29	719	1,638	7.2
	Dumb-bell-shaped nickel-plated steel belly type	4	1,004	3/29/35	9	7	35	1	38	90	9.0
		5	1,010	4/1/35	4	6	30	3	26	69	6.8
		6	996	4/1/35	4	3	37	0	31	75	7.5
		7	1,008	4/1/35	3	4	45	1	27	80	7.9
		0	1,015	4/2/35	2	4	43	2	37	88	8.7
		Totals	5,033		22	24	190	7	159	402	8.0

[1]) Tagged at Kalinin Bay.
[2]) Tagged at Redoubt Bay.
[3]) Tenakee recoveries considered doubtful, since the Cape Ommaney region was fished at the same time, and the tags probably were held over in the machinery.

20 mm. long by 2.8 mm. wide, and with bulbous ends 5.4 mm. in width. The new type, which is 7 mm. longer than the others, was used so as to have an increased length of metal, since this increase gives the newly developed electronic device a much greater probability of detection. The shank of this tag was reduced in size so as not to increase the weight greatly, and the bulbous ends were used to prevent the tag from working out of the fish as easily as would be the case if they were as narrow as the shank of the tag.

The recovery of 2.3 % of the plain-type tags, compared to 1.6 % of the dumb-bell-shaped tags from the Craig experiment, and 7.2 % of the plain type compared to 8.0 % of the dumb-bell-shaped tags from the Sitka tagging, (see Table 4) shows no difference in the efficiency of the two types. Apparently the increase in length of the tag caused no additional mortality due to tagging.

The recovery of the tags affixed at Kalinin Bay and at Redoubt Bay showed that these populations intermingled with the Jamestown Bay population on the feeding grounds. The spawning area on the west coast of Baranof Island extends from above the upper end of Kruzof Island on the north to below Redfish Bay on the south — a distance of approximately 60 miles — and spawning occurs on suitable grounds throughout this area. The spawning varies from season to season so that areas which in one year are heavily spawned show very light spawning the following year. This fact, coupled with tagging returns from the spawning areas mentioned, leads to the theory that the entire coastline is inhabited by one stock of herring, which migrates to Cape Ommaney (with occasional strays going across to Iphigenia Bay) during the feeding season, to return again to this area for spawning the following spring. A more extensive tagging to include the areas south of Redoubt Bay as far as Redfish Bay will check this theory.

Estimates of mortality.

There has always been a question as to how large a percentage of the population is taken by the fishery. The popular belief has been that only an immeasurable part is caught, and that the decline in abundance observed in certain intensively fished districts has been due entirely to the emigration of the herring from that area.

Assuming that the tagged fish are distributed with the remainder of the population in a random manner (which appears to be the case, from the fact that tags are returned from the various separate markings throughout a greater part of the season), then the percentage recovery of tags gives a measure of the percentage of the total population taken. The figures herein given are admittedly in error, and represent the absolute minima of imposed mortality. There are three known sources of error which, at present, cannot be evaluated. First, there is probably a mortality caused by the tagging; second, there may be a loss of the tags by their working out of the herring in life; and third, there is a failure to obtain all the tags recovered by the fishermen, due to the inefficiency of the magnets, the loss of tags to souvenir hunters, and the failure of some of the plant operators to return recovered tags. Each of these factors, of course, reduces the percentage recovery.

Without considering these sources of error, however, it is clearly evident that the fishery takes an appreciable toll from the populations in the more intensively fished areas. That this is the case in the Cape Ommaney fishery is evidenced by the recovery of 4 % of the Sitka tags in 1933, 4.4 % in 1934, and 7.2 % in 1935. The second main population from which the fishery is drawing is that which spawns at Craig. For this fishery, a 2.0 % return in 1934, and 2.3 % in 1935 indicates that it is not as intensively fished as is the Sitka population. This, too, appears reasonable from the fact that the Warren Channel area is fished intensively only during the first two or three weeks of the season, after which time these grounds are abandoned for more favourable areas. Consequently, it is only during a fifth of the fishing season that this population is subject to the inroads of the fleet, whereas the Cape Ommaney district is fished during practically all the rest of the four month open period.

