

**NOAA-NMFS-2013-0056**  
**Docket No. 130321272-4020-01**

**EXHIBIT I TO THE  
PEER REVIEW COMMENTS  
OF MIAMI SEAQUARIUM**

**May 23, 2014**

ECOLOGICAL RESERVES COLLECTION  
GOVERNMENT OF BRITISH COLUMBIA  
VICTORIA, B.C.  
V8V 1X4

Robson Bight (Michael Bigg)

Ref. No.:

**336**

ECOLOGICAL RESERVES COLLECTION  
GOVERNMENT OF BRITISH COLUMBIA  
VICTORIA, B.C.  
V8V 1X4

PRELIMINARY REPORT

Abundance and movements of killer whales off eastern and  
southern Vancouver Island with comments on management.

by:

Michael A. Bigg

Ian B. MacAskie

Graeme Ellis

*20P*

Arctic Biological Station

Ste. Anne de Bellevue

Quebec

Not to be cited in publication without permission of authors.

March 8, 1976

#### ADDENDUM

New information collected since this report was written is as follows:

1. Add to Table 2 a new encounter for pod J in June, pod K in April and March and pod L8 in April. Thus pod K was sighted during 11 of 12 consecutive months and pod L8 during 9 of 12 consecutive months.
2. Add to Tables 2, 4 and 6 a new pod, designated "pod S", which was captured by Sea World in Budd Inlet, Puget Sound on March 7, 1976. It contained 5-6 individuals, none of which were calves or large bulls. A calf and bull were reportedly associated with the pod prior to capture but were not photographically recorded thereafter. All but 2 whales escaped or were released with the remaining 2 individuals radio tagged and later released by the University of Washington. In all probability, this was a new transient pod to the community territory of Georgia Strait -- Puget Sound -- Juan de Fuca Strait.
3. In April, 1976, the National Marine Fisheries Service, Marine Mammal Laboratory, Seattle began a photograph census of killer whales in Puget Sound, Juan de Fuca Strait and Georgia Strait. The study will continue at least until September, 1976.

July 13, 1976.

TABLE OF CONTENTS

	<u>Page</u>
Abstract .....	iv
Introduction .....	1
Methods .....	1
Results .....	2
1. Evidence for individual identification .....	2
a. Dorsal fin .....	3
b. Saddle patch .....	3
c. Injuries .....	3
2. Pod definition .....	4
3. Number of pods .....	5
a. Eastern and southern Vancouver Island .....	5
b. Georgia Strait -- Juan de Fuca Strait -- Puget Sound ....	5
c. Campbell River -- Bella Bella .....	6
4. Pod movements .....	6
a. Eastern and southern Vancouver Island .....	6
b. Georgia Strait -- Juan de Fuca Strait -- Puget Sound ....	7
c. Campbell River -- Bella Bella .....	8
5. Large groups off southern Vancouver Island .....	9
6. Pod composition .....	12
7. Pods cropped .....	12
8. Recruitment .....	13
9. Original population size .....	15
10. Future research .....	15
11. Management .....	16
a. Fishery value .....	16

Table of contents (cont'd)

	<u>Page</u>
b. Aesthetic and recreational values .....	17
c. Regulations in 1975 .....	18
d. Future considerations .....	18
Acknowledgements .....	19
References .....	20

ABSTRACT

A new method for photographically identifying individual killer whales was used during 1972-75 to provide the first reliable information on abundance and movements off eastern and southern Vancouver Island. Data were collected from 304 encounters with 19 pods, totalling 210 whales. A pod is a permanent family unit containing up to 20 individuals. Based on a rapid decrease in the frequency of new pod discoveries few, if any, other pods frequent the area.

The pattern of pod movements suggests two community territories off eastern Vancouver Island with a boundary across northern Georgia Strait. Individual pods do not have exclusive territories. In the Georgia Strait -- Juan de Fuca Strait -- Puget Sound territory 11 pods totalling about 115 whales were identified. Of these, four pods with 65-70 individuals were residents and the remaining seven pods, totalling almost 50 whales, were transients. In the Campbell River -- Bella Bella territory 14 pods totalling about 160 whales were identified. Data on seasonal movements of these pods were less clear due to limited accessibility of the area. At least one pod was residential, three pods ranged throughout the area and five were probably transients. A total of six pods periodically crossed the territorial boundary.

During 1962-75, 64 whales were cropped in British Columbia and Washington, 60 of which were taken in Georgia Strait -- Juan de Fuca Strait -- Puget Sound. From photographs taken at eight captures, six pods were identified to be cropped, three were resident pods and three were transients.

Few data were collected on recruitment rates. Pods contained an average of 20% young whales, but because this included newborn to those several years of age, the annual birth rate must be considerably lower. While net recruitment was recorded in two small pods, the annual rate may not exceed 5%.

Uncertainty in this rate make estimates of the amount of population reduction, recovery and yield speculative.

The economic, aesthetic and recreational values and current regulations for the species are discussed. Research requirements for 1976 and the next 3-5 years should be to collect better data on net recruitment rates. If cropping is continued, perhaps it should be limited to the replacement of killer whales in Canadian aquaria.

## INTRODUCTION

This report was prepared for the Department of Environment, Fisheries and Marine Service to assist in setting management policy for killer whales in British Columbia during 1976.

Management of killer whales in British Columbia to date has lacked a reliable scientific basis because of difficulties in censusing the species. Recently, however, we developed a new censusing method which now provides information on population size, interchange of stocks between British Columbia and Washington and the identification of stocks which were cropped. The method involves photographic identification of individual whales based on distinctive dorsal fin and saddle patch characteristics. From encounters with identifiable whales in different localities and during different times we determined the composition of each pod (family group), the number of pods and their movements. Photographs of past captures in which identifiable whales were later released established the identity of some pods which were cropped.

This report summarizes our preliminary results collected during 1972-75 off eastern and southern Vancouver Island. This region is important from a management point of view, because essentially all killer whales exhibited in aquaria were captured here (Bigg and Wolman, 1975).

## METHODS

To photograph whales we used a 35 mm Pentax SLR camera and a 300 mm telephoto lens mounted on a shoulder brace. Film used was Kodak Tri X Pan taken and developed at 1200 ASA with a camera shutter speed of 1,000. About 7,000 photographs were taken.



Whales were located through an extensive network of volunteer observers who reported by telephone any killer whales they saw. On receiving such information we dispatched a staff member and boat to intercept the pod, count and photographically identify as many individuals as possible.

Figure 1 shows the geographical locations of the place names mentioned in the report.

Regional censuses were conducted as follows:

Aug-Sep 1972	N. Johnstone Strait	light effort
Feb 1973-Jul 1974	Juan de Fuca Strait -- Georgia Strait	light effort
Aug 1-31 1973	N. Johnstone Strait	intensive effort
Aug 1-10 1974	Juan de Fuca Strait -- Alert Bay	intensive effort
Sep 1974-Feb 1976	Juan de Fuca Strait -- Chatham Pt.	intensive effort
Mar-Dec 1975	Puget Sound	light effort
Aug 1-31 1975	N. Johnstone Strait -- Bella Bella	intensive effort
1967-1972	Georgia Strait -- Puget Sound -- Juan de Fuca Strait	misc. private photographs

Observations from the Barkley Sound area were combined with those from Juan de Fuca Strait.

