RESEARCH BRIEFS

FISH COMMISSION OF OREGON
307 State Office Building
Portland, Oregon

Volume Eleven—Number One

JUNE 1965

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FOREWORD

These short reports are intended to inform the public, fishing industry, sportsmen, and fisheries scientists of research conducted by the Fish Commission. Reports will be published from time to time as studies are sufficiently complete. Most of the reports provide biological evidence upon which measures are based to enhance and conserve the fishery resource. Research Briefs are free and may be obtained upon request from the editor.

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Tagging of Dungeness Crabs with Spaghetti and Dart Tags

C. DALE SNOW and EMERY J. WAGNER

INTRODUCTION

For many years Dungeness crabs *(Cancer magister* Dana) have been tagged with Petersen disk tags. The Petersen or button-type tag is placed on the crab by drilling or punching a hole at the base of the 10th antero-lateral spine and attaching the disks with a stainless steel pin. Because this tag is lost during molting or when corrosion erodes the pin (Waldron, 1958), it is limited to short term studies and little if anything can be learned about growth rates and natural mortality.

A new type of tag, termed the "suture" or "splitting line" tag, was developed and used on the blue crab *(Callinectes sapidus)* by W. A. Van Engel of the Virginia Fisheries Laboratory (personal communication, 1956). It was retained when the crabs molted. Van Engel used surgical steel wire with plastic tags attached. The epimeral line was pierced at two points, the wire was threaded through the holes with a surgical needle, and the plastic tag attached to the ends of the wire.

This method was subsequently used by Butler (1957) on the Dungeness crab in British Columbia and Mistakidis (1959) on the edible crab *(Cancer pagurus)* in England. Both workers had encouraging results, but Butler found a high incidence of tag loss on board vessels at the time of recovery which he felt was due to the fact that the tags were not being readily observed. He also found broken strands of the suture wire at recovery but attributed no tag loss to this condition.

This report presents the results of a tagging study in 1961 on Dungeness crabs in Yaquina Bay, Oregon using basically the methods employed by Van Engel, Butler, and Mistakidis, except that vinyl-plastic spaghetti and dart tags were used instead of surgical steel suture wire and plastic disk tags. The objective was to determine the feasibility of such tags placed on the epimeral line as an identification mark to follow the growth of individual crabs through a number of molts.

METHODS AND MATERIALS

Three types of vinyl-plastic tags were used:

Spaghetti tag. A 12-inch length of red tubular plastic 2 mm in diameter with black lettering (Figure 1). The tag was threaded with a small curved needle and long-nose pliers through two holes spaced ⅝ inch apart on the epimeral line and approximately 1 inch anterior to the insertion of the abdominal flap. The tag was then tied in a figure-eight knot 1 inch from the carapace to allow room for growth (Figure 2).

Dart tag with stopper. A ¾-inch piece of red tubular plastic, 2 mm in diameter with black lettering and a 1-inch nylon barbed shaft at one end.

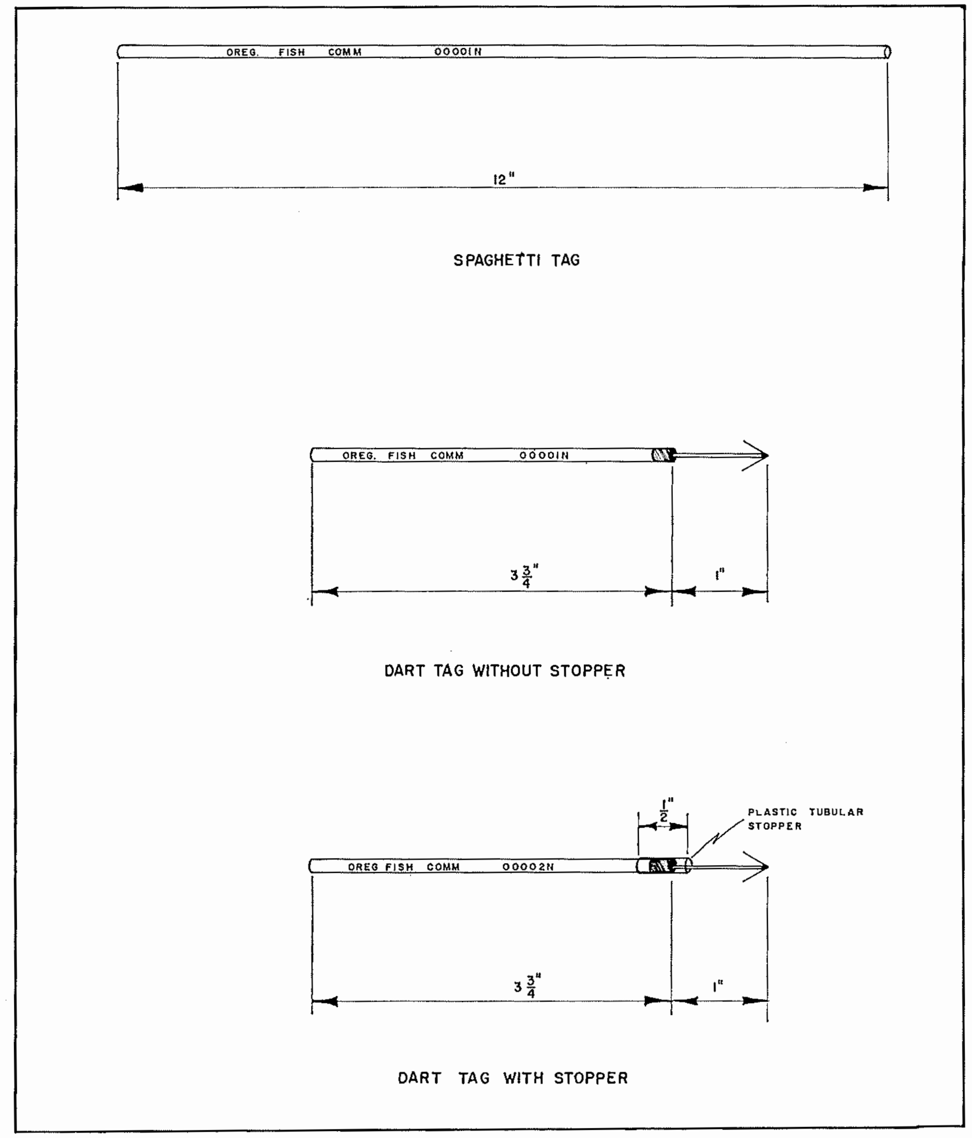

FIGURE 1. DIAGRAMMATIC DRAWING OF VINYL-PLASTIC SPAGHETTI AND DART TAGS WITH AND WITHOUT STOPPERS.

A clear ½-inch plastic sleeve (stopper) was fixed over the base of the barbed shaft, ¾ inch from the tip of the barb (Figure 1) to prevent the tag from being drawn into the gill cavity by normal respiratory activities. The tag was inserted into a hole punched along the epimeral line approximately 1 inch anterior of the abdominal flap insertion and pushed in just far enough to get the barb through the shell (Figure 3).

Dart tag without stopper. Identical to the above except that the plastic sleeve (stopper) was left off. The tag was inserted in a hole punched in

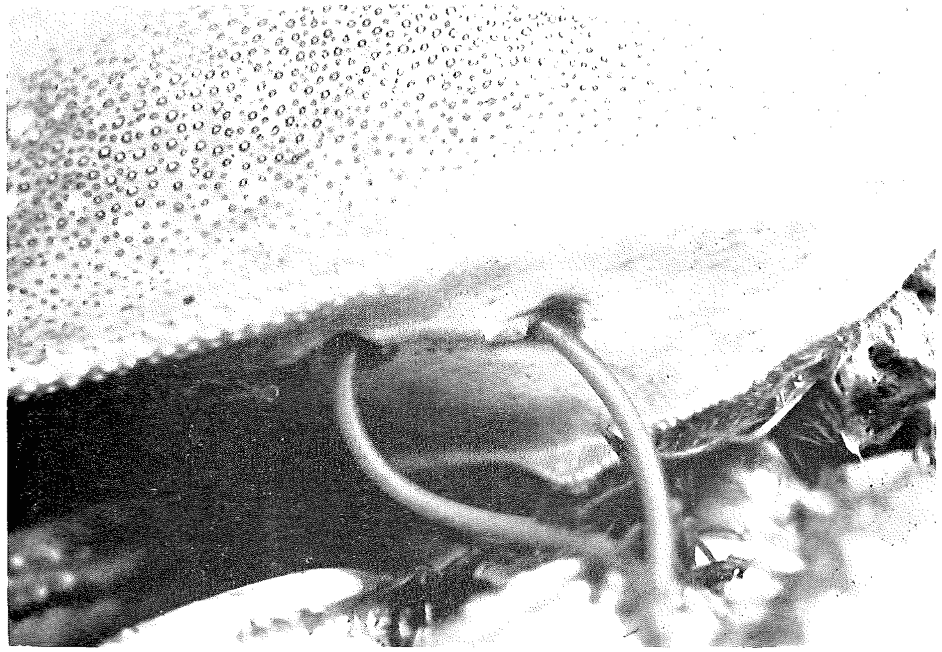

FIGURE 2. CRAB WITH SPAGHETTI TAG IN PLACE.

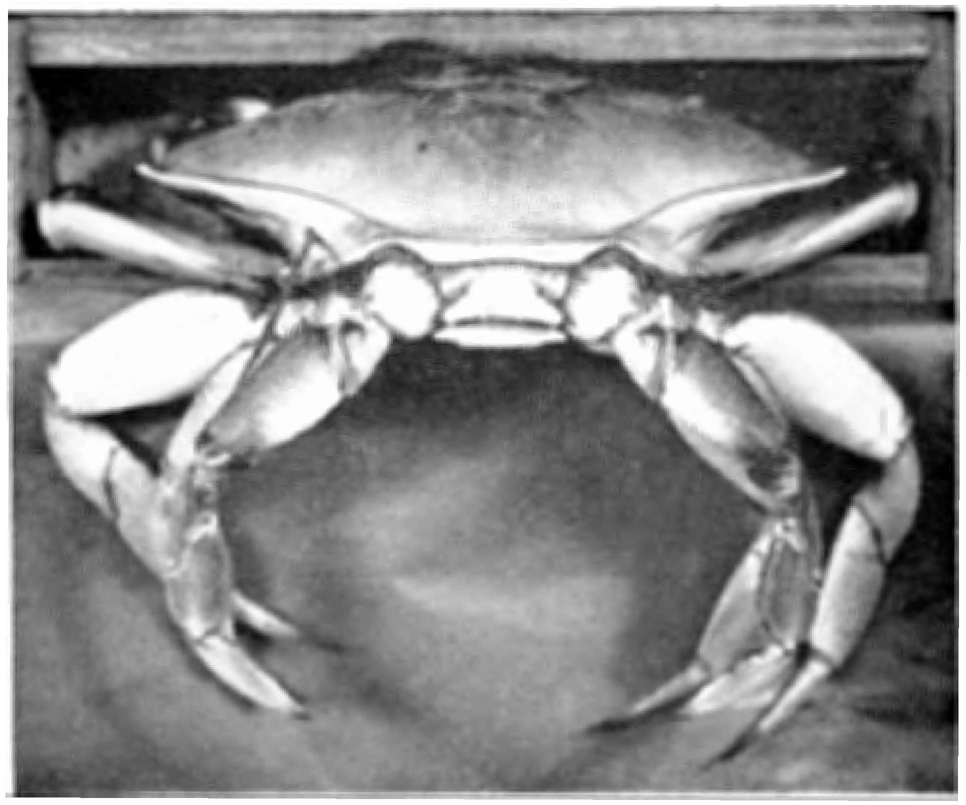

FIGURE 3. CRAB IN HOLDING BOX WITH DART TAG IN PLACE.

the epimeral line approximately ½ inch anterior of the abdominal flap insertion and was pushed into the body meat far enough to imbed the barbed tip.

During tagging the crabs were immobilized in a tagging box and holes were punched in the epimeral line (Figures 3 and 4). The spaghetti tag was threaded through the holes with an ordinary 3/9 sewing needle curved by heating and bending into a semi-circle. The excess needle was clipped off at the point so the tag could then be placed over the eye. The distance across the open section of the needle was ⅝ inch.

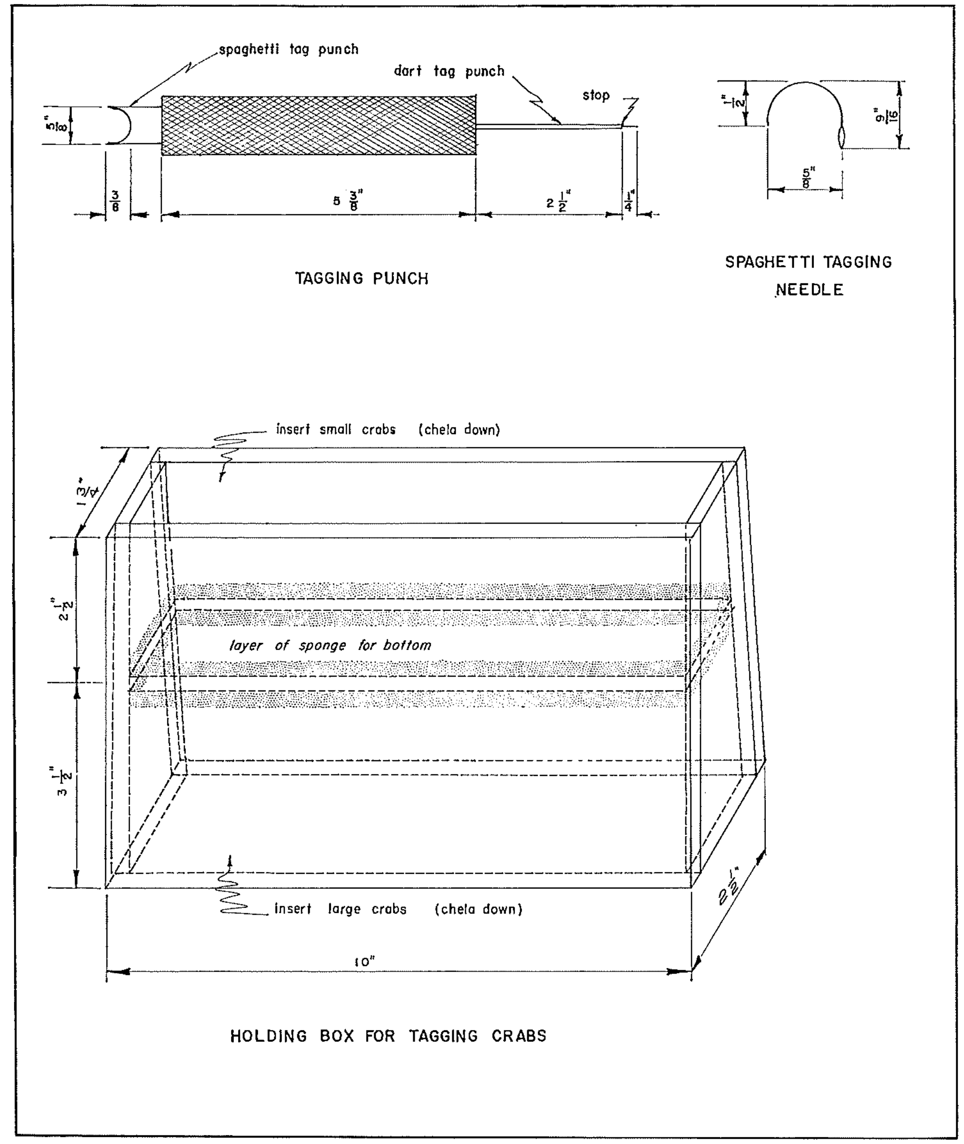

FIGURE 4. DIAGRAMMATIC DRAWING OF PUNCH, NEEDLE, AND TAGGING BOX.