Certain of the plants, on account of more efficient magnet installations and greater willingness to cooperate in the collection of tags, are known to give a more reliable return than the others. Basing the 1934 recoveries on four of the seven plants operated, it is found that these plants returned 341 of the Sitka tags, and 103 of the Craig series. Since these four plants took 55 % of the total season's catch, it is estimated that, had the other plants returned as large a proportion of tags as did those mentioned, 5.7 % of the Sitka tags and 2.5 % of the Craig tags would have been returned. On this same basis five out of the eight plants operating in 1935 returned 1,312 plain and 323 dumb-bell-shaped tags from the Sitka experiment, and 175 plain and 38 of the dumb-bell type from the Craig experiment. Since these plants took 64 % of the total catch for the season, then 9.0 % of the plain and 10 % of the dumb-bell type from the Sitka tagging; and 2.7 % of the plain and 1.9 % of the dumb-bell type from the Craig experiment should have been returned. While these figures are, at best, only estimates of the percentage mortality imposed on the population by the fishery, they are doubtless more indicative of the actual percentage taken than are those given in the tables.

The perfection of the electronic device, discussed in the following paragraphs, to the point where it will recover all the tags from the fish searched, will permit an accurate estimate of the percentage taken by the fishermen, together with a measure of the validity of that estimate, based on the variation between the number of tags per load throughout the season. If an adequate sample of the spawning population is tagged, and an estimate of the mortality caused by tagging and the loss of tags by the fish can be made, then statistically reliable figures will be available of the mortality imposed by the fishery. An estimate, too, of the total numbers of fish in a given population will also be available, based on the return of tags per barrel.

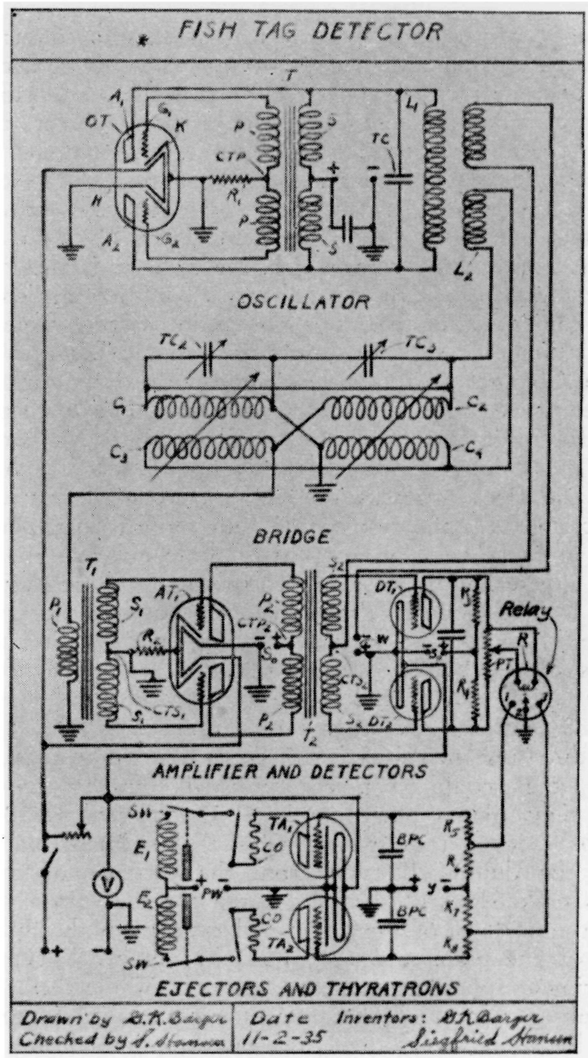

Figure 3. Wiring diagram of the electronic tag-detector circuit.

Description of the electronic tag-detector.

The operation of this device is dependent on an elaboration of a tuned bridge circuit. (See Figure 3.) Two sets of paired coils are so connected and arranged that their respective electro-magnetic fields are in balanced opposition to each other. Consequently, current passing through the one pair is neutralized by the current passing through the other. As a result, in the normal, balanced condition the current potential passing from these coils into the amplifier and detectors is neutralized and effectively cancelled out, so that the normal input approaches zero.