## RESULTS

### 1. Evidence for individual identification

The size and shape of the dorsal fin and the shape of the saddle patch (white area at the base of each side of the dorsal fin) provided approximate identification of individuals. Exact identification, however, required the presence of a recognizably unique nick on the dorsal fin or scar on the saddle patch as is shown in Figure 2. The better the photograph the greater the likelihood of distinguishing an individual. Some whales had no

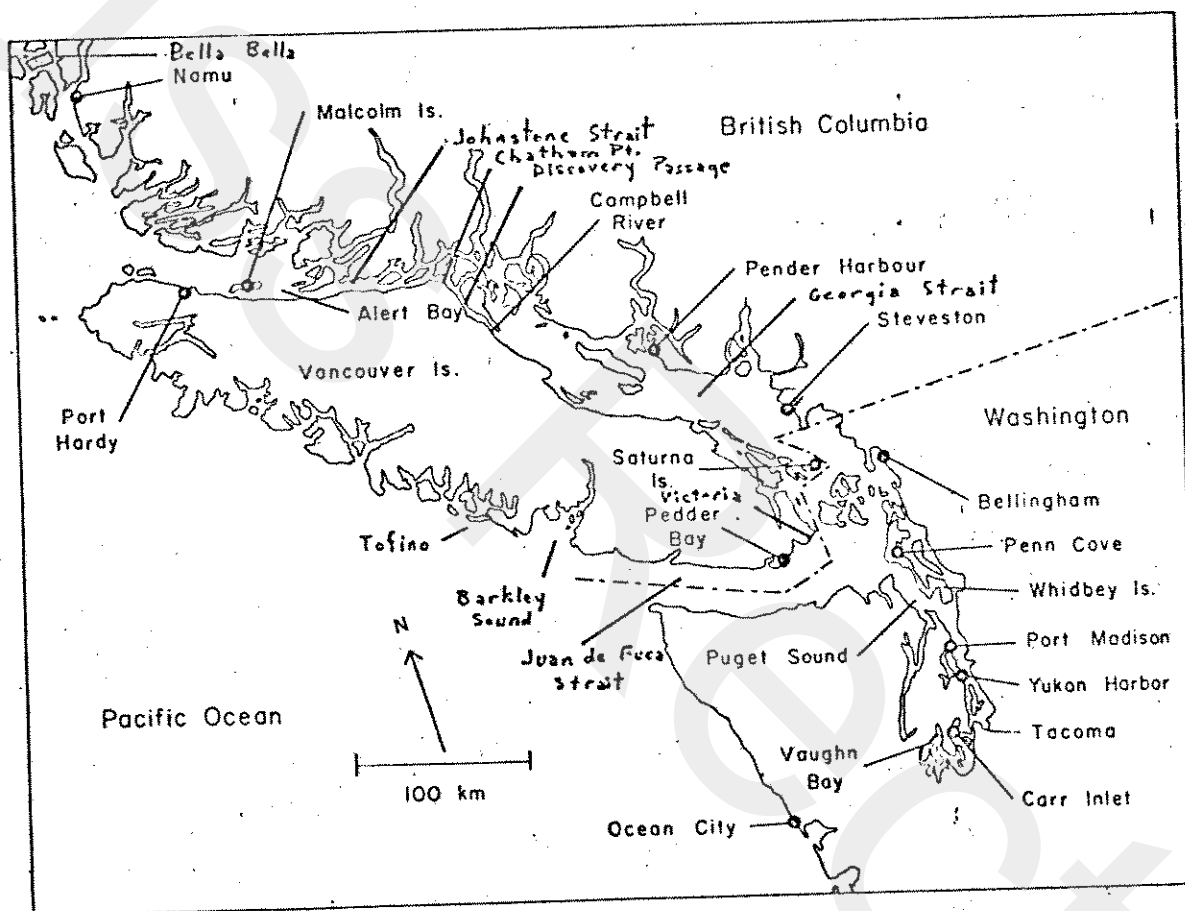
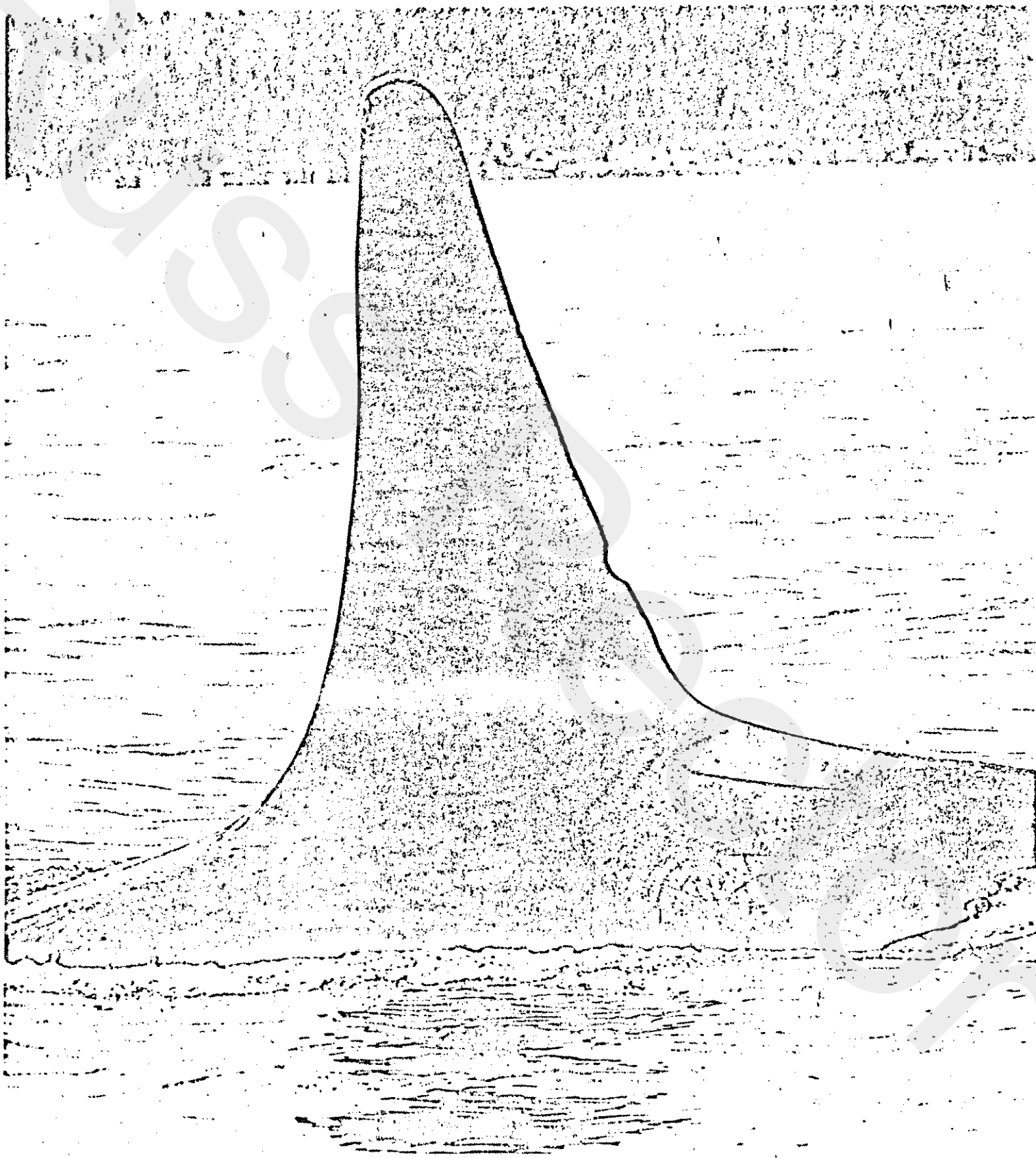


Figure 1. Geographical place names mentioned in the text.