During the period August 14–22, 1961, 966 male crabs ranging in size from 77 to 179 mm shoulder width (measured by Vernier calipers between the bases of the 10th anterolateral spines) were tagged in the Sally's Bend area of Yaquina Bay, Oregon. Of this group, 770 were below the legal size of 146 mm. Five hundred crabs were tagged with spaghetti tags, 250 with dart tags having stoppers, and 216 with dart tags without stoppers. The type of tag applied was randomly selected, but the first 250 dart tags used had stoppers and the last 216 dart tags used did not. After selecting the proper tag, the crab was placed in the tagging box. After tagging, it was released upside down in the water to allow air trapped under the carapace to escape. Upon release, all crabs promptly swam down and disappeared. An average of 138 crabs was tagged per day and the entire program was completed in nine days. The crabs were captured with ring nets. Two persons did the tagging and one kept the records.

Tag returns were voluntary from commercial and sport fishermen. Originally, people were asked to release all tagged crabs recovered until they had been out for one year, but the scarcity of crabs and a high market value precluded the desired cooperation.

RESULTS AND DISCUSSION

Between August 14, 1961, and September 1, 1963, 95 tags were returned by personal-use and commercial fishermen; 35 in 1961, 53 in 1962, and 7 in 1963. Time elapsed between tagging and recapture ranged from 1 to 714 days, with a mean of 213 days.

Of the 95 recoveries, 79 were spaghetti and 16 were dart tags. No dart tags with stoppers were recovered, and only those dart tags without stoppers that pierced the body meat between segments were retained after molting. Spaghetti tags showed a greater retention than dart tags.

Movement

Seventy-two tags came from Yaquina Bay, close to the place of tagging while 23 were recovered 3.5 to 34.0 miles from the tagging area. Six of these came from Alsea Bay, 12.5 miles south of the point of release, and 17 came from the ocean (Table 1). All but one of the tagged crabs recaptured outside of Yaquina Bay migrated south of the point of tagging. Since most of the Newport-based crab fishing vessels fish south of Yaquina Bay, this was expected and may not indicate the actual dispersion.

Tag Retention and Growth

Because of their rigid exoskeletons, Dungeness crabs are able to increase in size only immediately after molting and before their new shells become hardened. Any size increase at the time of tag recovery therefore indicates that molting had occurred.

Thirty-seven crabs were recovered which showed an increase in carapace width (Table 2). They ranged in size from 92 to 149 mm shoulder width. Growth increments ranged from 22 to 57 mm (0.87-2.24 inches). Increments from 22-34 mm were considered to represent a single molt after tagging. This is in line with Butler's (1957) findings and growth observed in aquaria. Using stainless steel wire with plastic tags affixed to the wire, Butler had 20 confirmed records of molting and tag retention out of 2,094 tagged crabs. He found that crabs from 145 to 172 mm in size increased 14-32 mm in one molt (measurement included 10th anterolateral spine).

TABLE 1. **DAYS AT LIBERTY, DISTANCE TRAVELED, AND AREA OF RECOVERY OF 23 TAGGED DUNGENESS CRABS WHICH LEFT YAQUINA BAY.**

Days at Liberty	*Distance Traveled (Miles)*	*Area of Recovery*
138	12.5	Ocean—2 miles south of Alsea Bay entrance
205	29.0	Ocean—off Heceta Head
206	14.0	Ocean—2 miles south of Alsea
239	6.0	Ocean—off Beaver Creek
240	6.0	Ocean—off Beaver Creek
245	10.0	Ocean—1 mile north of Alsea entrance
248	14.0	Ocean—2 miles south of Alsea entrance
277	12.5	Alsea Bay
278	19.0	Ocean—off Yachats
289	9.5	Ocean—between Seal Rocks and Alsea
291	19.0	Ocean—off Yachats
295	12.5	Alsea Bay
320	12.5	Alsea Bay
357	12.5	Alsea Bay
380	12.5	Alsea Bay
490	13.0	Ocean—off Big Stump Beach
493	34.0	Ocean—5 miles south of Heceta Head
505	19.0	Ocean—off Yachats
523	11.5	Ocean—off Alsea entrance
612	15.0	Ocean—3 miles south of Alsea Bay
678	15.0	Ocean—3 miles south of Alsea Bay
703	3.5	Ocean—25 fathoms off Yaquina Head
714	12.5	Alsea Bay

Growth increments in excess of 34 mm represent at least two molts. Ten of the recoveries showed increments of 49-57 mm. All ten were 114 mm or less in shoulder width at the time of tagging and 6 of these molted twice in one year or less (Table 2 and Figure 5). Crabs that were considered to have molted twice, with only one exception, were all recovered within the tagging area. No explanation of this is offered other than that there does not seem to be the seasonal pattern of molting within the estuary that occurs in the ocean.

FIGURE 5. DUNGENESS CRAB WITH SPAGHETTI SUTURE TAG IN PLACE AFTER TWO MOLTS. RIGHT CHELIPED WAS MISSING AT TIME OF TAGGING. SIZE AT TAGGING (4½ INCHES, 114 MM) SHOWN BY WHITE PAPER ON CARAPACE.

Of the 37 tagged crabs that exhibited growth, 33 bore spaghetti tags and 9 of these had been retained through at least two molts. All these animals seemed capable of tag retention through at least one more molt since the tags were still in the epimeral line and through the new shell forming under the old carapace. Although the two holes in the epimeral line of the exoskeleton had filled in around the tag, the shell was "rubbery" at the point where the tag was inserted.

Only 4 dart tags were retained upon molting and only one of these had been retained through two molts. Three of the four might have been retained through additional molts.

Fifty-three of the 95 crabs recovered had been sub-legal at the time of tagging. In 19 cases fishermen returned only the tag but stated the crabs were of legal size at the time of capture. It is probable that these animals had also molted and retained the tags since we were recovering crabs which had molted and retained their tags at this time.

SUMMARY AND CONCLUSIONS

A study was conducted in Yaquina Bay, Oregon in 1961 to determine the feasibility of inserting vinyl-plastic spaghetti and dart tags in the suture line of Dungeness crabs. Five hundred crabs were tagged with spaghetti tags and 466 with dart tags. At the end of 2 years 95 tags had been returned—33 spaghetti and 4 dart tags. Thirty-seven tags were retained after the crabs had molted and ten tags were retained through at least two molts.

TABLE 2. **CRAB SIZE AT RELEASE AND RECOVERY, GROWTH INCREMENT, DAYS AT LIBERTY, ESTIMATED NUMBER OF MOLTS, AND DISTANCE TRAVELED AT TIME OF RECOVERY.**

Crab Size (mm)		*Growth (mm)*	*Days at Liberty*	*Estimated Number of Molts*	*Distance Traveled (Miles from Yaquina Bay①)*
Release	*Recovery*				
142	172	30	248	1	14
142	174	32	138	1	14
128	155	27	333	1	0
128	154	26	228	1	0
136	170	34	279	1	0
92	141	49	405	2	0
95	149	54	366	2	0
131	160	29	226	1	0
148	181	33	678	1	15
119	143	24	385	1	0
135	164	29	230	1	0
107	160	53	334	2	0
123	145	22	261	1	0
112	167	55	343	2	0
97	154	57	279	2	0
107	154	47	318	2	0
136	166	30	245	1	10
114	165	51	298	2	0
133	165	32	523	1	12
130	161	31	483	1	0
130	161	31	320	1	12
104	159	55	473	2	0
141	167	26	262	1	0
149	181	32	291	1	19
138	166	28	493	1	34
147	180	33	240	1	6
145	174	29	206	1	14
120	146	26	269	1	0
110*	165	55	356	2	0
135*	161	26	220	1	0
113	165	52	703	2	4
120	146	26	290	1	0
118*	141	23	295	1	12
140*	169	29	220	1	0
138	166	28	380	1	12
129	157	28	612	1	15
138	165	27	505	1	19

* All recoveries are spaghetti-type except for 4 dart-tag recoveries marked with an asterisk.

① Yaquina Bay recoveries considered mile 0.

This study indicates that suture line tagging of Dungeness crabs with vinyl-plastic spaghetti tags is suitable for growth studies. Growth upon molting ranged from 22 to 34 mm for single molts and 49 to 57 mm for two or more molts.

No dart tags with stoppers were recovered. Dart tags without stoppers, although easy to apply, did not yield a desirable rate of return and only those that pierced the body meat between segments were retained. Visibility, as well as tag loss, could also be a problem with this tag as the single strand of plastic is not as readily observed as the knotted spaghetti tag.

ACKNOWLEDGMENTS

Appreciation is acknowledged for the cooperation of plant operators and commercial and personal-use fishermen who recovered and turned in tags and tagged crabs and to student trainees Ray Labbe, Paul Gregory, and Theodore Will who aided in the tagging operations.

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Production Trials Utilizing Sulfonamide Drugs For the Control of "Cold-Water" Disease In Juvenile Coho Salmon[1]

by

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and

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INTRODUCTION

"Cold-water" or peduncle disease caused by *Cytophage psychrophila* (Wood and Yasutake, 1956) is one of the most serious diseases presently encountered by juvenile coho salmon *(Oncorhynchus kisutch)* in Oregon Fish Commission hatcheries. Sulmet (sulfamethazine) is being used prophylactically and therapeutically for control of this disease in both fish-meat and Oregon pellet diets (Hublou, 1963). Customarily, a fish-meat diet is fed until the fish reach a size of about 700 per pound, after which the Oregon pellet diet is used. The initial ten days of fish-meat diet contains a therapeutic dose of Sulmet (10 grams per 100 pounds of fish per day); then a prophylactic dose (2 grams per 100 pounds of fish per day) is administered until seven days before feeding Oregon pellets, when the therapeutic 10 gram dose is again used. This has been standard hatchery procedure and will hereafter be referred to as the 10-2-10 treatment. Medicated pellets are fed so that the fish receive a prophylactic dose of about 2 grams of Sulmet per 100 pounds of fish per day until the mean water temperature is above 50 F.

The Fish Commission has used variations of the treatment described above since 1958. In many instances the prophylactic use of Sulmet in the fish-meat diet did not appear to offer adequate control of cold-water disease. Because the disease is a serious problem, and the use of Sulmet was not always completely satisfactory, the following experiment was conducted to compare the effectiveness of two newer sulfonamides with Sulmet in controlling this disease.

MATERIALS AND METHODS

Gantrisin (Sulfisoxazole) and S.E.Z. (Sulfaethoxypyridazine) were compared with Sulmet. Gantrisin was chosen because it showed a high degree of activity in *in vitro* tests. American Cyanamid, the producer of Sulmet, suggested testing the experimental drug S.E.Z. because it seemed more effective than Sulmet against bacteria susceptible to sulfonamides. The two experimental dosage levels employed were the 10-2-10 treatment and a continuous 4 grams per 100 pounds of fish per day. Previous experimentation by the authors with Sulmet indicated that the 4 gram level would provide prophylactic blood concentrations.

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[1] Technical Paper No. 1921, Oregon Agricultural Experiment Station.

[2] Formerly biologist, Oregon Fish Commission; now with the Department of Food Science and Technology, Oregon State University.

[3] Department of Microbiology, Oregon State University.

The Siletz Hatchery was chosen for the experimental trials because it has had a high incidence of cold-water disease. The test utilized 720,000 coho salmon stocked over an 8-day period in 10 cement raceway ponds. There were three ponds for each drug used and one control pond. One pond in each set of three received the continuous 4-gram treatment while the other two received the alternating 10-2-10 treatment. Effects of the various treatments were determined by the occurrence of deaths and incidence of cold-water disease from February to May 1963.

Treatment was initiated within 24 hours after the fish were stocked in the rearing ponds. The drugs were added directly to a premixed fish-meat diet while the medicated pellets were prepared by Bioproducts, Inc., Warrenton, Oregon. The medicated food was fed daily over an 8-hour period. Weight samples were taken from each pond weekly and the amount of drugs and food adjusted accordingly. Each treatment lasted approximately 63 days; 26 days on the fish-meat diet and 37 days on Oregon pellets. Dead fish were collected daily, and periodically examined for cold-water disease by preparing bacteriological cultures from the kidney or lesions on Myxo media[4]. A positive culture of cold-water disease on this medium was characterized by circular, convex spreading colonies with a smooth surface. The colonies were yellowish, transluscent, and viscid. Wet mounts revealed single long flexing rods and gram stains of the organisms were negative.

RESULTS AND DISCUSSION

As in previous years, cold-water disease was again present at the Siletz Hatchery in 1963. The majority of fish which died after the first week of ponding had symptoms of the disease, and positive cultures were obtained from all lots within 10 days.