It is characteristic of coils, however, that changing them in any of several ways changes their electro-magnetic field. Thus, if a core of metal is placed through the centre of a coil, the change in the inductance of that coil can be measured by an ordinary instrument.

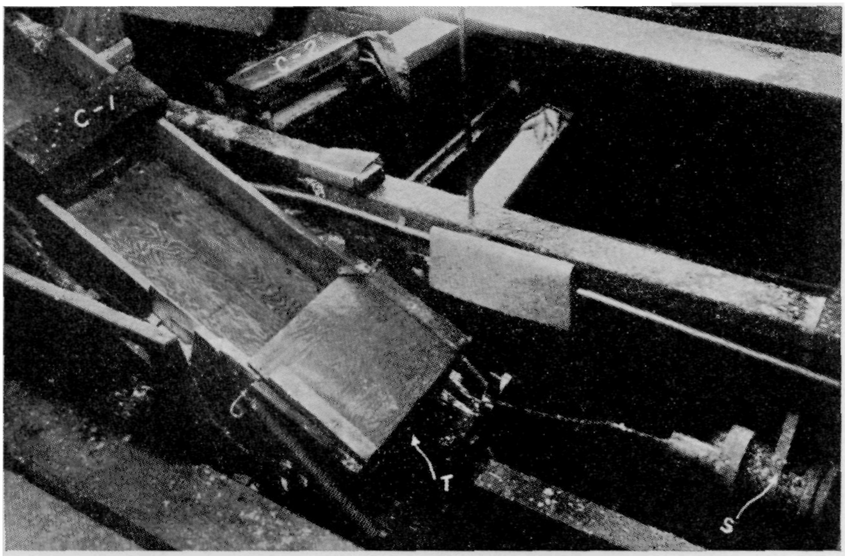

Figure 4. The actual installation of the detector apparatus in the field. The presence of a metal tag passing through the core of the encased coil-pair C-1 transmits an impulse through wires carried in the pipe to the unit, which is mounted about fifteen feet distant. The power surge developed in the set operates the solenoid coil S, releasing the trap door T, which is closed by the springs shown, thus boxing off a part of the chute. The flow of fish is then cut off. The fish held in the box are passed through the coil a few at a time until the tag again activates the unit, which indicates the presence of the metal, enabling the operator to select the tagged individual. The trap is then reset, the unit is again ready for operation, and the flow of fish continues. The balancing coil-pair C-2 is also shown.

This principle, made much more sensitive by the use of paired coils in tuned opposition, and by amplifying the impulse before detecting it, has made it possible to detect the metal tag, weighing only 0.45 grammes, passing through a coil with a 5″ × 20″ core area.

To explain in another way, the presence of a metal tag in the field of one of the sets of paired coils destroys the balance which has been set up. This "unbalance" is amplified and detected by the unit, which converts this impulse, through a sensitive relay and the use of gaseous control tubes, to control the necessary power circuit. This control circuit is used to operate a mechanical device for isolating the tagged individual. In the present set-up, this is so arranged as to hold, in the chute on which the fish are carried, the individual bearing the tag, along with such others as may be in the field at the time of detection. It is then necessary only to separate the