Figure 2. Photograph of the left side of the dorsal fin of adult male L8 showing a large nick near the base of the fin and light and dark scars on the white saddle patch.



injuries and thus could not be identified exactly. Others were so distinctively marked that they could be identified visually.

Figures 3 and 4 provide additional photographic evidence for individual identification. Figure 3 shows nine whales from pod J and Figure 4 shows one whale from pod J and one from pod K, each photographed on three different occasions.

a. Dorsal fin

Our field observations suggest that dorsal fin height varied from about 10" in the smallest individuals to about 6' in the largest males. The height in 11 large females measured by Carl (1945, p.23) did not exceed 2'. Fins less than about 3' high (females and immature males) varied in shape from slightly to strongly falcate. The shape in whales with fins 3'-6' high (adult males) were straight and erect. Females and immature males cannot be distinguished by dorsal fin shape or height.

b. Saddle patch

The shape of the saddle patch varied considerably between individuals from basically a solid circular pattern (see Fig. 3, J2) to an angular letter U (see Fig. 3, J7). A dorso-posterior and ventro-anterior flare is present. Usually the shape of the saddle patch on the left and right sides of the dorsal fin was the same but occasionally differed considerably. In very small individuals the saddle patch was indistinct or missing entirely.

c. Injuries

Nicks, gouges and cuts of various sizes and positions occurred along the posterior edge of the dorsal fin. Few were located on the anterior edge. Photographs of the same individuals taken over a 7-8 year period indicated that these natural marks were permanent. An experimentally marked male captured in August 1973 retained two surgically made notches on the posterior edge of its dorsal fin after 26 months (Fig. 4).

Figure 3. Photographs of 9 whales from pod J showing the individual variations in shape of the dorsal fin and saddle patch, dorsal fin nicks (arrows) and scars on the saddle patch. Whales J1, J3 and J6 are adult males and the remainder are females or immature males.