The number of deaths in the control pond was high during the first week, continued to rise during the second, and remained at a high level throughout the meat-feeding phase of the experiment. Two weeks after pellet feeding was initiated, losses dropped rapidly to a level comparable with that of the treated ponds (Figures 1 and 2). There was no immediate explanation for the decrease, as the pellets were not medicated and water temperature remained favorable for the disease, never exceeding 50 F during the experiment. The incidence of the disease as determined by bacteriological examination corresponded directly with the reduced number of deaths. This same situation occurred in the treated ponds, but the difference was not as apparent. The effects of the various treatments can best be analyzed by comparing the results during the meat-feeding phase of the experiment only. In all cases each drug significantly reduced the mortality during this period.[5]

Figures 1 and 2 show that losses in each treated group were less than in the control ponds. There was no significant difference between losses in groups of fish receiving the two dosage schedules of any of the three drugs. All three gave equivalent results with the 10-2-10-gram dosage schedule,

[4] Myxo media: 0.5% tryptone, 0.25% yeast infusion, 0.9% agar, in distilled water.

[5] Losses in all experimental groups were compared by means of analysis of variance (P=.05).

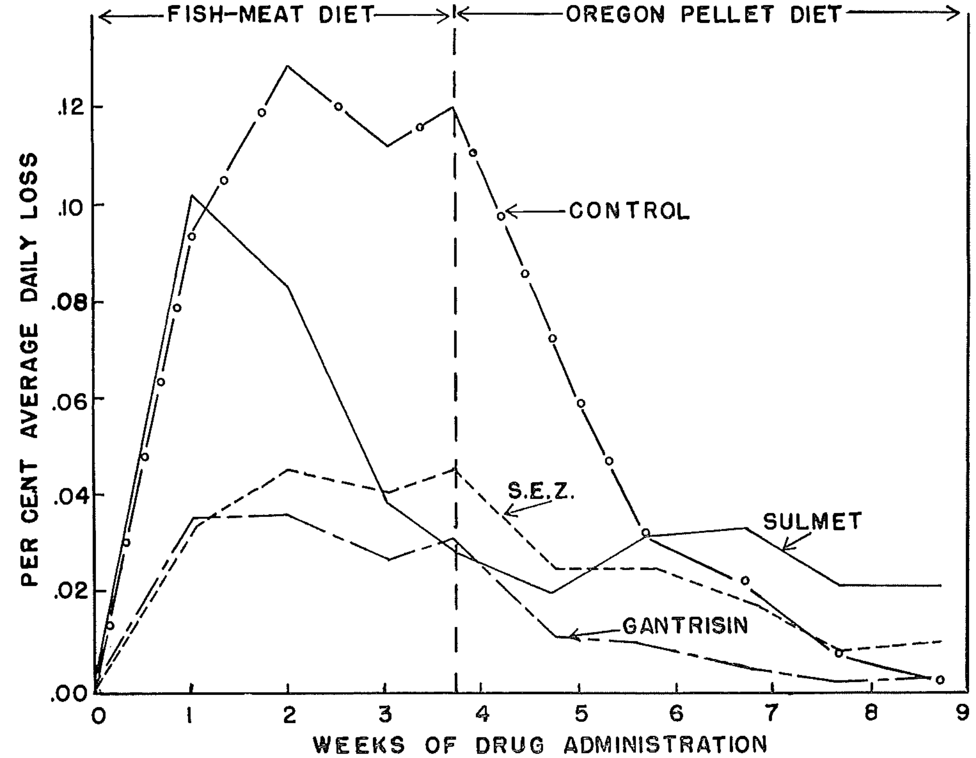

FIGURE 1. AVERAGE DAILY PER CENT LOSS WITH DRUGS ADMINISTERED AT 4 GRAM LEVEL IN FISH-MEAT DIET AND 2 GRAM LEVEL IN OREGON PELLETS.

but with the continuous 4-gram schedule, S.E.Z. and Gantrisin were more effective than Sulmet. The fact that the 4-gram schedule controlled the disease as well as the 10-2-10 schedule was important since the cost of treatment was 53-60% less in the 4-gram treatment.

Statistical tests indicated a significant difference between Sulmet and the other two drugs when used at the 4-gram dosage schedule. For fish treated with Sulmet, losses were highest during the first week, almost approximating those of the control pond. After that, deaths declined sharply to a value comparable to the other two drugs while those in the control pond remained high. In previous experiments Sulmet had proved to be slowly absorbed, taking from 8 to 9 days to reach maximal blood concentrations (Snieszko and Friddle, 1950). This may explain why Sulmet showed little effect during the first week. Gantrisin, being absorbed quickly (less than 24 hours), appears to have controlled the disease somewhat faster. Information concerning the absorption of S.E.Z. by fish is not available.

It was not possible during this trial to administer the drugs at the 2-gram dosage level for an interval longer than seven days. During the period at this dosage level, the average daily loss began to decrease with all three drugs. However, the decline in losses may have been only a reflection of effective blood levels attained during the therapeutic treatment.

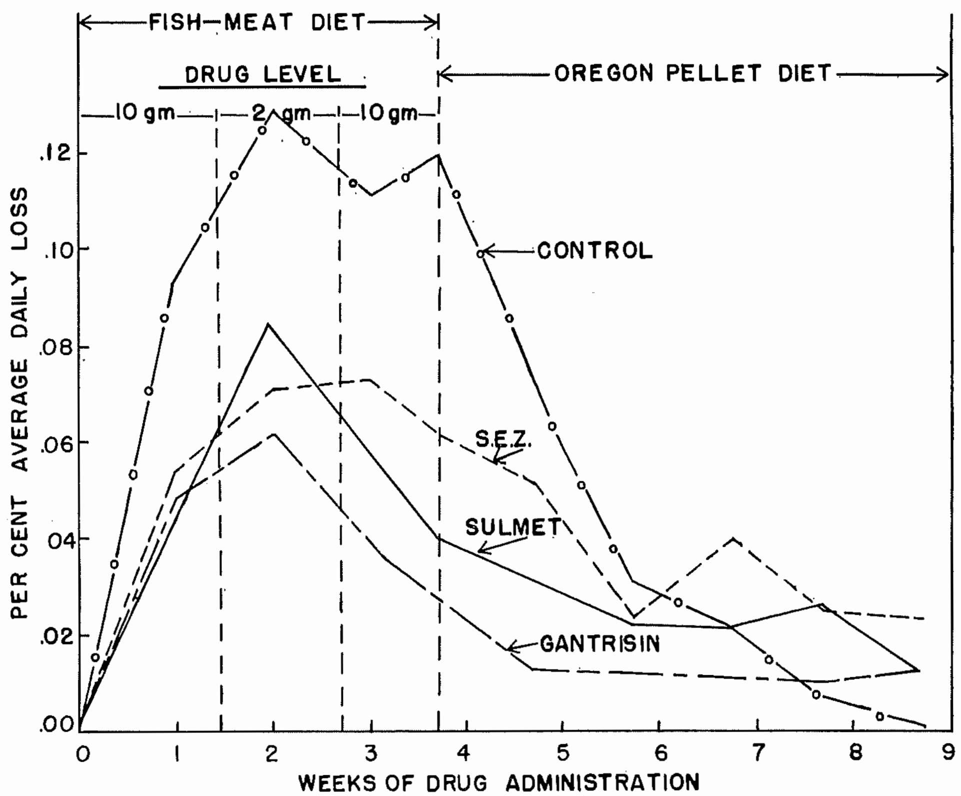

FIGURE 2. AVERAGE DAILY PER CENT LOSS WITH DRUGS ADMINISTERED AT 10-2-10 GRAM LEVEL IN FISH MEAT DIET AND 2 GRAM LEVEL IN OREGON PELLETS.

CONCLUSIONS

Treatment with each of three sulfonamide drugs reduced the loss of juvenile coho salmon due to "cold-water" disease.

A continuous 4-gram per 100 pounds of fish per day treatment controlled the disease as well as an alternating 10-2-10-gram treatment and required smaller amounts of the drugs.

Gantrisin and S.E.Z. appeared to control the disease more quickly than Sulmet when used at the 4-gram dosage level.

ACKNOWLEDGMENTS

The authors wish to thank the crew of the Siletz River Salmon Hatchery for their valuable contribution to this study.

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Length-Weight Relationships of Columbia River Chinook Salmon

ROBERT L. DEMORY

INTRODUCTION

The chinook salmon *(Oncorhynchus tshawytscha)* population in the Columbia River is generally recognized as being comprised of three runs—spring, summer, and fall. Each of the runs is managed independently. There are five commercial fishing seasons for chinook corresponding in general to the timing of the runs: (1) winter—last half of February; (2) spring—May; (3) summer—last half of June and first half of July; (4) early fall—August; and (5) late fall—September-October. Fish caught during the winter season are believed to be an early segment of the spring run and those caught during the early and late fall are thought to be components of the fall run.

For management purposes the commercial fishing area of the Columbia River is divided into six zones representing nearly 200 miles of river (Pulford, 1964). Zones 1-5 extend (in ascending order) upstream to within 5 miles of Bonneville Dam. Zone 6 represents the Indian fishery and extends from Bonneville Dam to the confluence of the Deschutes River.

Commercial landings of chinook salmon are recorded in pounds due to poundage tax requirements, but to be of use in the management program these landings must be converted to numbers. There are two methods of converting pounds to numbers: (1) average weight or (2) length-weight in conjunction with length-frequency. Since 1957 the latter method has been used.

The purpose of this paper is to compare the length-weight relationships of chinook salmon by time and zone of catch and to determine if stratification significantly improves the reliability of the regression coefficient. The different strata studied are year, season, and zone in a season.

METHODS AND MATERIALS

Length-weight data were obtained from sampling the commercial landings in selected years from 1913 to 1963. Samples were obtained by gill netting, except one from an undetermined source in 1913 and another by beach seine in 1948. Sample size was 8,233 for the year and season strata. Sample size of the zone stratum was 4,751 because fish from mixed zones and zone six were omitted from comparisons (Table 1).

Length measurements were standardized to the nearest lower inch fork length. Logarithmic transformation was at the mid-point of each inch interval. Mean weights of each length interval were used.

Length-weight formulas were calculated by electronic computer[1] according to the formula Log W=Log $a+b$ Log L, where W= weight and L=length. Constants a and b were determined by least squares. Regression

[1] IBM 1620, Statistics Department Data Processing Laboratory, Oregon State University, Corvallis, Oregon.

coefficients were tested for homogeneity by analysis of covariance at the 5% significance level.

RESULTS AND DISCUSSION

Analyses of length-weight relationships of the year, season, and zone categories are presented in Tables 2, 3, and 4. For the yearly comparison all samples collected by year were used and a pooled regression coefficient was calculated. Similarly, for the seasonal comparison, data collected from each season were combined to produce five regression coefficients (one for each season). In the zone analyses, data were stratified by zone within season.

TABLE 1. **NUMBERS OF CHINOOK SALMON SAMPLED FOR LENGTH-WEIGHT DATA IN THE COLUMBIA RIVER COMMERCIAL FISHERY BY SEASON, YEAR, AND ZONE.**

Year and Zone	*Season*				
	Winter	*Spring*	*Summer*	*Early Fall*	*Late Fall*
1913					
Mixed Zones	......	99	......	......	......
1948					
Zone 2	......	......	......	228	......
Zone 4-5	......	......	......	186	559
Zone 6	......	......	......	......	347
1949					
Zone 4	......	286	......	......	......
Zone 5	......	254	......	......	......
Zone 6	......	......	......	......	253
1950					
Zone 2	......	390	......	......	......
Zone 4	......	256	......	......	......
Zone 5	......	256	......	......	......
1952					
Zone 1-2	700	......	......	......	......
1957					
Mixed Zones	234	......	......	......	......
Zone 1	......	383	420	434	......
Zone 2	......	525	364	489	......
Zone 3	......	......	316	......	......
Zone 4-5	......	281	491	......	......
1963					
Mixed Zones	......	......	......	150	182
Zone 1	......	......	......	150	......
Total	934	2,730	1,591	1,637	1,341
Grand Total					8,233

Comparisons Among Years

The test of homogeneity of regression coefficients shows a significant difference between years (Table 2). Data were not tested to determine which years were significantly different since the purpose of this analysis was to learn whether or not a single length-weight relationship was representative of all years. This analysis indicates that significant differences exist and that stratification by year is desirable.

Comparisons of Seasons

The regression coefficients of the various seasons were tested for homogeneity and a significant difference was obtained (Table 3). When the regression coefficients were examined by a ranking test, the slope for each season was determined to be significantly different. This test indicates that stratification by season is also desirable.

Comparisons of Zones

Length-weight data were analyzed by zone in a season to determine whether or not samples from one zone in a season would suffice for all other zones in the same season. Because of limited and mixed samples, analysis of zonal length-weight relationships in a season was restricted to spring, summer, and early fall. Differences between zones could be due to the selective action of gill nets since mesh size ranges from less than 5 to over 8 inches stretched measure between and within zones. Further differences between zones may occur as fish proceed upstream and lose weight. Pulford (1964) has shown this to be true for average weight samples.

The test of homogeneity of regression coefficients by zone in a season showed no significant difference between zones. However, when data were combined, a significant difference was found (Table 4). The reason for this is probably the limited number of samples from pure zones (Table 1). It is concluded that stratification by zone is desirable, but until adequate samples from all zones within the five seasons are obtained data from zones should be pooled by season.

TABLE 2. **ANALYSIS OF COLUMBIA RIVER CHINOOK SALMON LENGTH-WEIGHT RELATIONSHIPS BY YEAR.**

Variation due to:	*SS*	*DF*	*MS*	*F*	*Conclusion*
Regression due to $\bar{b}$	50.16943	1	50.16943		
Variation among b's	0.03649	6	0.00608	14.47	Significant
Pooled residual	0.15021	361	0.00042		
Within sample	50.35750				

$F_{.05} = 2.10$ with 6 and 361 d.f.

TABLE 3. **ANALYSIS OF COLUMBIA RIVER CHINOOK SALMON LENGTH-WEIGHT RELATIONSHIPS BY SEASON.**

Variation due to:	*SS*	*DF*	*MS*	*F*	*Conclusion*
Regression due to $\bar{b}$	50.16730	1	50.16730		
Variation among b's	0.04096	4	0.01024	25.60	Significant
Pooled residual	0.14744	365	0.00040		
Within sample	50.35570				

$F_{.05} = 2.37$ with 4 and 365 d.f.