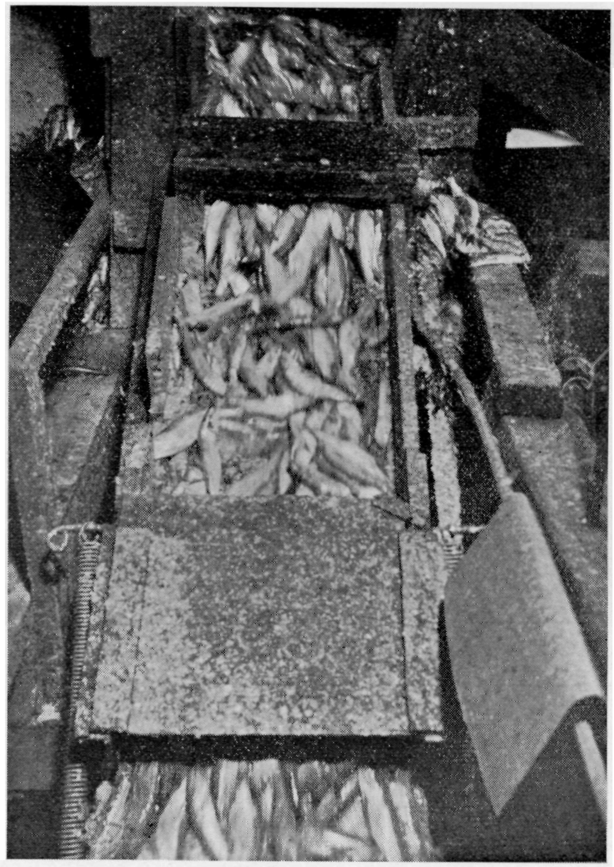

Figure 5. Herring passing through the coil, being mechanically searched for tags. The assembly is mounted so that the fish drop from the chute directly into the storage tank. Approximately 5,000 fish per minute pass through the coil.

individual bearing the tag from the others ejected, by passing the lot of fish, a few at a time, through the coils again, in which case the same unbalance occurs, the same series of impulses follow, and the individual bearing the tag is isolated.

The design of an instrument capable of doing this in the laboratory is comparatively simple. The application to field conditions, however, coupled with the fact that the centre of the coils must be of a size to permit the passing of 5,000 fish a minute, has been much more difficult. The detector must be sensitive enough to register a change of one part in many thousands — a change so small that extreme sensitivity must be maintained in all parts of the circuit.

More detailed information on the design of the detector, and of the mechanics of installation, are available through the Bureau of Fisheries Laboratory at 2725 Montlake Boulevard, Seattle, Washington.

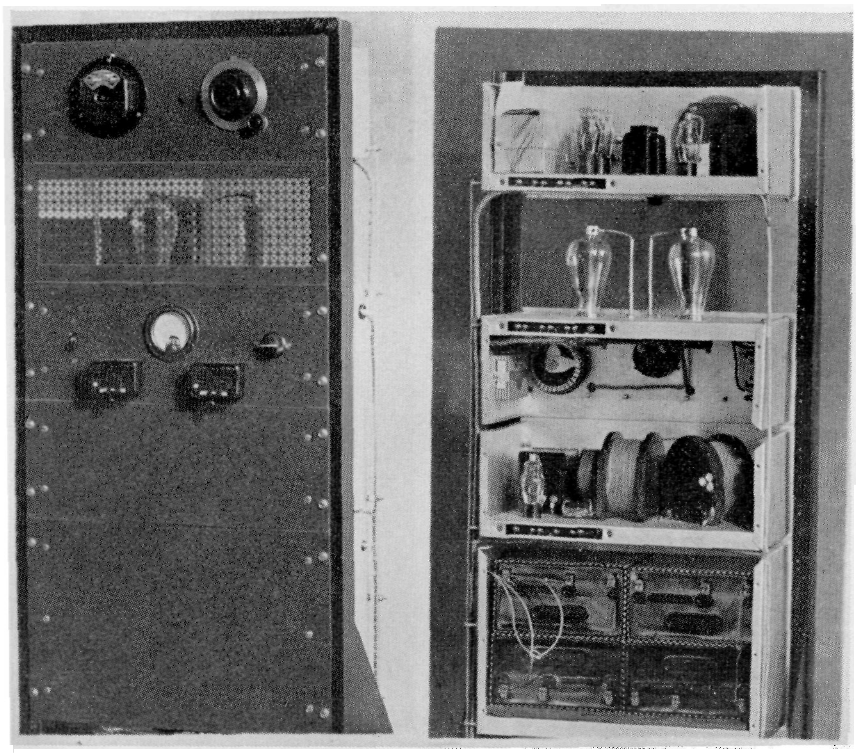

Figure 6. Front and back views of electronic tag-detector assembly. This unit, situated at some distance from the coils through which the fish pass, converts the "unbalance" created by the presence of the tag in the coil, into a power impulse for mechanical ejection of the individual bearing the tag.

Operation of the unit.

The first unit was installed in the field in the 1935 season. (See Figures 4 and 5.) During the short time the unit was in operation, 66 tagged individuals were recovered. Mechanical difficulties of installation and operation, to be expected in the development of such a device, precluded the recovery of a larger number of tagged individuals. In addition to proving the feasibility of the device, however, this first season's operation has given some valuable information.