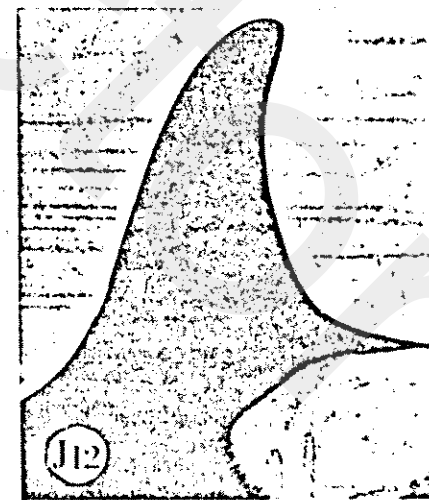
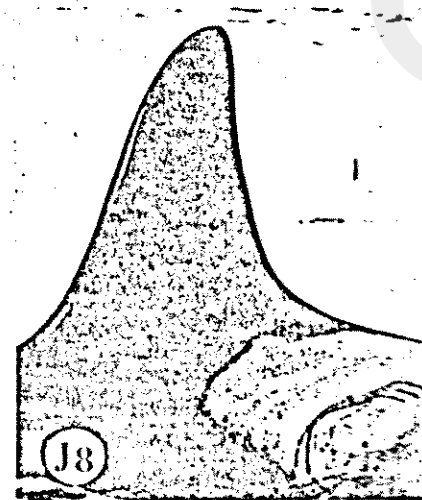
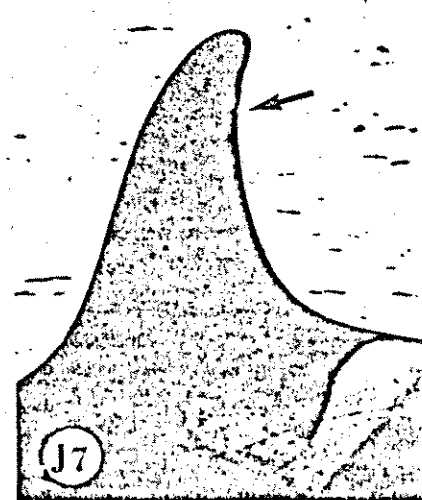
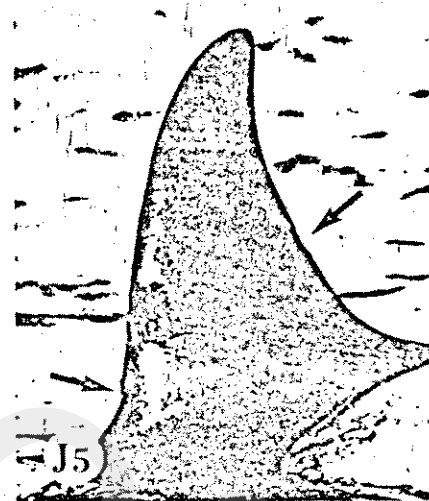
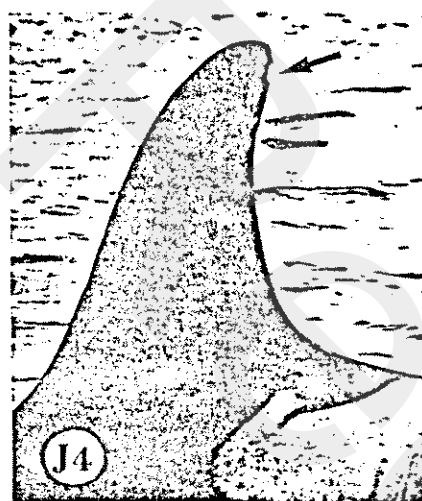
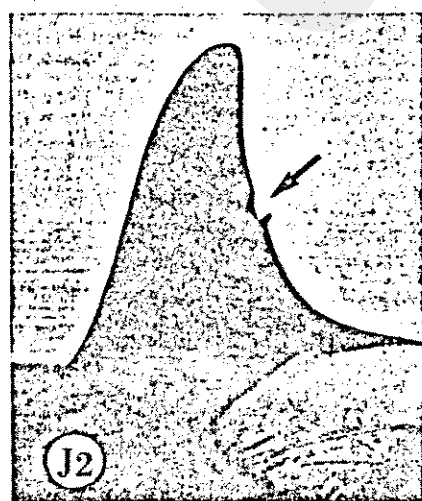
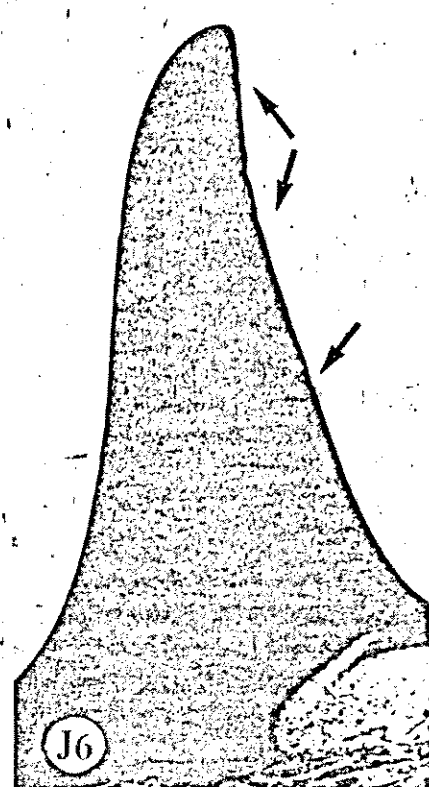
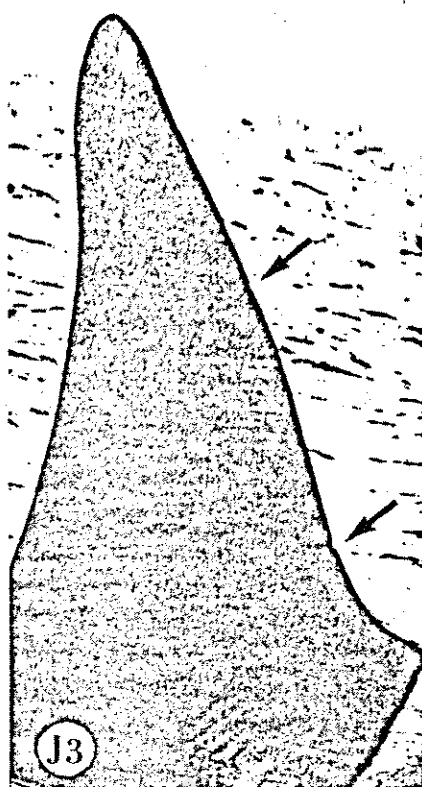
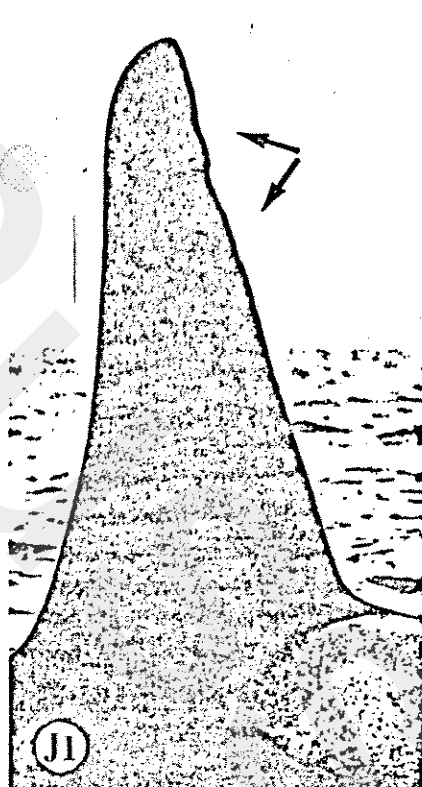
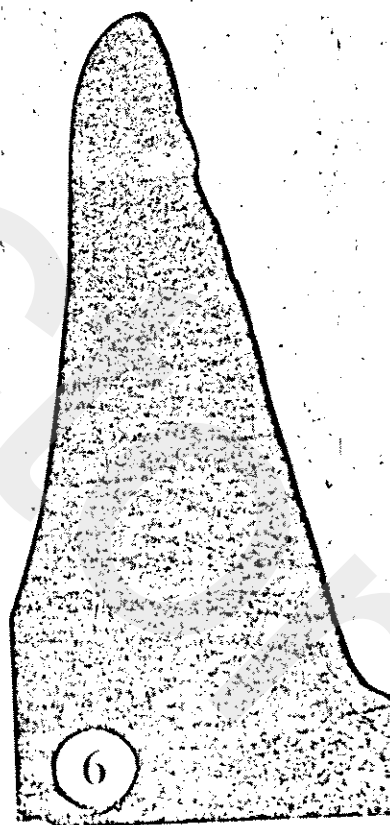
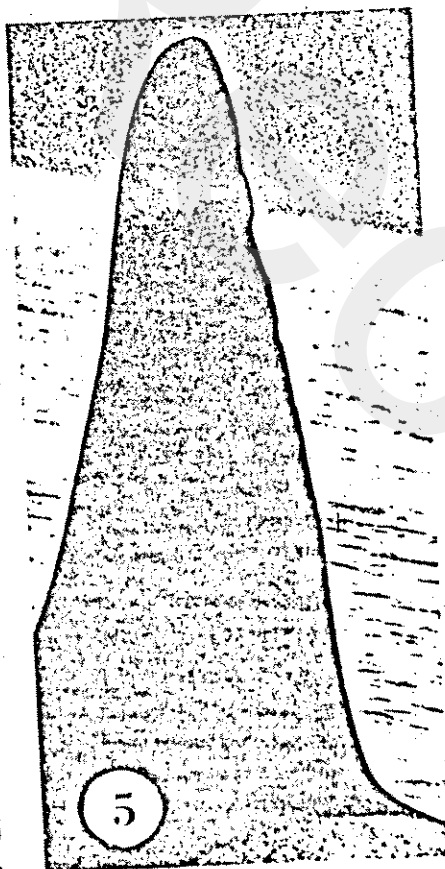
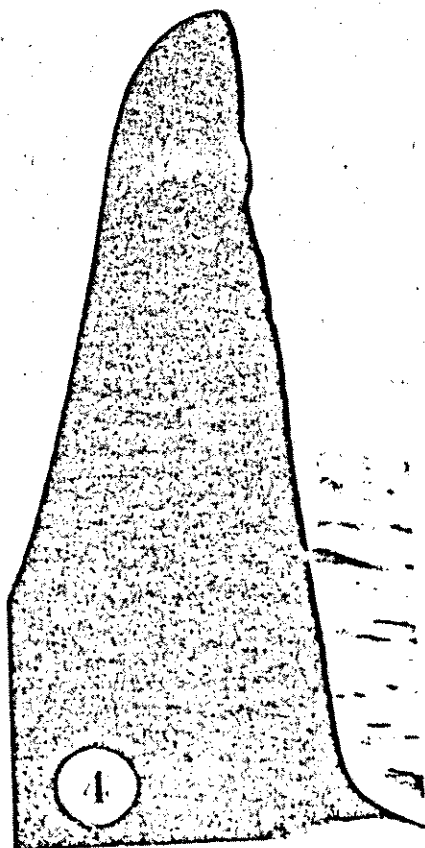
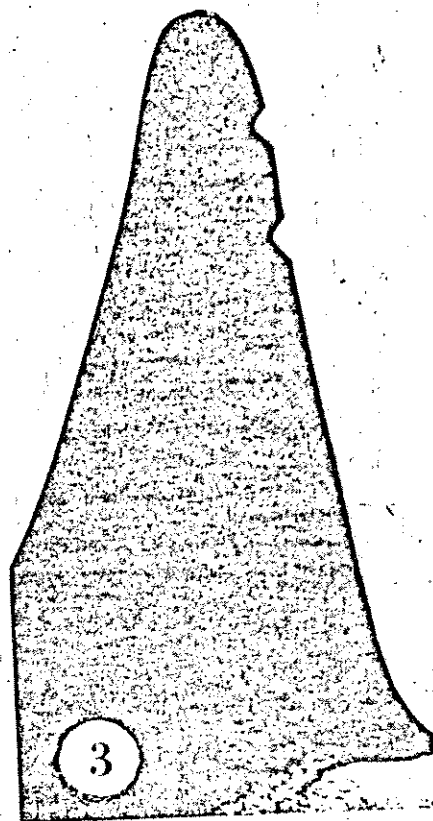
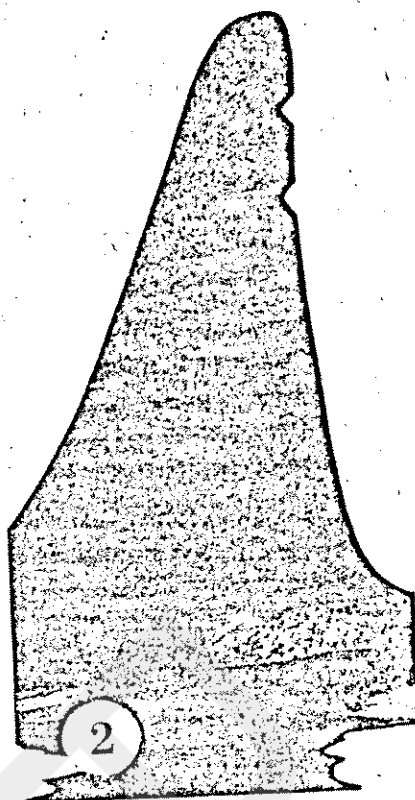
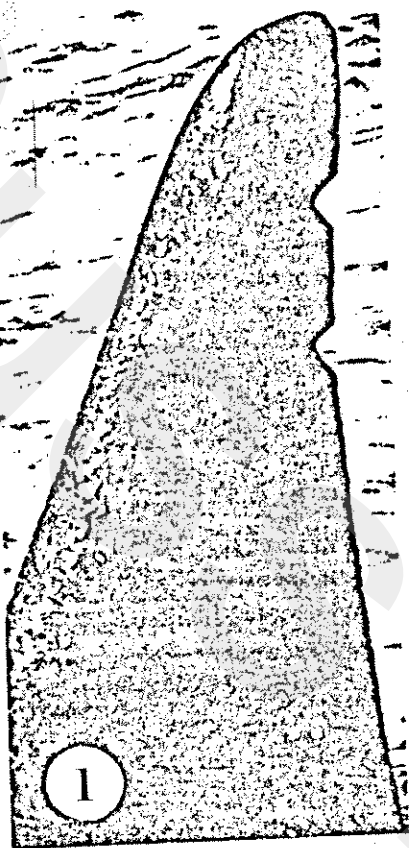