TABLE 4. **ANALYSIS OF COLUMBIA RIVER CHINOOK SALMON LENGTH-WEIGHT RELATIONSHIPS BY ZONE IN A SEASON.**

Season	*Sample Size (n)*	*SSx*	*SP*	*SSy*	*Var. among b's*		*Residual*		*F*	*Conclusion*
					SS	*DF*	*SS*	*DF*		
Spring	163	1.74538	5.01130	14.44653	0.00252	3	0.05557	155	2.33	Not Significant
Summer	87	1.41512	4.24976	12.78777	0.00118	2	0.02413	81	1.97	Not Significant
Early Fall	115	2.04648	5.94142	17.29795	0.00009	1	0.04850	111	0.20	Not Significant
Combined	365	5.20698	15.20248	44.53225	0.01450	2	0.12820	347	19.59	Significant

$F_{.05}$ = 2.60 with 3 and 155 d.f.; 3.07 with 2 and 81 d.f.; 3.84 with 1 and 111 d.f.; 2.99 with 2 and 347 d.f.

Relative Evaluation of Length-Weight Relationships

To determine which length-weight relationship is most accurate, or best suited to typify the length-weight relationship of Columbia River chinook, the season strata were evaluated by comparison with some arbitrary standard. This was accomplished by assigning a value of 100% to the standard deviation of the year category. This value was then divided by the standard deviation of the season category. Thus, the percentage gain or loss becomes a measure of relative accuracy. Length-weight relationships of the season category showed a gain of 16% over the year category (Table 5). This further suggests that stratification is desirable. Length-weight relationships of individual seasons were similarly evaluated, but instead of reference to the year category the standard deviation of individual seasons was compared to the pooled seasonal standard deviation. The percentage gain or loss in accuracy ranged from -28% for late fall to +66% for the summer—additional evidence that stratification is desirable. The reduction in accuracy for the late fall run might be due to the fact that most of the samples were taken near the upper limit of the fishery.

Table 6 shows length-weight data stratified by season and Table 7 the appropriate length-weight equations by season. These data are the best presently available for Columbia River chinook and are included as reference for possible future studies.

TABLE 5. **SUMMARY OF RELATIVE ACCURACY OF CALCULATIONS USED TO EVALUATE LENGTH-WEIGHT RELATIONSHIPS OF COLUMBIA RIVER CHINOOK SALMON.**

Stratum	*Weighted Standard Deviation*	*Standard Deviation*	*Relative Accuracy*	*Relative Gain or Loss in Accuracy*	
Years Pooled	0.0225①	......	100%	0%	
Seasons					
Seasons Pooled	0.0194	......	116%	+16%	
Winter	......	0.0175	111%	+11%	Compared to pooled seasonal *s* of 0.0194 equivalent to 100%
Spring	......	0.0163	119%	+19%	
Summer	......	0.0117	166%	+66%	
Early Fall	......	0.0170	114%	+14%	
Late Fall	......	0.0268	72%	—28%	

① Arbitrarily set at 100%.

TABLE 6. **OBSERVED AND CALCULATED MEAN WEIGHTS OF COLUMBIA RIVER CHINOOK SALMON, BY SEASON.**

	Winter Season			*Spring Season*			*Summer Season*			*Early-Fall Season*			*Late-Fall Season*		
Fork Length in Inches	*No. Fish*	*Mean Wt.—Pounds Observed*	*Calc.*	*No. Fish*	*Mean Wt.—Pounds Observed*	*Calc.*	*No. Fish*	*Mean Wt.—Pounds Observed*	*Calc.*	*No. Fish*	*Mean Wt.—Pounds Observed*	*Calc.*	*No. Fish*	*Mean Wt.—Pounds Observed*	*Calc.*
13.5	....	......	1.14	......	......	1.40	....	......	1.28	......	......	1.35	1	1.00	1.11
14.5	....	......	1.42	......	......	1.71	2	1.75	1.59	2	1.65	1.66	2	1.00	1.38
15.5	....	......	1.74	2	2.10	2.07	2	1.85	1.94	8	2.05	2.02	7	1.79	1.69
16.5	....	......	2.11	2	2.65	2.46	13	2.32	2.34	13	2.35	2.43	12	2.00	2.04
17.5	....	......	2.52	11	3.06	2.91	30	2.74	2.80	17	2.76	2.89	18	2.47	2.44
18.5	....	......	2.99	34	3.60	3.41	36	3.30	3.30	21	3.49	3.40	32	2.81	2.89
19.5	....	......	3.52	41	4.25	3.95	62	3.96	3.87	31	3.83	3.97	33	3.45	3.40
20.5	....	......	4.11	34	4.64	4.55	69	4.53	4.50	52	4.69	4.60	36	3.97	3.95
21.5	5	4.50	4.75	27	5.36	5.21	68	5.20	5.19	49	5.43	5.30	39	4.42	4.57
22.5	4	5.75	5.47	52	6.02	5.93	73	6.05	5.94	57	6.06	6.05	39	5.02	5.25
23.5	6	6.18	6.25	63	6.91	6.70	62	6.65	6.77	54	6.90	6.88	31	5.81	5.99
24.5	8	7.25	7.11	90	7.67	7.54	57	7.64	7.68	44	7.96	7.77	42	6.70	6.81
25.5	14	7.94	8.04	128	8.32	8.44	48	8.71	8.65	42	8.66	8.74	30	7.51	7.69
26.5	13	9.42	9.05	133	9.35	9.42	61	9.48	9.71	53	9.93	9.79	35	8.56	8.64
27.5	17	10.42	10.14	160	10.37	10.46	54	10.70	10.86	49	11.30	10.92	34	9.94	9.68
28.5	18	11.48	11.31	177	11.29	11.57	65	11.87	12.08	48	12.67	12.12	35	10.57	10.79
29.5	25	12.91	12.85	170	12.58	12.75	65	13.22	13.40	54	13.79	13.42	51	12.38	11.91
30.5	25	14.40	13.94	147	14.01	14.02	69	14.53	14.81	53	15.35	14.80	40	13.29	13.26
31.5	51	15.72	15.40	134	15.27	15.35	66	15.97	16.32	70	16.94	16.27	60	14.79	14.63
32.5	80	17.36	16.95	150	16.47	16.77	66	18.20	17.92	74	18.28	17.83	69	16.09	16.10
33.5	112	18.89	18.61	140	18.18	18.27	70	19.22	19.63	81	19.50	19.50	95	17.87	17.65
34.5	130	20.30	20.37	152	20.02	19.86	66	21.51	21.44	102	21.75	21.26	91	19.09	19.32
35.5	126	22.51	22.24	202	21.79	21.53	70	23.25	23.36	104	22.85	23.12	87	20.54	21.05
36.5	122	24.20	24.22	205	23.23	23.29	70	25.13	25.39	98	25.05	25.09	75	22.38	22.92
37.5	79	26.38	26.33	169	25.33	25.14	66	27.04	27.54	102	27.18	27.16	75	24.61	24.89
38.5	45	28.27	28.55	119	27.71	27.09	66	29.38	29.80	80	29.58	29.34	66	26.67	26.97
39.5	25	31.16	30.89	76	29.64	29.13	65	32.33	32.19	71	31.70	31.64	55	28.31	29.16
40.5	14	33.25	33.36	50	32.46	31.26	53	34.21	34.70	67	34.39	34.05	56	30.32	31.47
41.5	7	37.00	35.96	33	35.76	33.50	42	37.37	37.33	53	36.18	36.59	34	33.69	33.89
42.5	5	38.62	38.69	18	38.51	35.83	36	40.37	40.10	50	40.17	39.24	36	35.77	36.44
43.5	1	38.50	41.56	9	39.52	38.27	15	45.61	43.00	26	41.87	42.01	14	38.18	39.12
44.5	2	46.50	44.57	1	37.50	40.81	3	47.37	46.03	10	46.01	44.91	10	42.5	41.92
45.5	....	......	47.72	......	......	43.46	1	50.40	49.21	2	46.25	47.94	1	46.00	44.86
46.5	....	......	51.02	......	......	46.21	....	......	52.52	......	......	51.11	....	......	47.93
47.5	....	......	54.47	1	49.50	49.08	....	......	55.99	......	......	54.40	....	......	51.14

TABLE 7. **LENGTH-WEIGHT EQUATIONS OF COLUMBIA RIVER CHINOOK SALMON, BY SEASON.**

Winter	$W=0.0003781L^{3.07062}$
Spring	$W=0.0008851L^{2.82934}$
Summer	$W=0.0005191L^{3.00166}$
Early Fall	$W=0.0006422L^{2.93911}$
Late Fall	$W=0.0003992L^{3.04622}$

SUMMARY

Columbia River chinook length-weight data were stratified by year, season, and zone in a season. Regression coefficients were tested for significant differences by analysis of covariance at the 5% significance level. Significant differences were found between years. Limited data from pure zones suggest no significant difference between zones for the spring, summer and early fall seasons, but when data were combined a significant difference was found.

Relative evaluation of pooled data indicated that, in general, individual seasons provided the most reliable estimate of regression coefficients.

A single length-weight sample from any year from one of several seasons or zones is not representative of all Columbia River chinook. For reliability length-weight samples should be stratified by year, season, and probably zone in a season. If pooling of data is necessary, the first consideration should be pooling by zone in a season.

ACKNOWLEDGMENT

Thanks are due Earl F. Pulford of the Oregon Fish Commission for advice and assistance with the analysis of the data presented in this paper.

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Wind, Nearshore Ocean Temperature, and the Albacore Tuna Catch Off Oregon

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INTRODUCTION

A considerable annual variation in the fishery for albacore tuna, *Thunnus alalunga* (Bonnaterre), exists in Oregon waters (Ayers and Meehan, 1963). Although it is commonly known that the occurrence of this species is related to water temperature (Alverson, 1961; Johnson, 1962), fishermen lack a method of predicting the catch. Recent studies by the Oregon State University Department of Oceanography on oceanographic processes along the Oregon coast suggest a correlation of tuna catches with predictable weather and oceanographic events.

Perhaps the most dramatic physical event in nearshore ocean regions adjacent to the western United States is upwelling. During the summer and early autumn, when offshore waters are warming and tuna are migrating northward or eastward in this region, predominantly northerly winds transport surface waters away from the coast. These waters are replaced from below by cooler water, hence the term "upwelling." It is reasoned that during such periods of upwelling, when surface waters are cool, the tuna are displaced offshore, while during intervals when southerly winds prevail, nearshore temperatures are higher and the fish move closer to shore and are more readily available to the tuna fleet.

METHODS

An analysis of daily temperatures of coastal sea water (obtained from the Seaside Aquarium at Seaside, Oregon), changes in wind direction (measured from daily U. S. Weather Bureau surface pressure charts for the offshore position 48°N, 130°W), and data on tuna catches for 1962-63 (obtained from fishermen by the Oregon Fish Commission) was used to explore the relationship between the wind, temperature, and tuna. These data include five-day mean wind speeds oriented in net northerly and southerly components, five-day mean water temperatures, and daily tuna catches from the region bounded by the coast, 45° to 46° N, and 125° W. For the periods when tuna catches were reported, daily values of wind and temperature are shown.

RESULTS AND DISCUSSION

Data for the summer of 1962 show the wind, temperature, and catch relationships well (Figure 1). The seasonal northerlies were interrupted in mid-August by a period of southerlies associated with the passage of a low pressure area. Relaxation of upwelling is clearly shown by the warm-

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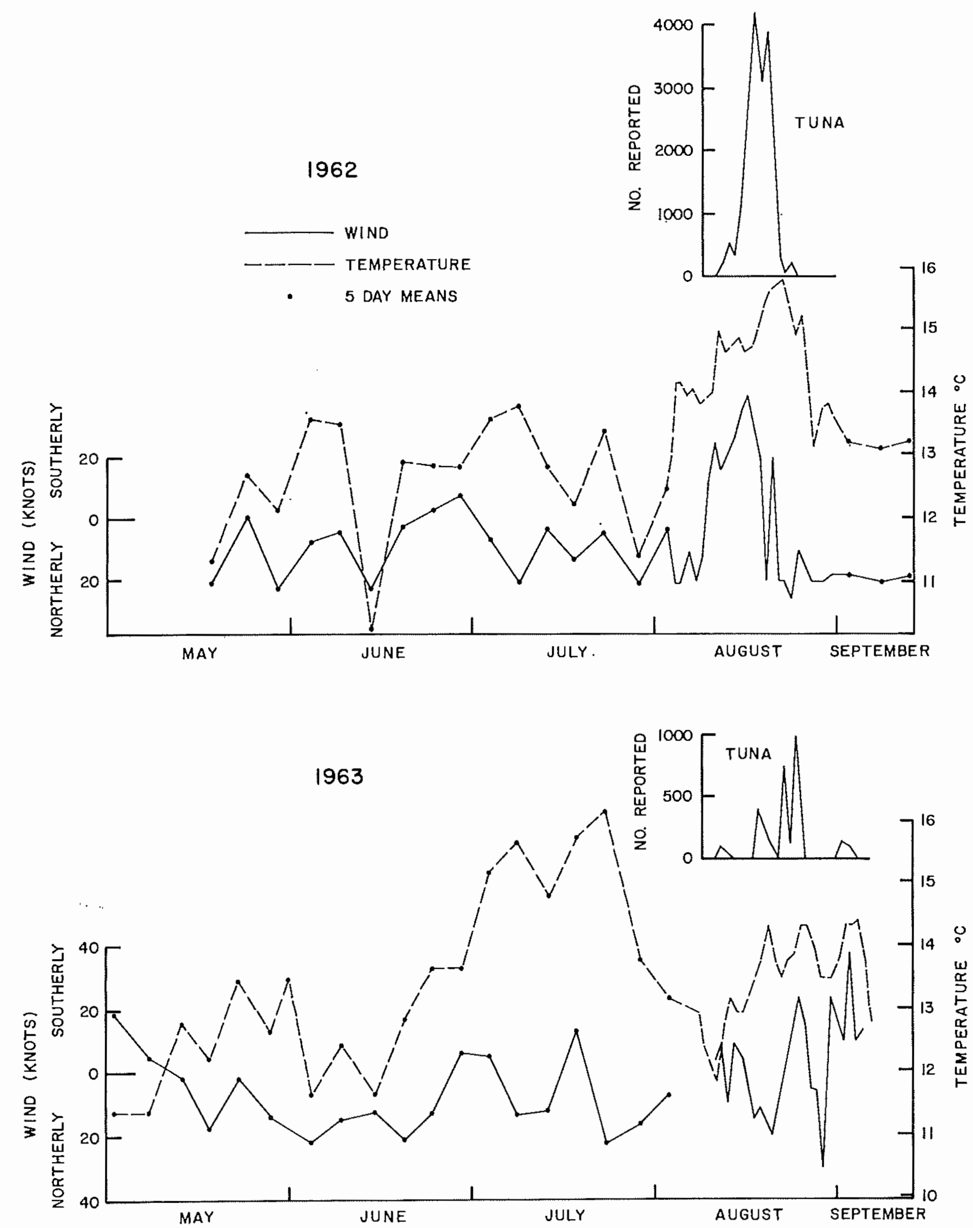

FIGURE 1. SEA TEMPERATURES AT SEASIDE, OREGON, WINDS MEASURED OFFSHORE, AND DAILY TUNA CATCH REPORTED FROM THE NORTHERN OREGON INSHORE REGION.

ing of the nearshore waters. High temperatures continued for a few days after the return of northerly winds and the tuna catch increased with the warming trend. A two-day forecast of wind direction change could have predicted this series of events and prepared the fishing fleet to take advantage of an inshore fishery.