Table 5.
1935 Detector recoveries.

Location of Tagging	Type of Tag	Years of Tagging	Number of tags recovered with locality of recapture: Outside Cape Ommaney			Inside Cape Ommaney		Port Malmesbury	Total Recoveries
			Big Branch Bay	Puffin Bay	Larch Bay	Off Port Alexander	Port Conclusion		
Jamestown Bay	Nickel-plated steel belly type	1934			1	2			3
		1935	5	1	7	15		1[1])	29
	Dumb-bell-shaped nickel-plated steel belly type	1935		2	2	7	1		12
Kalinin Bay	Nickel-plated steel belly type	1935		1		12			13
Redoubt Bay		1935	3			5	1		9
	Totals		8	4	10	41	2	1	66

[1]) Locality doubtful because small part of load taken at Cape Ommaney, balance at Port Malmesbury.

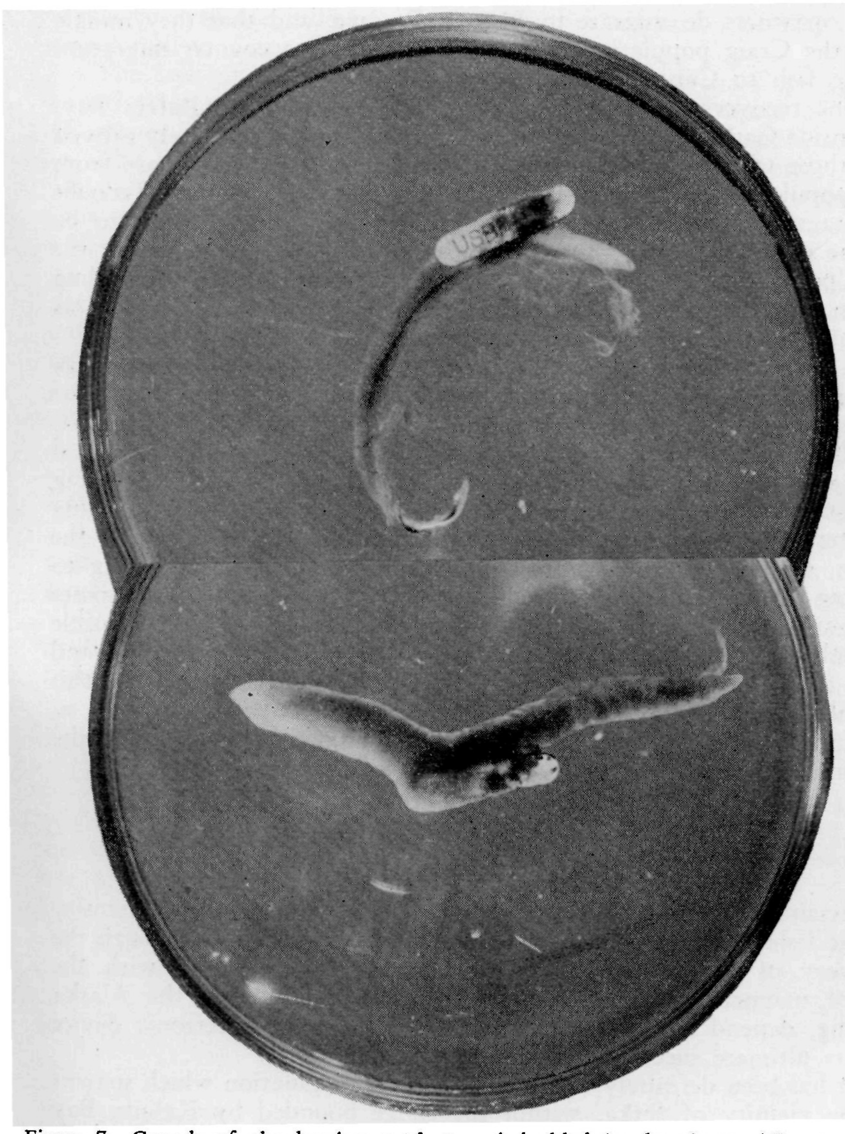

Figure 7. Gonads of the herring, with tags imbedded in the tissue. The tag is surrounded with sex products which are not re-absorbed, although the rest of the organ appears normal.