Figure 4. Photographs showing the same individual is recognizable during different encounters. Photographs 1-3 are of adult male K1 seen off southern Vancouver Island on August 1, 1974, November 1, 1974 and August 8, 1975, respectively. The two dorsal fin nicks were surgically made on October 26, 1973. Photographs 4-6 are of adult male J1 seen off southern Vancouver Island on July 4, 1974, April 17, 1975 and October 15, 1975, respectively.





Dark and light scarring often occurred on the saddle patch (see Fig. 3, J8) many of which also appear to be permanent.

Reasons for injuries to the dorsal fin and saddle patch remain unclear.

## 2. Pod definition

Evidence from pods captured or stranded and encountered through the year suggests that they are permanent family groups. Table I gives the size and sex composition of three captured and two stranded pods in British Columbia. Pod size ranged from 5-20 whales with mixed size and sex. Assuming, as suggested by Jonsgard and Lyshoel (1970, p. 46-7), that births occur at lengths 6'-9' and sexual maturity in females at 16' and males at 19', each pod contained mature and immature individuals.

Figure 5 shows members of pod J remained together during 30 encounters over a 12-month period. In this pod, which contained 15 whales, 11 were individually identifiable (see Fig. 3). Time limitations and poor weather prevented recognition of all identifiable whales on each encounter. Adult males J1, J3 and J6 were seen 30, 26, and 25 times, respectively. Females or immature males J2, J4, J7 and J8 were seen, respectively, 28, 25, 20 and 23 times. Whales J9, J10 and J12 had few distinguishing features and thus were identified only 12, 11 and 10 times.

In each pod we found at least one readily identifiable individual. No immigration of individuals from one pod to another was observed. However, some pods frequently joined and travelled with others for varying periods of time. Only on rare occasions did a pod split into subgroups which remained separated for more than a few hours. Generally members of a pod were dispersed over an area of less than 1/2-mile wide. Travelling speeds varied with group size, single pods generally travelling at 3-4 knots while groups consisting of several pods generally travelled at 5-6 knots.

Table 1. Sex and size composition of 3 captured and 2 stranded pods of killer whales in British Columbia. See text p. 4 for assumptions on sizes at maturity.

Captured	Place	Date	Pod size	Immature						Mature		
				8-11'			12-15'			12-18'		
				F	M	?	F	M	?	F	M	?
1	Pender Harbour	Apr./68	7	0	1	0	1			1	2	1
2	Pender Harbour	Dec./69	13	1	0	1	2			2	4	2
3	Pedder Bay	Mar./70	5	1	0	0	1			0	2	1
Stranded												
4	Masset	Jan./41	11	1	0	0	2			2	3	2
5	Estevan Pt.	Jun./45	20	0	1	0	1			2	12	4

Captured 1-3, data from Arctic Biological Station; pod size of capture 2 differs from that given in Bigg and

Wolman (1975) because of revised information.

Stranded 4, data from Cameron, 1941 p. 17. Size of one female not recorded.

5, data from Carl, 1946 p. 23.

Whale

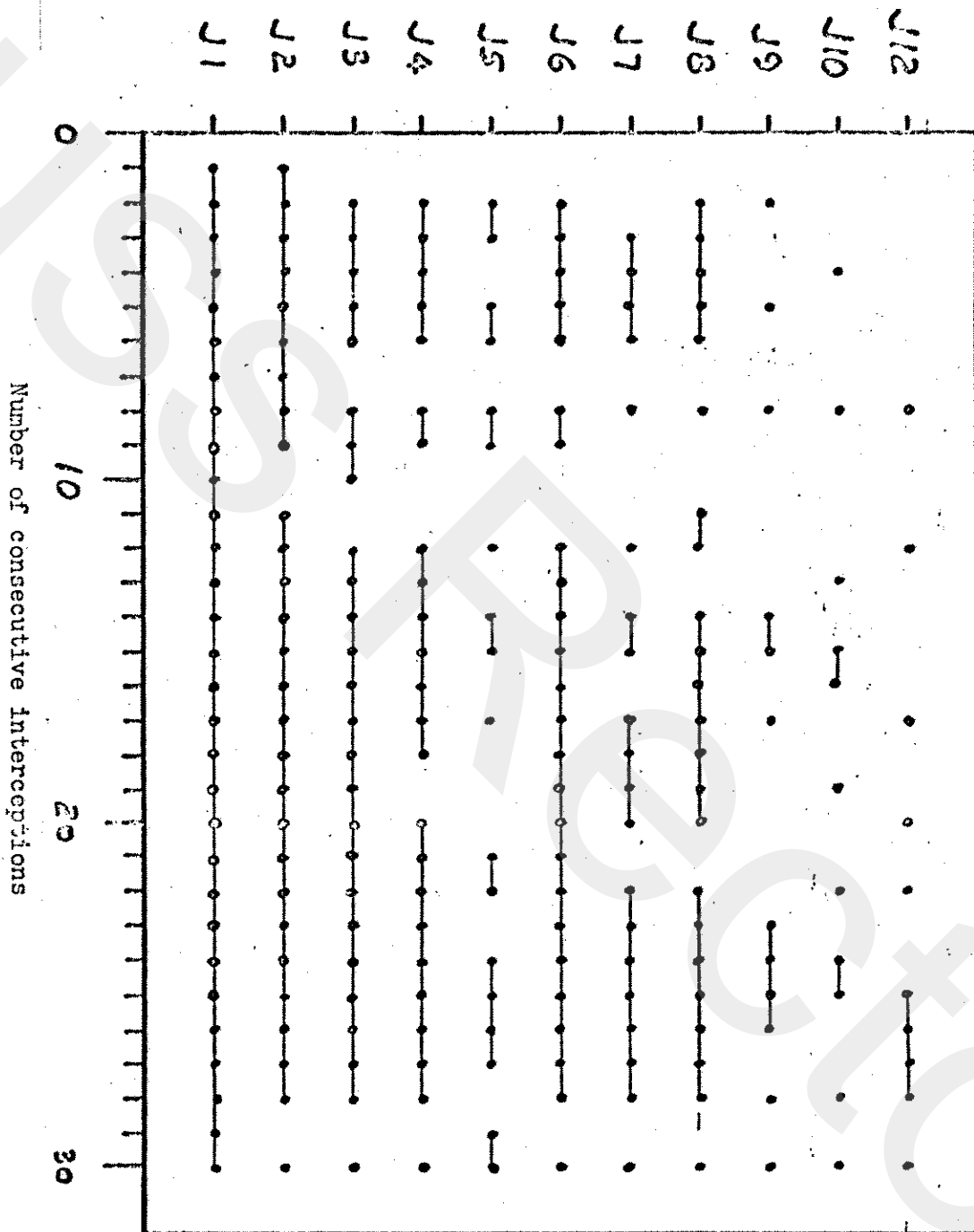


Figure 5. Individual whale composition of pod J during 30 consecutive interceptions covering 12 consecutive months, June 1974 - May 1975. Horizontal lines connect consecutive encounters with the same individual.