The example just presented is perhaps an ideal one because the change in wind direction was dramatic and followed a relatively long period of upwelling. In a season where wind direction changes are frequent, there is little chance for the establishment of a pronounced upwelling situation. Changes in nearshore temperatures are then more sporadic and probably more closely related to other factors such as air-sea heat exchange and advection of transient water masses. Data for the summer of 1963 (Figure 1) may be used as an example and here it is seen that wind forecasts would have been less useful in these circumstances. During the summer of 1963 wind direction changes were frequent and the number of boats reporting tuna from the study region was smaller than in 1962—for example, 117 boats were sampled for the five highest catch days in 1962 but only 25 in 1963. The unit "boat days" represents the sum of the days each boat sampled fished in this period. Following the May and early June northerlies in 1963, two periods of southerlies resulted in high coastal temperatures. The absence of tuna catches in this period may be explained by the migratory habits of the fish which usually make them available to the Oregon fishery during August and September, or by the fact that tuna were there during the warm period in July but fishermen were not expecting them. The late July and early August northerlies resulted in a pronounced early August cooling. During August and early September, wind, temperature, and tuna catch fluctuated. The peak catch just after mid-August and the September catch appear to follow the coincident wind and temperature changes and could possibly have been predicted. In general, the 1963 data are less instructive than those for 1962.

The temperature data used here are only indicators of the reaction of the ocean to the wind. Coastal oceanography in this region is complicated by the presence of Columbia River water, especially in late summer. It must be emphasized that the temperature values observed at the Seaside site do not in themselves reflect the coastal oceanographic situation. It is the changes in these values, following wind direction changes, which serve to indicate the reaction of the ocean.

With detailed wind and temperature data, it may be possible to develop a more concise technique for predicting the nearshore availability of tuna. Based on the data examined, particularly for 1962, the following technique is suggested. In mid-summer, when the tuna fishery has started beyond the upwelling region off the coast of Oregon, or when surface temperatures beyond the upwelling region indicate that the fishery is imminent, the surface synoptic pressure charts of the Weather Bureau should be examined daily. During this season the pressure pattern generally features a high pressure area off the Pacific coast (Haurwitz and Austin, 1944) and northerly winds near the coast. The time of passage of low pressure areas (which bring southerly winds) may be predicted from a study of surface pressure charts or obtained from Weather Bureau forecasts. Intensity and duration of the southerlies expected to accompany the low will be an indication of the extent to which nearshore temperatures may be expected to rise and the confidence with which one might expect to find tuna near the coast. For example, if a slow-moving low pressure area were expected to move into the Washington-Oregon region sometime during the tuna season, and the history of previous winds indicated a prevalence of strong northerlies, a two- to five-day forecast of this low would enable tuna fishermen to prepare for favorable nearshore fishing conditions.

CONCLUSIONS

The distribution of albacore tuna is closely related to characteristics of the marine environment. Although the prediction of these characteristics involves many complexities it is shown that a large scale oceanographic event (upwelling) will under favorable circumstances overshadow these complexities and become a determinant factor. The use of wind forecasts to predict variations of upwelling, and especially its cessation, could be valuable to the fisherman in determining the possible availability of tuna in the nearshore region.

ACKNOWLEDGMENTS

This work has been supported by the Office of Naval Research under Contract Nonr 1286(10); Project NR 083-102. The author wishes to acknowledge the comments of Dr. W. G. Pearcy and Dr. J. E. McCauley of the Department of Oceanography, Oregon State University.

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Timing of Willamette River Spring Chinook Salmon Through the Lower Columbia River

JAMES L. GALBREATH

INTRODUCTION

The Willamette River, with a drainage area of 11,200 square miles, is the largest tributary of the Columbia River below the Snake River (Figure 1). Although the Willamette basin represents only about 4% of the entire Columbia River drainage, its importance as a producer of spring chinook salmon *(Oncorhynchus tshawytscha)* is demonstrated by Table 1 which shows that approximately 20% of the spring chinook migrating through the Columbia River enter the Willamette system to spawn. Principal spring chinook spawning tributaries of the system are the McKenzie, Middle Willamette, North and South Santiam, and Clackamas rivers. The Molalla, Pudding, and Calapooya rivers also support small runs.

The Willamette race of spring chinook receives a large amount of public attention because there is a popular sport fishery in the lower river. Commercial fishing has not been permitted on the Willamette River during the spring months since 1913 but Willamette fish are taken in the Columbia River gill-net fishery as well as in the ocean.

At least 75% of Oregon's human population resides in the Willamette Basin. In recent decades many environmental changes have occurred in

TABLE 1. **COMPARISON OF THE WILLAMETTE RIVER SPRING CHINOOK RUN AND TOTAL COLUMBIA RIVER SPRING CHINOOK RUN, 1946-63.**

Year	*Willamette① Run*	*Total Columbia River Spring Chinook Run②*	*Per Cent Entering Willamette River*
1946	68,600	192,450	35.6
1947	59,000	244,450	24.1
1948	40,100	165,850	24.2
1949	37,850	176,000	21.5
1950	24,800	144,400	17.2
1951	49,600	249,150	19.9
1952	67,500	313,350	21.5
1953	96,800	326,200	29.7
1954	44,400	233,100	19.0
1955	32,500	313,500	10.4
1956	77,600	293,900	26.2
1957	52,800	306,350	17.2
1958	62,800	255,400	24.6
1959	53,400	190,900	28.0
1960	24,200	158,100	15.3
1961	27,500	188,350	15.0
1962	38,200	236,150	16.1
1963	48,100	198,100	24.3
Average	50,300	245,500	20.5

① Derived by adding Willamette Falls fishway count, Clackamas River escapement, and Willamette sport fishery catch.

② Includes Willamette River run, Bonneville Dam count of spring chinook, and commercial catch below Bonneville Dam. Excludes unknown sport catch on the main Columbia River below Bonneville Dam and fish entering the Cowlitz River.

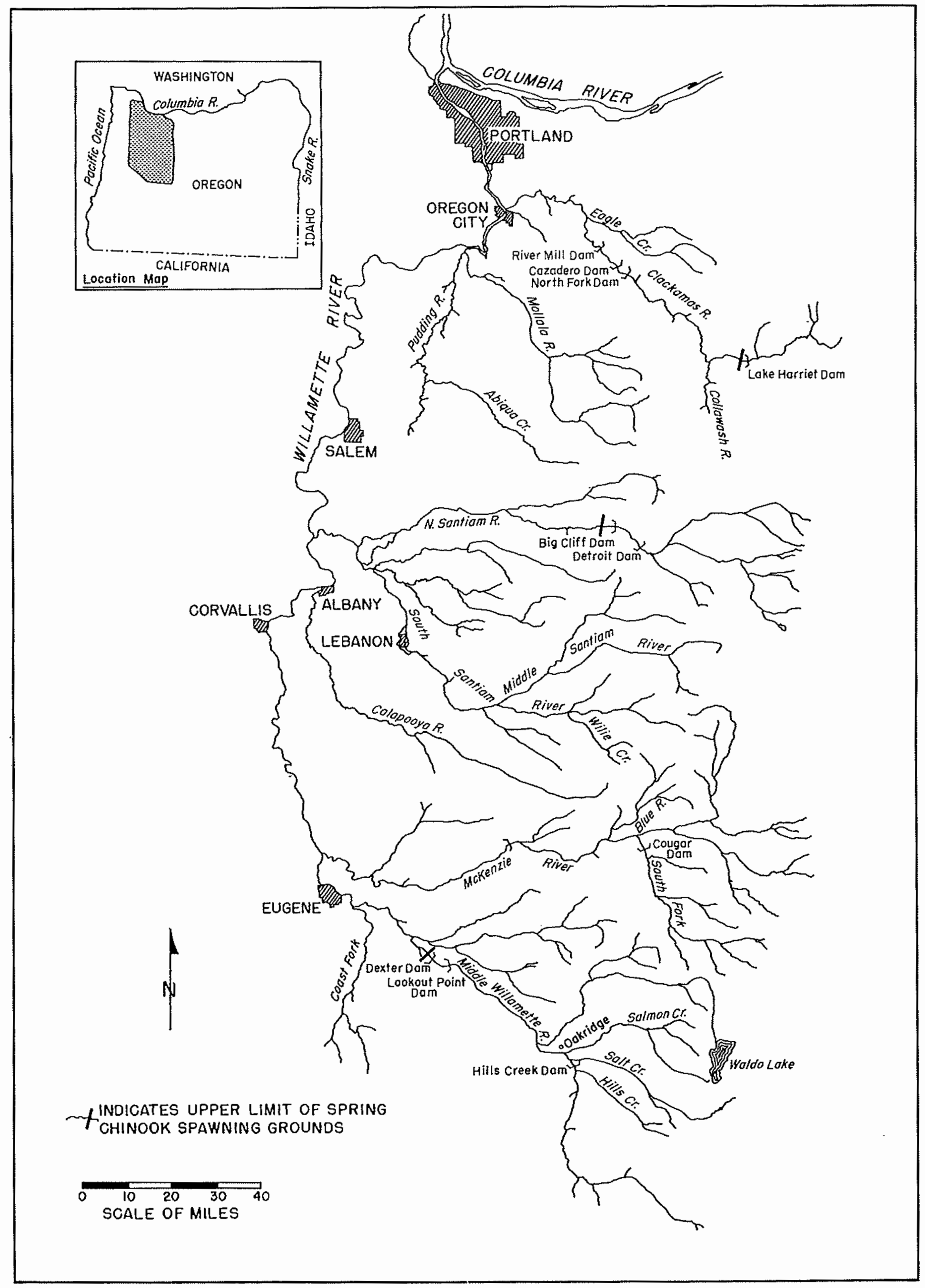

FIGURE 1. WILLAMETTE RIVER SYSTEM.

the system due to increased agriculture, industrialization, and construction of dams, all of which have adversely affected anadromous fish populations. Even so, the Willamette River remains Oregon's major spring chinook stream. Increased inroads on the productive capacity of the river, however, may make it necessary to afford this race of spring chinook special protection in the future. To do so will require an understanding of the time of migration of the fish destined for the Willamette River.

There has been no study specifically designed to define the Willamette spring chinook migration through the Columbia River and into the Willamette system. However, information available from other studies and correspondence does provide some background on the general timing of these stocks.

The purpose of this paper is to summarize pertinent information on the migration of Willamette spring chinook to provide a basis for future management of the fishery.

Correspondence prior to 1900 (Abernethy, 1886) established the presence of spring chinook in the Clackamas River in February, with the bulk of the fish entering in March and early April (as determined by the commercial fishery in operation at that time). Results from marking experiments by Rich and Holmes (1929) indicated that chinook entered the Willamette from February through May. Craig and Townsend (1946), reporting on U. S. Fish and Wildlife Service inventories of the Willamette spring chinook sport catch in 1941 and 1942, stated that the adults make a rapid migration through the lower Columbia River in February, March, and April. They felt that Willamette chinook contributed to the winter commercial fishery in the Columbia and undoubtedly were caught after April 30, when the spring season normally opens, but that no great numbers were taken since most of the run was already in the Willamette. Preliminary analysis of returns of spring chinook tagged on the lower Columbia during March and April in 1948 and 1949 indicated that Willamette runs generally had passed through the lower Columbia by April 15 (Fish Commission of Oregon, 1950) and that the bulk of the tagged fish recovered in the Willamette system had entered the Columbia during late February, March, and April. Wendler (1959) asserted, on the basis of tag recoveries in 1955, that 50% of the Willamette fish passed through the lower Columbia River before March 30.

METHODS

Information from three sources was used to document the timing of spring chinook runs in the Willamette River: (1) recoveries from tagging experiments; (2) recoveries of fin-marked fish; and (3) patterns of peak sport catch.

Tagging Studies

Spring chinook were tagged on the lower Columbia River from 1948 to 1963. Through 1956 tagging was conducted jointly by the Washington Department of Fisheries and the Oregon Fish Commission. Tagging was then discontinued and resumed in 1960 during an Oregon Fish Commission test-fishing program.[1] The first tagging was at Clifton and later in the McGowan-Astoria area up to Altoona and at Woody Island (Table 2, Figure 2). All the fish were captured by gill nets except those taken in a commercial-type trap at McGowan. Before 1960 Petersen-type plastic discs were fastened at the origin of the dorsal fin and spaghetti-tube tags were applied just below and slightly forward of the insertion of the dorsal fin. During test-fishing operations from 1960-63, fish were tagged with nylon dart-type tags between the origin and insertion of the dorsal fin. A total of 5,593 spring chinook from all sources was tagged in the years 1948-63, about 98% of them in March and April (Table 2). Recoveries were from sport and commercial fisheries, hatcheries, and miscellaneous sources (spawning grounds, traps, etc.).

TABLE 2. **NUMBERS OF COLUMBIA RIVER SPRING CHINOOK TAGGED, 1948-63.**

Tagging Location	*Date*	*Month Tagged*						*Total*
		Dec.	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May 1-15*	
Clifton	3/31-4/29/48				3	279		282
Clifton	3/10-4/26/49				112	266		378
McGowan	5/11-12/52						2	2
McGowan	3/4-5/15/53				74	199	65	338
Astoria-Altoona	12/2/54-4/25/55		9	28	551	898		1,486[1]
Woody Island	11/27/55-3/30/56	4	5		511			520[1]
Woody Island (Test Fishing)	3/15/60-4/24/63				720	1,867		2,587
Total Number Tagged		4	14	28	1,971	3,509	67	5,593

[1] Tagged during a winter steelhead program. Wendler (1959) reported on chinook and Korn (1961) on steelhead.