Summary of detector recoveries.

The recoveries from the detector are listed in Table 5. In this table, with the one exception noted, the localities of recoveries are known to be reliable. It is significant that, out of these recoveries, no Craig tag was retaken. Therefore, while it is known that the

Sitka spawners do migrate to Warren Passage, and that they mingle with the Craig population there, it appears that a counter migration (Craig fish to Cape Ommaney) did not take place.

The recovery of Sitka tags from Big Branch Bay, Puffin Bay, and inside Cape Ommaney as far as Port Conclusion, definitely proved that those taken at any place in the Cape Ommaney region are from this population. The recovery of Kalinin Bay tags, and of Redoubt Bay tags, along with those of Jamestown Bay, proved these to be of one population. It is therefore possible to state definitely that the Sitka population, which migrates to Cape Ommaney during the feeding season, is composed of individuals which spawn as far north as Kalinin Bay, and at least as far south as Redoubt Bay.

A clue to the cause for the failure to recover a larger percentage of tags during the second year is furnished by the fact that in 59 of those recovered, the tag had penetrated the gonad. (See Figure 7.) At the time the tags are applied, the fish are so ripe and distended with spawn that it is virtually impossible, apparently, to insert a tag without puncturing the organs. That the fish spawn after the tagging is attested to by the normal appearance of the ova and milt in the organ, except for an accumulation of unspent products adhering to the tag itself. This accumulation, which is not re-absorbed, becomes extremely hard, and adheres tightly to the tag. It is quite possible that this interferes with the spawning during the next season, and as a result the individual fails to survive, although, of course, this is only a matter of conjecture. Experimental tagging, as well as continued field experiments, will be necessary to obtain definite information on this matter.

Summary.

Accurate tracing of migration routes, and estimates of the intensity of the fishery by the interpretation of the data provided through the recovery of tagged individuals, while partially successful with the use of magnet recoveries, must, at least in the case of the Alaska herring, depend on the use of the newly developed electronic device for its ultimate success.

It has been definitely established that the population which spawns in the vicinity of Sitka, within the range bounded by Kalinin Bay on the north and Redoubt Bay on the south, is of one stock, which intermingles on the summer feeding grounds. From observations of the spawning habits of the herring, it is concluded that the entire spawning population of the west coast of Baranof Island is included in this stock.

It has also been established that this Baranof spawning population migrates during the summer feeding season to the Cape Ommaney region, with occasional migrants appearing at Warren Channel, in the Iphigenia Bay region, mingling with the Craig population there.

Negative evidence indicates that no counter migration of this Craig population to Cape Ommaney takes place.

The lack of recoveries from the Auke Bay and the Cape Bendel experiments prove these stocks to be separate from those of Cape Ommaney, confirming the racial data which has been published.

The belly-type tags have proved superior to the opercle type. Of these, the nickel-plated steel have proved more efficient than the pure nickel ones. Increasing the size of the steel tags caused no additional tagging mortality.

An estimate of the mortality imposed by the fishery, based on the percentage recovery of tags, admittedly in error and representing only the minimum mortality, shows that intensive fishing takes a much greater toll from the stocks than has been generally supposed by the industry. Basing the percentage recovery on the number of tags retaken by those plants known to give the most accurate returns *shows that in 1934 5.7 %, and in 1935 at least 9.0 %, of the population* which spawns in the vicinity of Sitka is taken by the commercial fishery. For that population which spawns in the vicinity of Craig, a 2.5 % recovery in 1934, and a 2.7 % recovery of the plain type tags in 1935, indicates that this population does not contribute as large a percentage as does that taken in the vicinity of Cape Ommaney.

Perfection of the electronic device will permit of an accurate evaluation of the percentage mortality imposed by the fishery, together with a measure of the validity of that estimate, based on the variation in number of tags recovered per unit of fish delivered throughout the season.

The application of electronic detection to the recovery of fish, bearing metal tags, is succesful. This will make possible tracing migrations and establishing mortality statistics in other fisheries, by the use of this method, since the recovery need no longer depend on the utilization of the fish for reduction.