### 3. Number of pods

#### a. Eastern and southern Vancouver Island

As indicated in Table 2 we identified 19 pods totalling about 210 whales. A letter name was given to each pod. Data were collected from 304 pod interceptions. One pod interception is location and identification of one pod on one day. When two pods were found travelling together, this was recorded as two interceptions. Figure 6 shows the location of each encounter.

Pod size varied from 1 to 20 individuals with no size being particularly typical. Estimates of pod sizes with 15-20 individuals are probably correct to within 1-2 individuals. All sizes may not be natural because several pods are known to have been cropped. The sizes of some pods may be changed after additional encounters or a better understanding of interpod relationships.

Pods E, F, I, N and P for example were encountered only one or two times and thus their size and discreteness may not be correct. Also, the discreteness of pod L10 is still uncertain despite 27 interceptions. It may be a subgroup of pod L8 because the two pods generally travelled together.

Figure 7 plots the cumulative number of new pods discovered against the cumulative number of pod interceptions. Because the plot has now levelled, we may well have identified most, if not all, pods which commonly occur here.. For the first 154 interceptions 18 new pods were found for an average new pod discovery rate of 1/9 interceptions. For the last 150 interceptions only one new pod was found and it was seen only once.

#### b. Georgia Strait -- Juan de Fuca Strait -- Puget Sound

In this subregion we observed 11 pods for a total of about 115 whales. The pods identified were A5, E, G, J, K, L8, L10, M, N, O and Q. In Figure 7 the plot of cumulative interceptions and new pods here indicates a distinct levelling after 64 interceptions with no new pods seen during the last 116.

Table 2. Pods identified off eastern and southern Vancouver Island and the number of times each was encountered, 1967-75.

Pod name	A1	A5	B	C	D	E	F	G	I	J	K	L8	L10	M	N	O	P	Q	R	Total
Pod size	16	10	8	10	12	4	2+	19	16	15	12	20	20	3	1	7	10	4	19	208
Jan.	1									1										2
Feb.	2					1				2	1	2	1	1		1	1			12
Mar.	2									2				1						5
Apr.	2									3										5
May	3									4	1									9
Jun.	1	1								7	6	1	1			2				19
Jul.	4	4	5						1	10	3	4	3							34
Aug.	32	17	20	3	4			1	2	14	9	9	8			1	1	4	1	126
Sep.	2					1				9	7	6	5	3						33
Oct.	2				2			5		10	5	5	4	2	2					37
Nov.	1							2		1	3	4	4							15
Dec.	1									1	1	2	1			1				7

Total encounters	37	38	25	3	6	2	1	8	3	64	36	33	27	7	2	5	2	4	1	304
------------------	----	----	----	---	---	---	---	---	---	----	----	----	----	---	---	---	---	---	---	-----

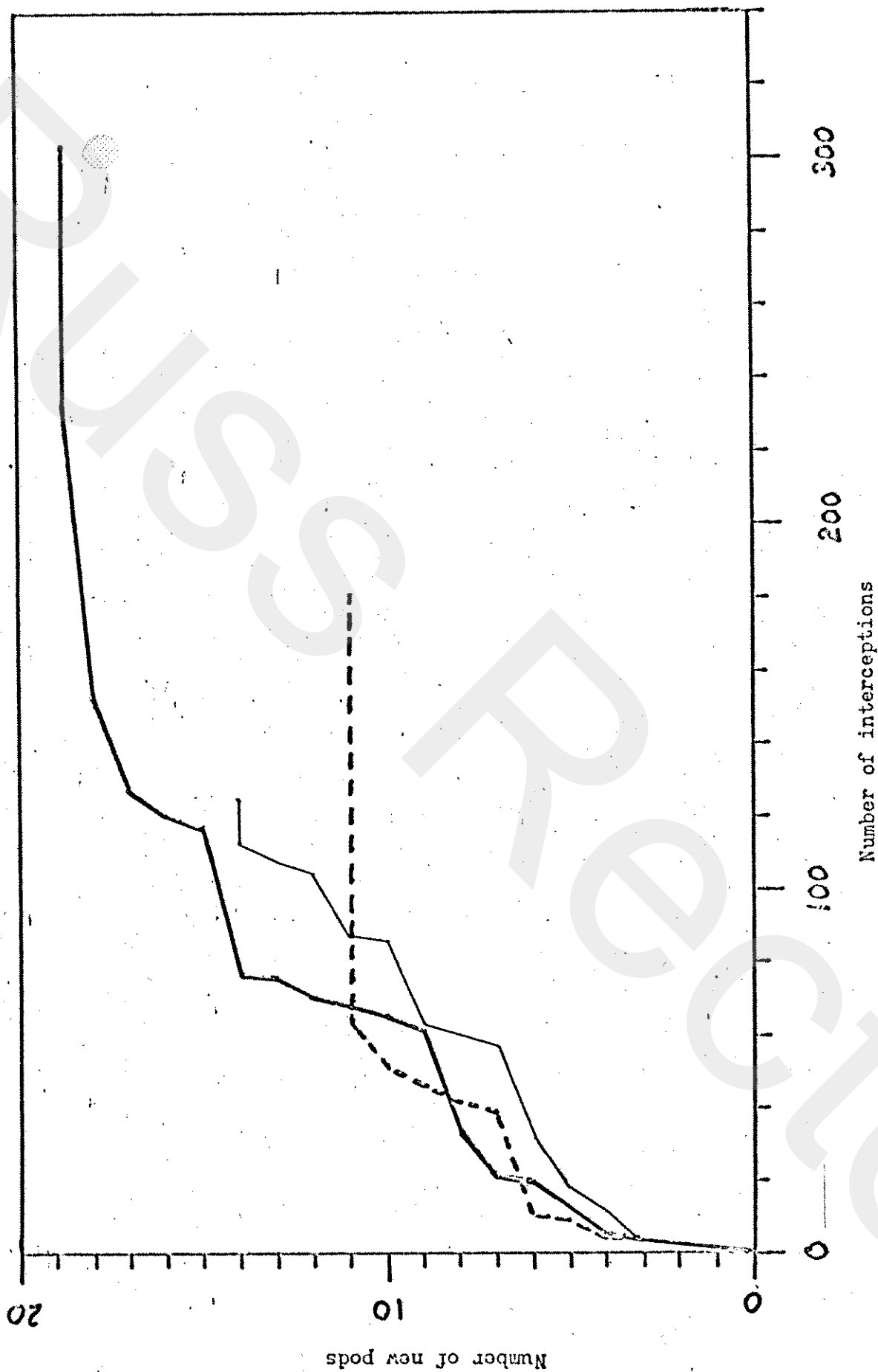


Figure 7. Rate of new pod discoveries in eastern and southern Vancouver Island (—) and in the subregions Georgia Strait --- Juan de Fuca Strait -.-.- Puget Sound (---) and Campbell River --- Bella Bella (—)