Marking Experiments

Mark recoveries were from releases of approximately 1.5 million spring chinook fingerlings from brood years 1946-58. Virtually all the fingerlings were released into the Middle Willamette River and tributaries. Exceptions were in 1951 and 1953 into the Row River (tributary of the Coast Fork Willamette River) in an attempt to establish a spring run in that stream, and the 1953-brood fish of McKenzie River origin put back into the McKenzie River. These marking experiments were designed primarily to: (1) determine effect of time of liberation on survival of fingerlings; and (2) compare survival of fish fed normal hatchery diet with those fed the Oregon pellet diet.

Recoveries of marked fish were made while sampling landings of the Columbia River gill-net fishery at various canneries in Astoria and Portland during the winter and spring commercial seasons. Fish were also checked for marks during test fishing in March and April 1960-63. Because only sporadic sampling programs were conducted on the sport fishery, most of the sport returns were on a voluntary basis.

[1] Annual program to determine time of migration of spring chinook used in setting the opening date for the commercial gill-net season.

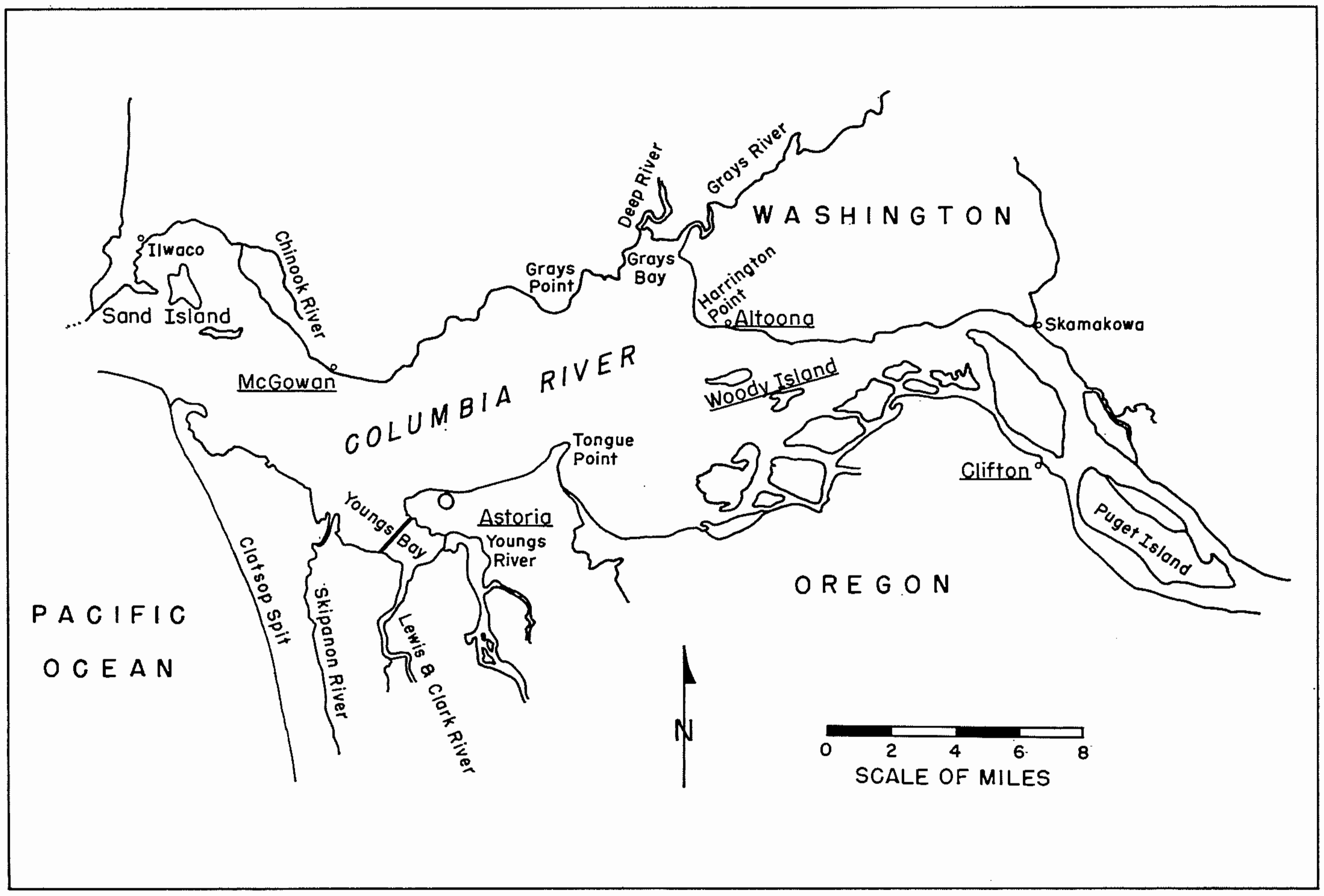

FIGURE 2. LOWER COLUMBIA RIVER TAGGING SITES, 1947-63.

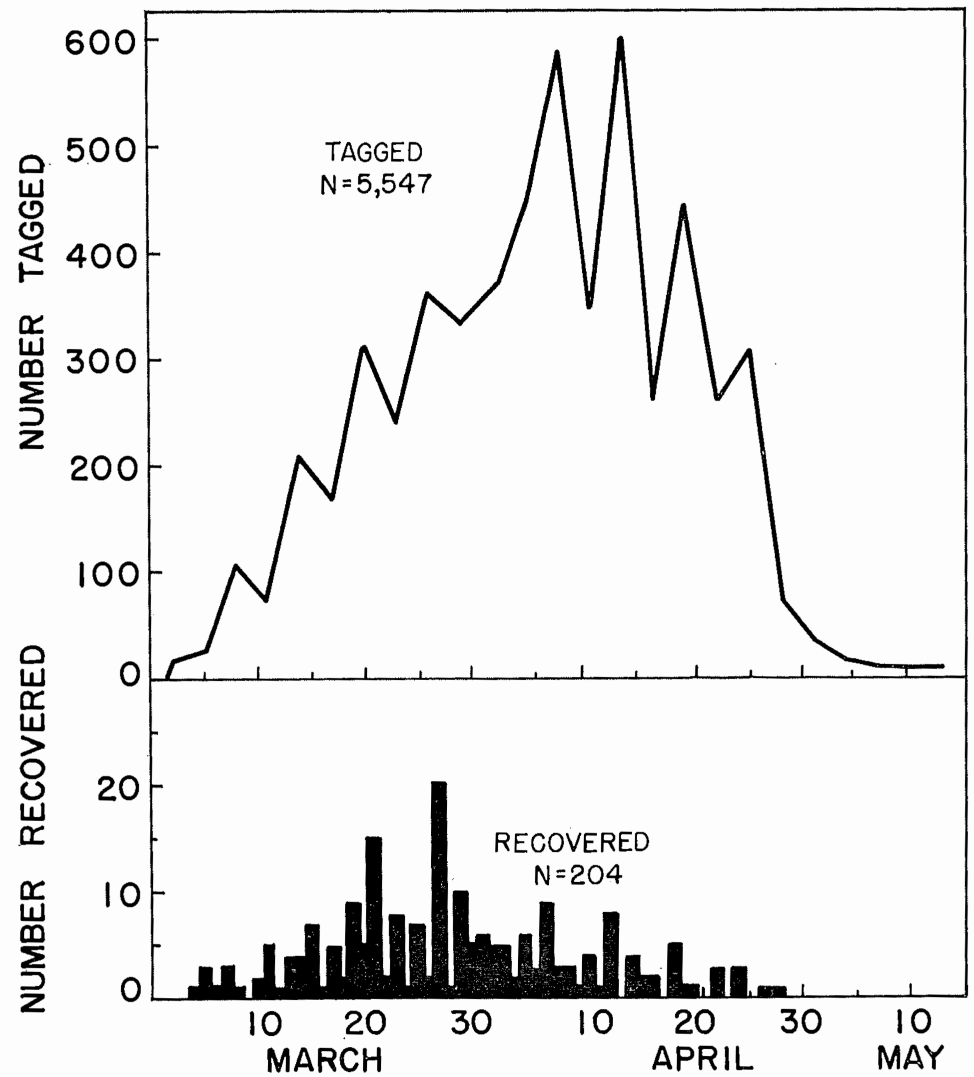

FIGURE 4. NUMBERS OF SPRING CHINOOK TAGGED IN THE COLUMBIA RIVER AND NUMBERS RECOVERED IN THE WILLAMETTE RIVER BY DATE OF TAGGING, MARCH 1-MAY 13, 1948-63.

Fish tagged in May were not recovered in the Willamette River, but the commercial fishery in the Columbia captured 38 of 67 fish tagged, all below the Willamette, suggesting that some might have been destined for the Willamette System.

Figure 5 depicts tag recoveries in the Willamette River and tributaries by date of tagging from March 4 to April 28 (excluding one fish tagged on February 9 and recovered in the McKenzie River). The sport fishery provided 133 (65%) of the total tag recoveries, hatcheries recovered 68 (33%), and 4 (2%) were recovered from fishways or found dead in tributaries.

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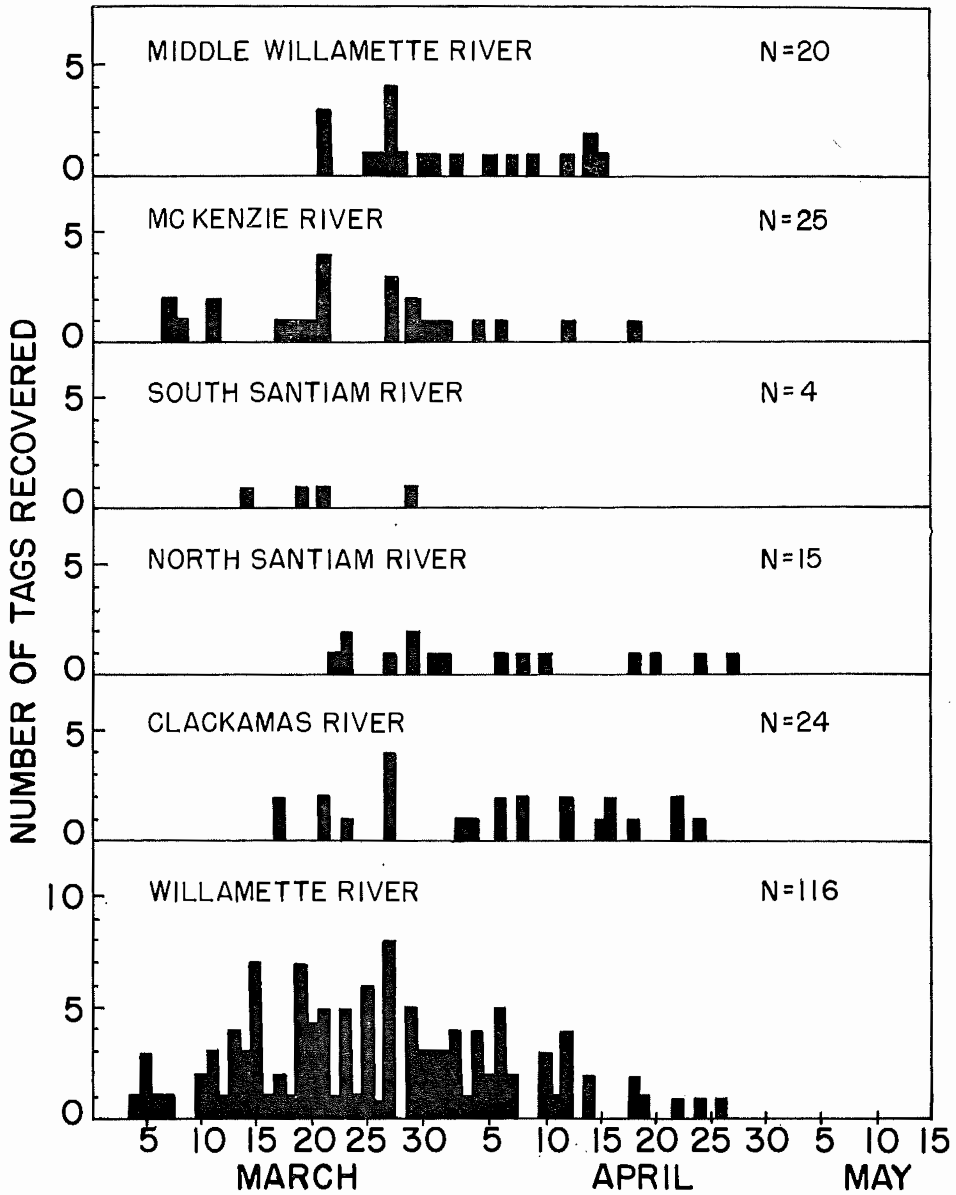

FIGURE 5. TAG RECOVERIES BY DATE OF TAGGING FOR THE WILLAMETTE RIVER AND TRIBUTARIES, 1948-63.

The majority of the recoveries were from the main Willamette River where the sport fishery is concentrated. Most of the fish recaptured in tributaries were taken at the hatcheries, particularly the Oregon Fish Commission Willamette Hatchery on the Middle Fork of the Willamette and the U. S. Fish and Wildlife Service Eagle Creek Hatchery on the Clackamas River. The majority of the McKenzie River recoveries, however, were made by sport fishing.

Lack of a large number of tributary recoveries precluded making definite statements on timing of tributary races, but based on available recoveries it appears that the earliest fish passing into the Willamette River are possibly headed for more distant tributaries such as the McKenzie River; the Middle Willamette, Santiam, and Clackamas rivers appear to contain later arriving fish.

Mark Recoveries

Mark recoveries are summarized in Table 4 by month and method of recovery. A total of 1,274 marked fish was recovered from all sources except the ocean fisheries during 1953-63.

TABLE 4. **RECOVERIES OF WILLAMETTE SPRING CHINOOK MARKED AT THE MIDDLE WILLAMETTE HATCHERY, 1951-63.**

	Month					
Method of Recovery	*Feb.*	*Mar.*	*Apr.*	*May 1-15*	*Other*	*Total*
River Sport	3	9	56	11	....	79①
River Gill Net	50	9	81	119	....	259
Test Fishing	....	5	10	....	....	15
Hatchery	....	....	....	....	916	916
Other	....	....	1	4	....	5
Combined	53	23	148	134	916	1,274

① Six recoveries were made in the lower Columbia River below the Willamette and 73 in the Willamette River system.