- 1 interception
- 10 interceptions
- 50 interceptions

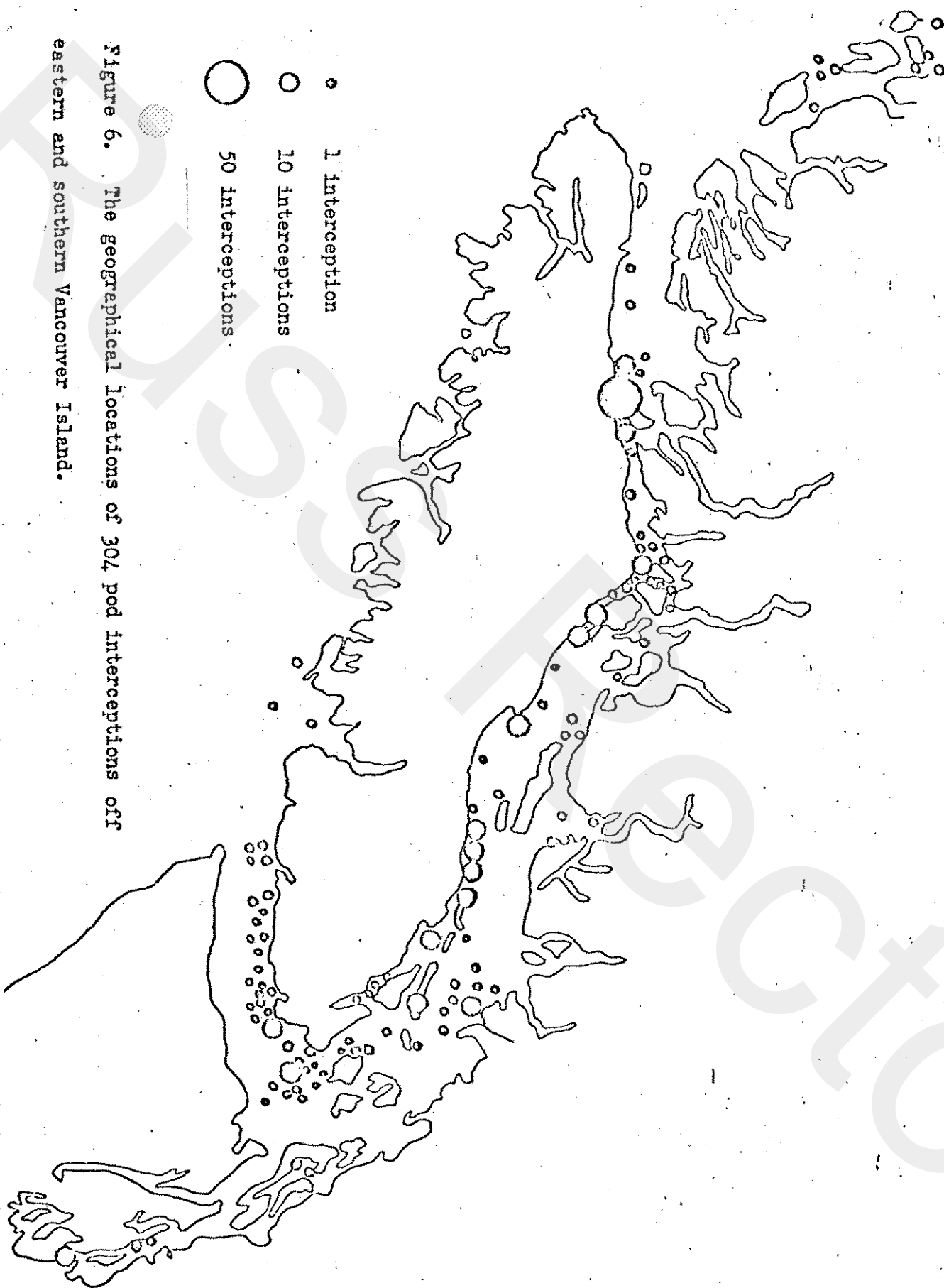


Figure 6. The geographical locations of 304 pod interceptions off eastern and southern Vancouver Island.



During the first 64 interceptions the discovery rate was 1/6 interceptions. The early levelling of the plot strongly suggests that all pods commonly occurring here were identified.

c. Campbell River -- Bella Bella

In this subregion we observed 14 pods totalling about 160 whales. The pods identified were A1, A5, B, C, D, E, F, G, I, L8, O, P, Q and R. From Figure 7 the plot here has not yet levelled and thus more pods may occur. The new pod discovery rate was relatively constant at about 1/9 interceptions from a total of 124 interceptions. A total of six pods, A5, E, G, L8, O and Q occurred in both Campbell River -- Bella Bella and Georgia Strait -- Juan de Fuca Strait -- Puget Sound.

4. Pod movements

a. Eastern and southern Vancouver Island

The movements of pods fell into two general patterns, those pods which travelled primarily in Georgia Strait -- Juan de Fuca Strait -- Puget Sound and those which travelled primarily in Campbell River -- Bella Bella. As figure 8 shows, most pods inhabiting one subregion seldom entered the other.

Off eastern Vancouver Island, northern Georgia Strait appears to be the northern boundary for some pods and the southern boundary for others. On numerous occasions we followed pods A5, A1, B, D and G south in Discovery Passage then observed them turn northward before entering Georgia Strait. Similarly, we observed pods J, K, L8 and L10 to travel north in Georgia Strait then turn south before reaching Campbell River. No oceanic barriers exist to prevent pod movements between these subregions. Of interest is the fact that the distance between southern Georgia Strait and northern Johnstone Strait, the areas where pods are most frequently sighted in each subregion, is only a 2-day journey for a pod.