In the winter season, 23,220 fish were examined and 59 marks were recovered, a ratio of 1:400. Marked chinook destined for the Willamette system entered the lower Columbia River as early as February 2. However, only 10 of the 29 recoveries in February were made before the 15th during the years prior to 1959 when the commercial fishing season extended through the entire month of February. After 1958 the first two weeks of February were closed to commercial fishing and 21 recoveries were reported in the latter part of the month. The closing date of the winter season has always been March 1, and 9 marks were recovered on this day in the period 1951-63.

Approximately 301,000 fish were examined in the Columbia River spring commercial fishing season and 200 marks were found, a ratio of 1:1500. The April recoveries (81) were from only 1 to 4 fishing days because the season opens late in the month, whereas the May recoveries (119) came from catches up to the middle of the month. The numbers of fish sampled in April were therefore relatively small compared to the May sampling. More marks would have probably been recovered in April than May had equal fishing days been allowed each month. The observed change in the marked to unmarked ratio from February-March to April-May indicates a dilution of Willamette River chinook by other races as the season progresses. This suggests that Willamette fish are relatively more abundant early in the spring compared to the main portion of the Columbia River spring run.

During test-fishing operations from 1959-63, 15 marked chinook were found from examination of 4,214 fish, a ratio of 1:280. These fish were released and may have been taken again by another method. Three-fourths of the mark recoveries by test fishing were made prior to April 15.

Of 79 marked fish reported by sport fishermen only the 6 captured in the lower Columbia River could be used to denote timing; 5 were recovered in March and 1 in April. It must be emphasized that the number of sport recoveries cannot be compared with other recoveries as no concentrated recovery program was in effect.

Peak Periods of Sport Catch

The sport catch in the Willamette River does not provide a precise indication of the timing of the run because angling apparently is affected by river flow, Columbia River backwater, turbidity, fish passage conditions at Willamette Falls, and perhaps in some years by the opening of the gill-net season on the Columbia River. However, sport catches can be used in a general way to show the time of arrival of chinook into the Willamette.

The weekly sport catch in the lower area of the Willamette River for each year from 1946-63 is shown in Figure 6. The periods of peak catches provide an indication of when the bulk of the run was present in this area. Peak catches in the 18 years shown vary considerably between years, but have occurred from the second week in April to the first week of May. In general the highest level of sport take has been reached in advance of the opening of the commercial season (week of April 27-May 3) and catches begin to decline well before that date. It might be concluded that the main body of the run moves into the Willamette River in April. In certain years of late or delayed runs, however, such as 1955 and 1960 the commercial fishery may have influenced the week of peak catch. An artifact is created in the later peak catches because many sport fishermen cease to fish the lower Willamette after the commercial fishery commences in the belief that fish are no longer available.

SUMMARY AND CONCLUSIONS

Recoveries of tagged and marked fish and sport catches were used to add to early preliminary information on the general timing of adult Willamette River spring chinook through the lower Columbia River and into the Willamette River.

A total of 5,593 spring chinook was tagged in the lower Columbia River from 1948-63. Recoveries in the Willamette River system totaled 205 (3.7%). All but one of the recoveries were from fish tagged in March and April. Recoveries by date of tagging indicate that the major portion of the Willamette spring chinook run is present in the lower Columbia River in March and early April. Approximately 92% of the recoveries were from fish tagged before April 15.

About 1.5 million fin-clipped spring chinook were released into the Middle Willamette River (or its tributaries) from brood years 1946-58. Recoveries were obtained from commercial and sport fisheries, test fishing, and at the Fish Commission's Willamette River Hatchery. Approximately 324,000 chinook were examined for marks from 1951 to 1963 during

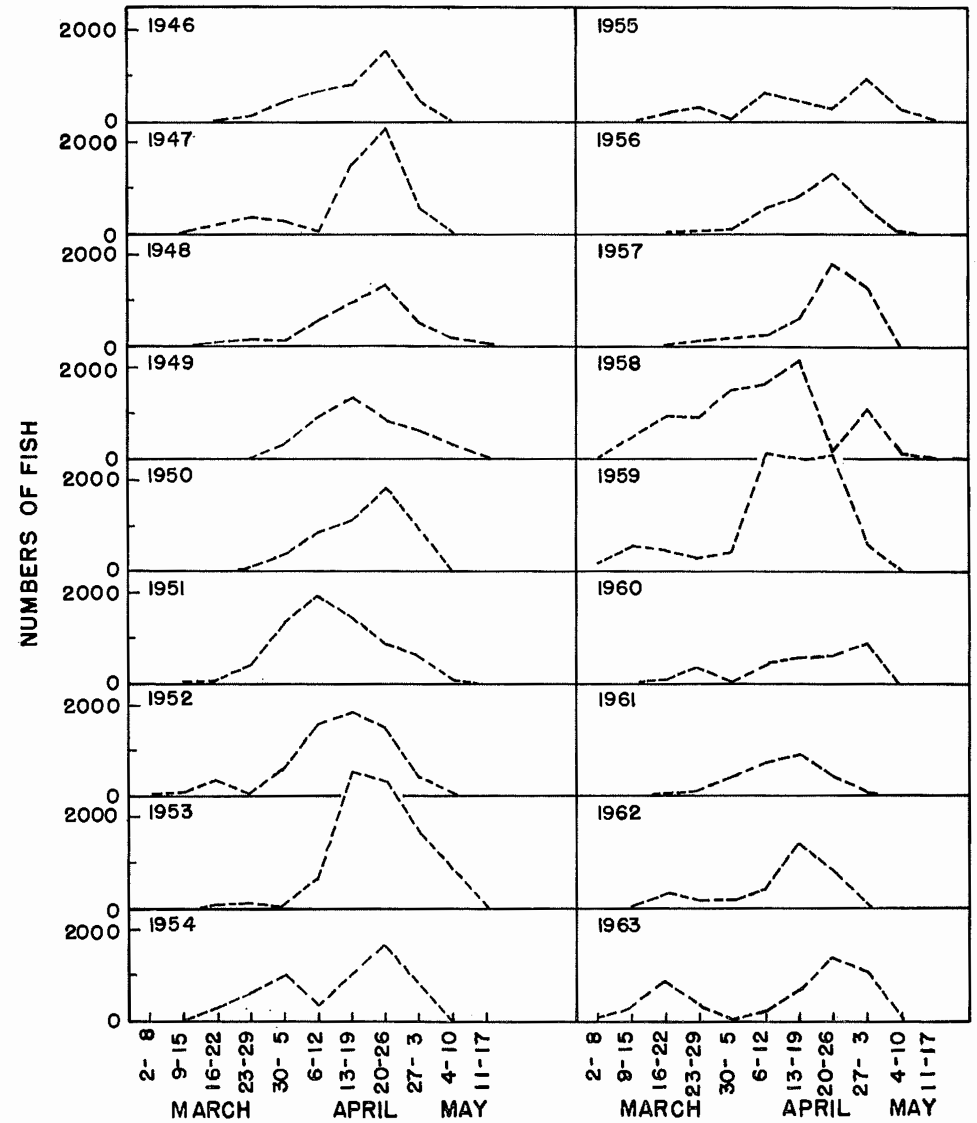

FIGURE 6. WEEKLY SPORT CATCH OF SPRING CHINOOK IN THE WILLAMETTE RIVER BELOW ROSS ISLAND BRIDGE, MARCH 2-MAY 18, 1946-63.

winter and spring commercial fishing seasons. In the winter seasons (February-early March), 23,220 chinook were checked and 59 marks recovered, a ratio of 1:400. In the spring seasons (late April-May, 301,000 were examined and 200 marks were recovered, a ratio of 1:1500. Examination of 4,214 chinook during test fishing in March-April 1959-63 yielded 15 marked chinook, a ratio of 1:280. Seventy-nine sport recoveries of marked fish were reported, but only 6—5 in March and 1 in April—were from the lower Columbia River and could be used in an analysis of timing. Mark recoveries indicated that the Willamette Hatchery stocks pass through the lower Columbia River from February through May with a suggestion of an earlier timing than the other components of the Columbia River spring run.

Sport catch data from the lower Willamette indicated that although chinook are caught from February to June, the weekly peak catch has been in April.

Results from these three sources—recoveries from tagging experiments, recoveries of marked fish, and study of sports catch—may be modified to an unknown extent by the commercial gill-net fishery. However, these data analyzed in this report indicate that the majority of Willamette spring chinook migrate through the lower Columbia during late March and early April and show peak abundance in the lower Willamette in April. This confirms work of earlier investigators such as Rich and Holmes (1929) and Craig and Townsend (1946) who noted the time of migration of the Willamette run at approximately this same period.

ACKNOWLEDGMENTS

The writer wishes to thank his co-workers for providing mark recovery information and for data on the sport catch in the Willamette River.

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Western North American Crawfishes (Pacifastacus) In Brackish Water Environments[1]

GEORGE C. MILLER[2]

INTRODUCTION

During a study of the western North American fresh-water crawfishes, some specimens of *Pacifastacus leniusculus* (Dana) and *Pacifastacus trowbridgii* (Stimpson) were found in brackish water. The purpose of this paper is to review literature reporting fresh-water crawfishes in brackish areas, list brackish areas in the western United States where *Pacifastacus* species are found, substantiate migration of crawfishes from brackish to fresh water in the lower Columbia River, present observations on crawfishes in brackish water, and list the fauna associated with crawfishes in a tributary of the Columbia River estuary.

REVIEW OF LITERATURE

Three species of the European fresh-water crawfish, genus *Astacus,* occur in brackish water. Huxley (1880) reported that *Astacus astacus* (Linnaeus), under the name of *Astacus nobilis* (Schrank), "is said occasionally to be met with on the Livonian coast in the waters of the Baltic, which, however, it must be remembered are much less salt than ordinary sea water"; *A. leptodactylus* Eschscholtz, "not only thrives in the brackish waters of the estuaries of the rivers which debouche into the Black Sea and the Sea of Azov, but that it is found even in the salter parts of the Caspian in which it lives at considerable depths"; and *A. pachypus* Rathke, "In the Caspian and in the brackish waters of the estuaries of the Dniester and the Bug, a somewhat different crayfish, which has been called *Astacus pachypus* occurs."

Western North American crawfish have been reported from brackish waters in Washington and California. Cooper (1860) found *P. trowbridgii* in streams running into Shoalwater Bay (now called Willapa Bay), Washington, and stated, "It sometimes gets into the brackish water of the bay, but probably returns to the fresh streams as soon as possible." Collins (1892) reported lobsters in Monterey Bay, California, during the rainy season, but Smith (1896) noted that such specimens captured during the summer were identified by Professor Charles H. Gilbert as fresh-water crawfish. Faxon (1898) identified a form intermediate between *P. leniusculus* and *P. trowbridgii* as *P. trowbridgii* and added that "this large female had been taken from a bunch of seaweed in salt water at Monterey, California." Riegel (1959) noted that on one occasion *P. leniusculus* was collected in California in dilute brackish water.

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[1] Contribution No. 74, U. S. Bureau of Commercial Fisheries Biological Laboratory, Brunswick, Georgia. Based upon portions of a thesis accepted by the Graduate School, Oregon State University, 1960, in partial fulfillment of the requirements for the degree of Master of Science.

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Four species of the eastern North American crawfish are known to occur in brackish environments. Penn (1943) reported that *Procambarus clarkii* (Girard) "extends even down to the coastal marshes, if they are not more than slightly brackish." In another study Penn (1956) said that "A number of collections of *P. clarkii* have been made in slightly brackish marshes and along the shores of Lake Pontchartrain where salinity ranged as high as $6^0/_{00}$. In this connection it is worth noting that Helff (1929, 1931) using mature specimens and Steeg (1942) using juveniles demonstrated that *P. clarkii* can survive laboratory tests for a week in 1.17 and 1.5 per cent solutions (11.7 and $15.0^0/_{00}$) of NaCl respectively, but are killed in significant numbers by stronger NaCl solutions."

In referring to *Procambarus pycnogonopodus* Hobbs in Florida, Hobbs (1942) said that "In Walton County, about 16 miles east of Niceville, a small stream from a flatwoods pond flows into the bay. Here several specimens of *pycnogonopodus* were taken from the stream proper, and one was taken about 50 yards from the mouth of this stream in Choctawhatchee Bay, where the water is definitely brackish. Several clear streams also flow into the bay from its northern shore in Walton County. In several of these *pycnogonopodus* was collected within 15 yards of the bay."

Referring to *Cambarus uhleri* Faxon, Faxon (1884) remarked, "It is found in salt marshes, covered twice daily by the tides, and also in brackish and fresh-water ditches in company with *C. blandingii*."

The Asiatic crawfish, *Cambaroides schrenckii* Kessler, also may occur in brackish water since this species and the brackish water crustaceans, *Crangon septemspinosa* Say, *Mesidotea entomon orientalis* Gurianova, and *Pagurus capillatus* Benedict, were all found in the stomach contents of white whales by Tomilin (1957).

OCCURRENCE OF P. trowbridgii AND P. leniusculus IN BRACKISH AREAS

The localities where crawfishes were captured in brackish water in Oregon and Washington are given in Table 1, and the localities in the Columbia River estuary are shown in Figure 1.

MIGRATION BETWEEN BRACKISH AND FRESH WATER

Upstream and downstream migrations of crawfish occur in some of the streams entering brackish water in Oregon and Washington. Henry (1951) reported a downstream movement of *P. klamathensis* (Stimpson) in the spring and an upstream migration in the fall in Spring Creek, a tributary of the coastal Wilson River in Oregon. All the crawfish collected in Spring Creek were *P. trowbridgii,* as confirmed by Dr. James Lynch of the University of Washington.

Dr. Ernest Salo of Humboldt State College, and R. E. Noble of Washington State Department of Fisheries (in litt.) reported a definite downstream movement of crawfish in the spring at the Minter Creek weir in Washington. Other members of the Washington Department (in litt.)

TABLE 1. **LOCALITIES WHERE CRAWFISH WERE CAPTURED IN OREGON AND WASHINGTON IN BRACKISH WATER.**

Species	*Locality*	*County*	*State*
Pacifastacus trowbridgii	Columbia estuary, at Megler and Fort Columbia	Pacific	Wash.
"	Columbia estuary, beneath docks at Astoria	Clatsop	Oregon
"	Skipanon River, under U. S. Highway 101 bridge	"	"
"	Youngs River, immediately upstream from U. S. Highway 101 bridge	"	"
"	Creek, entering Youngs River at the Astoria garbage dump	"	"
"	Walluski River, beneath Oregon State Highway 202 bridge	"	"
"	Alder Creek, under highway bridge between towns of Warrenton and Hammond	"	"
"	Necanicum River at Seaside	"	"
"	Siuslaw River, in tidal pool 1 mile above U. S. Highway 101 bridge	Lane	"
"	Chinook River, at Prest Farm	Pacific	Wash.
"	Wallicut River, under U. S. Highway 101 bridge	"	"
"	Bear River, at lime quarry	"	"
"	Naselle (Nasel) River, immediately above town of Naselle	"	"
"	Middle Nemah River, under U. S. Highway 101 bridge	"	"
"	Deep River, at Peters-McKinnon log dump	"	"
Pacifastacus leniusculus	Columbia estuary, beneath docks at Astoria	Clatsop	Oregon
"	John Day River, beneath U. S. Highway 30 bridge	"	"
"	Deep River at Peters-McKinnon log dump	Pacific	Wash.

stated that crawfish move downstream through the weir at North Nemah River hatchery in spring and early summer. Dr. Donald Chapman found (in litt.) that crawfish move downstream in the spring through a weir in a tributary of the Alsea River in Oregon. All the specimens I examined from Minter Creek, Alsea River, and North Nemah River were *P. trowbridgii.*

Many small creeks and streams where *P. trowbridgii* is found flow into the Columbia River estuary. Because there are no weirs near the mouths of these streams, it cannot be determined if a downstream movement occurs in the spring. It may be only surmised that the crawfish from these tributaries have the same general migration pattern as those cited for this species in coastal areas.

Within a short period of time, crawfish definitely migrate in the fall from the brackish Columbia estuary into fresh-water creeks and rivers. Whether this migration includes the total population in the estuary or only a part is not known. The migration is well known to many people of the Astoria region who engage in a sport fishery for the crustaceans along the shore (also reported to me by Dr. George Y. Harry, Jr., Edwin Niska, and Eldon Korpela of the Oregon Fish Commission in Astoria, and Russell Sinnhuber and Duncan Law of Oregon State University).

In early November 1957, personnel at the Columbia River Packers Association's Elmore Cannery on the Columbia River at Astoria (Figure 1) were seen lifting traps loaded with barnacled crawfish. One of the workers

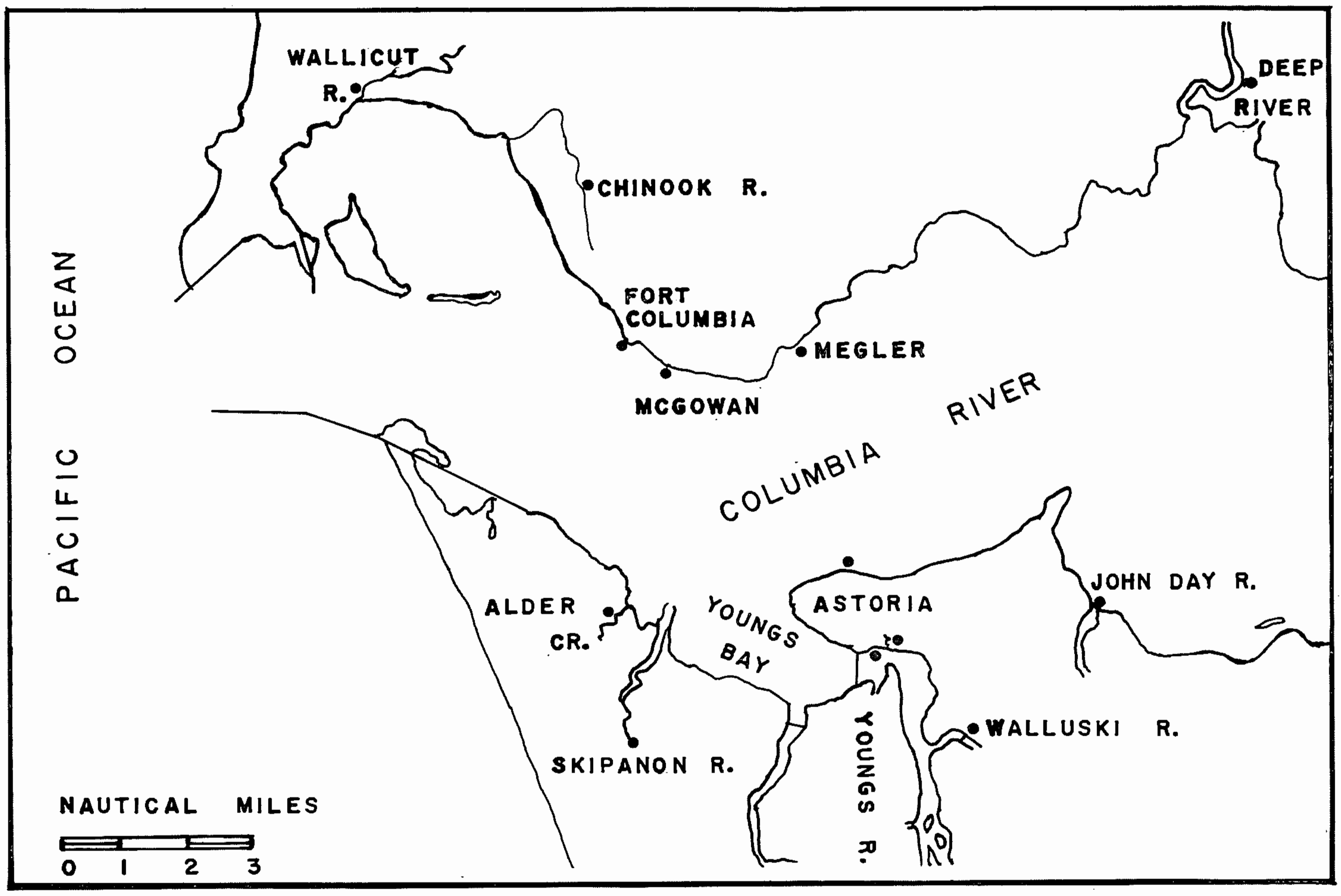

FIGURE 1. BRACKISH WATER AREAS IN THE LOWER COLUMBIA RIVER WHERE CRAWFISHES WERE CAPTURED.

1955 to November 1957, in about 20 feet of water at the Peters-McKinnon log dump. Salinities were measured by a standard hydrometer. Only the data pertinent to this report are given here.

During the investigation salinity was unusually high in Deep River, ranging from 12.8‰ to 13.7‰ between May 19 and July 29, 1956. During a comparable period in 1957 the salinities in the same area ranged from 0.2‰ to 0.6‰, comparable to those reported by Burt and McAlister (1959) in their study of the Columbia River estuary.

The trap catch, reproduction, and growth of *P. leniusculus* in Deep River, when compared with that of populations found in other areas, did not appear to be affected by the high salinity in Deep River in 1956. During the period from May 19 to September 30, 1956, when the bottom water temperatures were warm, varying between 16 to 22 C., crawfish were actively entering the traps and feeding. Seven trap samples taken between June 15 and September 30 yielded 2,702 specimens, an average of 386 per sample. In both *P. leniusculus* and *P. trowbridgii* increasing feeding activity, as evidenced by increasing trap catch, can be correlated with rising bottom water temperatures in spring and summer, while the converse is true in the fall and winter.

Andrew's (1907) speculation that female *P. leniusculus* become ovigerous in October agrees with my findings for the population of this species in Deep River. A sample from Deep River, taken on September 30, 1956, yielded no ovigerous females but such females occurred in the sample taken on November 3. Six samples taken from Deep River between November 3, 1956 and March 22, 1957 produced 182 females, of which 75 were ovigerous.

Moulting is indicative of growth in crawfish. The criteria used for determining the time of moulting in Deep River were based on texture and coloration of the carapace and chelipeds. All specimens that had undergone a recent moult were light brown in color and tinged blue ventrally, whereas those that had not moulted recently were dark brown to black and lacked the blue ventral tinge. Recently moulted crawfish were classified in three categories: (1) soft, those in which the carapace was still soft and spongy; (2) semi-hard, those in an early post-moult condition in which the carapace had hardened on the dorsal surface but was still semi-soft laterally; and (3) hard, those in a late post-moult condition with the carapace completely hardened but distinguishable by the light brown exoskeleton tinged with blue. Lateral pressure on the sides of the carapace of a semi-hard crawfish would cause an indentation which disappeared after the pressure was released. The crawfish catch in Deep River on July 29, 1956 consisted of 7 males and 11 females in a soft condition, 2 males and 9 females in a semi-hard condition, and 6 males and 11 females in a hard condition.

FAUNA ASSOCIATED WITH CRAWFISH IN YOUNGS RIVER

The barnacles on the crawfish in the estuary were identified by Dr. William Newman of the University of California as *Balanus improvisus*. Dr. Ralph Smith, also of the University of California, noted (in litt.) that this species is not an indicator of any particular salinity although it suggests that the water was not quite fresh.

The fishes captured with *P. trowbridgii* in traps and trawls in Youngs River are commonly found in estuarine environments with the exception of the longfin smelt which is catadromous. They included Pacific staghorn sculpin, *Leptocottus armatus* (Girard); prickly sculpin, *Cottus asper* Richardson; shiner perch, *Cymatogaster aggregata* Gibbons; starry flounder, *Platichthys stellatus* (Pallas); juvenile English sole, *Parophrys vetulus* Girard; and longfin smelt *Spirinchus dilatus* Schultz and Chapman. In reporting on *Cottus asper,* McAllister and Lindsey (1960) noted that "its wide range may be attributed in part to its tolerance of brackish water."

ACKNOWLEDGMENTS

Thanks are due to Howard McKinnon for the use of his boating facilities and wharves at Deep River, Washington; Clyde Sayce of the Washington Department of Fisheries for his assistance with salinity determinations and cooperation on the Deep River study; and Dr. William Newman and Dr. Ralph Smith for identifying and providing information on *Balanus improvisus.* Some members and associates of the Oregon Fish Commission research staff cooperated in the study. Dr. Horton H. Hobbs, Jr., U. S. National Museum, reviewed the manuscript and gave helpful suggestions and criticisms.

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Occurrence of Small Chinook Salmon in Stomachs Of Spent Adult Chinook Salmon

Surveys of adult spring chinook salmon *(Onchorhynchus tschawytscha)* were conducted on Lookingglass Creek, a tributary of the Grand Ronde River in northeastern Oregon, during the 1964 spawning season. Carcasses of spent fish were examined to determine sex and completeness of spawning. On August 31, while opening the body cavity of a 28-inch male, the stomach was accidentally cut open, exposing 2 small chinook. The ingested fish measured 95 and 100 mm fork length and scale patterns indicated they were in their second year of life. Both appeared to have been dead for some time, and it was impossible to determine the sex of the larger one. The smaller fish was a male with mature testes. On September 11 the stomach of a 27-inch female was accidentally opened and found to contain a chinook 95 mm long, apparently in its second year of life, and also a male with mature testes.

These observations show that spawning or spent adult chinook salmon of both sexes occasionally ingest small salmon. The frequency of and reasons for this predation are not known. However, the fact that two of the three ingested fish were mature males leads to the speculation that they were attempting to participate in the spawning act when they became victims of the inhospitable adult spawners.

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New Northern Record for Ocean Whitefish

The incidence of ocean whitefish *(Caulolatilus princeps,* Jenyns) in waters north of 42° north latitude is not recorded in the literature. Roedel (1953) stated that *C. princeps* was uncommon north of Point Conception, California, while Radovich (1961) noted that two specimens were collected off the Farallon Islands in 1957. Jow (1963) extended the northern range to northern California with the capture of a specimen off Redding Rock. Since 1951 five specimens have been captured off the coasts of Oregon and Washington by trawlers and represent northern extensions of the published range for this species.

A specimen taken off Willapa Bay, Washington, on July 29, 1951 represents a range extension of 330 miles and establishes the present known northern limit. This 416 mm (total length) fish was captured in 45 fathoms by the vessel *Trask* at 46°32′ to 46°43′ north latitude and 124°26′ west longitude and was given to the Oregon Fish Commission by the vessel's skipper, Captain Al Mather.

Four other specimens are known to have been caught off the Oregon coast: one off Cape Blanco in 1963, the second off the Columbia River in 1963, another off Tillamook Head in 1965, and the fourth off Cascade Head in 1965. All specimens landed in Oregon were identified by the descriptions of Jordan and Evermann (1898) and Roedel (1953). Data for the Cape Blanco specimen was obtained from the California Department of Fish and Game.

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First Occurrence of Bigeye Tuna on the Oregon Coast

The range of the bigeye tuna *(Thunnus obesus,* Lowe) in the Pacific Ocean was described by Kishinowye (1923), Jordan and Evermann (1926), Fowler (1928), and Brock (1949) as the waters of Japan and the Hawaiian Islands. All these writers except Brock also reported on the presence of bigeye tuna in the eastern Pacific, but their descriptions do not provide enough information for positive identification. Verification was made by Godsil and Byers (1944) on the strength of captures in the Galapagos Islands area. Roedel (1953) described its range as the Galapagos Islands to Guadalupe Island and Alijos Rocks. Shimada (1954) recorded a southern extension of the range to 200 miles south of the Galapagos Islands. Radovich (1961) reported an extension of the range to Iron Springs, Washington (47°10′ N. Lat.) in 1959 as well as the first California occurrence southwest of Cape Mendocino.

The presence of bigeye tuna in temperate waters of the northeastern Pacific Ocean was reconfirmed on April 21, 1963 when a live 36-inch, 40-pound female was found in a tide pool about 8 miles south of the Columbia River by Bonnie Pedersen and Gordon Smith of Gearhart, Oregon. Identification was made from descriptions by Godsil and Byers (1944) and Brock (1949).

The U. S. Bureau of Commercial Fisheries (Renner, 1963) reported that average water temperatures recorded off the Oregon coast beyond the 50 fathom line for April 1963 were several degrees higher than the long-term average. Temperatures shoreward of the 50 fathom line, however, were a fraction of a degree cooler than the long-term average. From April 14 to 27, the Seaside Aquarium, about 14 miles south of the Columbia River, recorded temperatures of 49-52 F. in their water supply from the 0 fathom line.

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