Number of interceptions

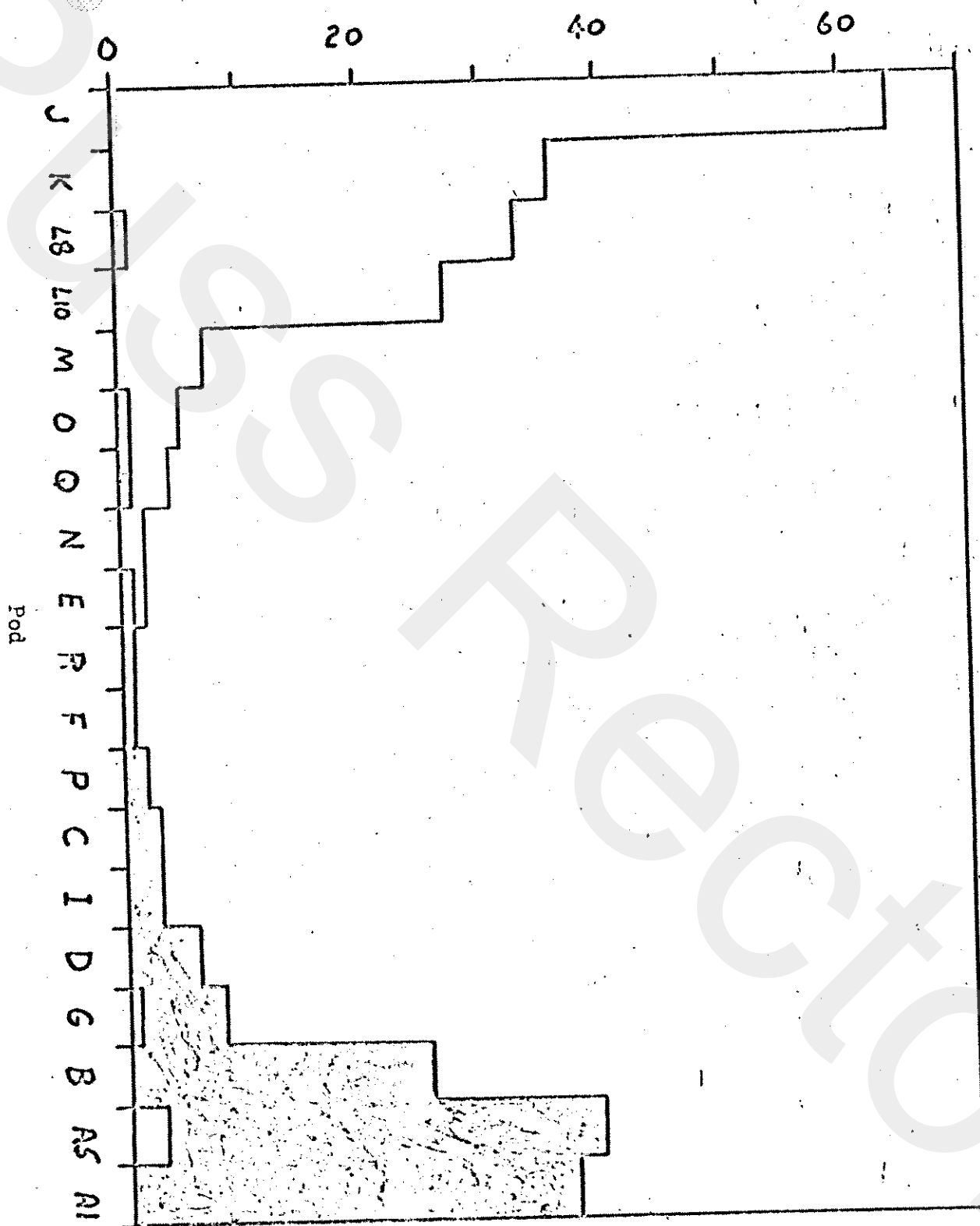


Figure 8. Number of interceptions of each pod in Georgia Strait - Juan de Fuca Strait - Puget Sound

Pod

These observations suggest that some form of territoriality exists between pods. It does not appear to involve single pods but rather several pods together because we have no evidence that any one pod has an exclusive territory. As will be shown in the following subregion accounts, some pods travel the same routes and periodically join with other pods. It may be that the pods which travel together maintain a community territory. This being the case, two-community territories exist off eastern and southern Vancouver Island with their boundary located across northern Georgia Strait.

b. Georgia Strait -- Juan de Fuca Strait -- Puget Sound

In this subregion we observed primarily four pods, J, K, L8 and L10, totalling 65-70 whales (Table 2, Fig. 8). While at times each pod travelled alone each also periodically travelled with the others. Thus, these four pods appear to comprise the members of this community territory. The remaining seven pods identified here (A5, E, G, M, N, O and Q), were seen relatively infrequently and never in company of the other four pods. They were probably transient from perhaps some other community territory. Pods A5 and G will be shown to be examples of this.

Figure 9 summarizes the movement routes of pods J, K, L8 and L10. Pod J is the only completely residential pod. It was observed during all months of the year and travelled throughout Georgia Strait and Puget Sound. We did not see it north of Georgia Strait or west in Juan de Fuca Strait. Its range was about 210 nautical miles. While this pod travelled primarily alone, it occasionally travelled with pod K and less frequently with pods L8 and L10. On four occasions we saw pod J join with pods K, L8 and L10 to form the largest group which we have ever seen totalling 65-70 whales.

Pods K, L8 and L10 were observed for 8-9 months of the year, although they could occur here in all months. Poor weather in the winter

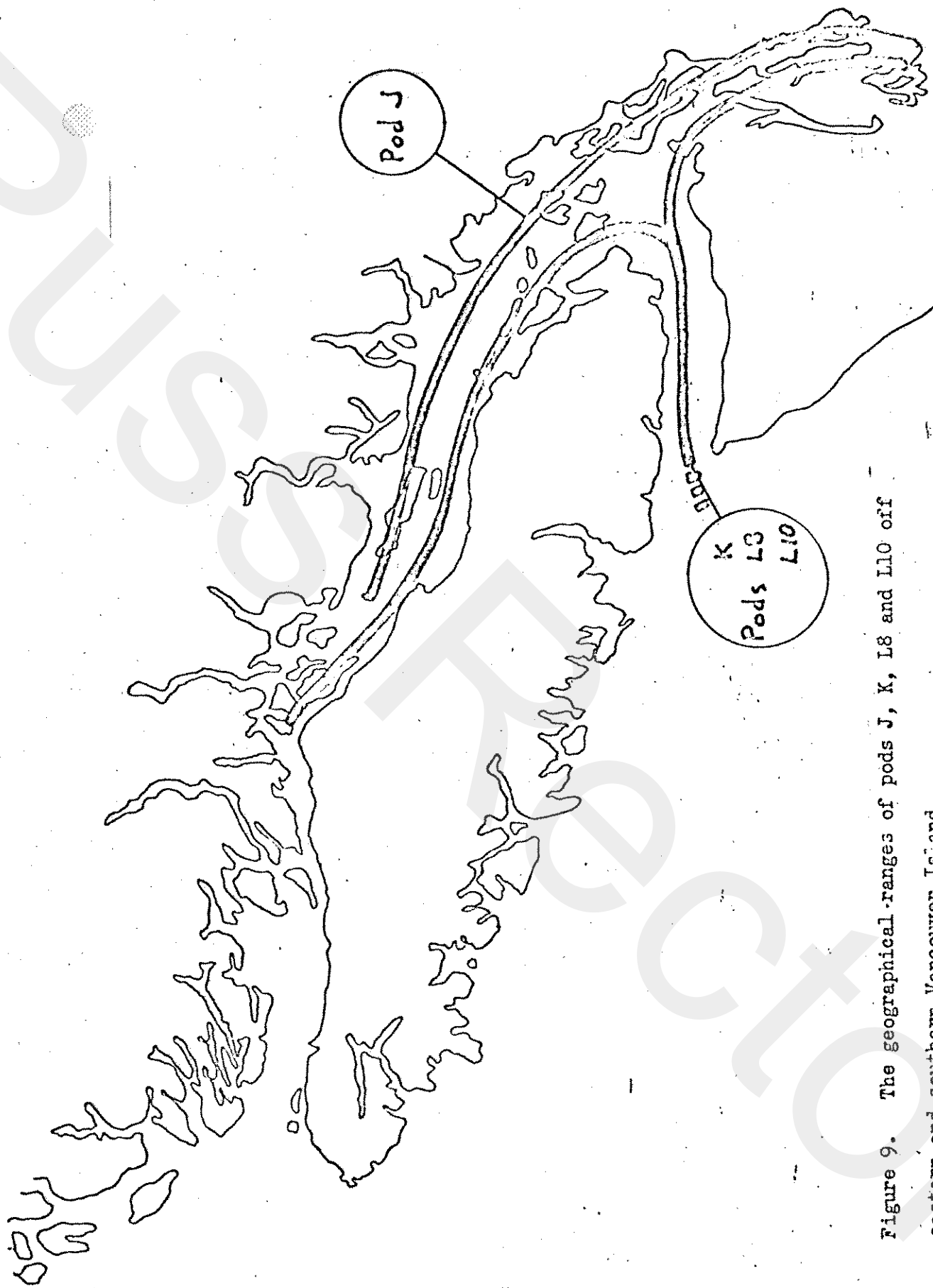


Figure 9. The geographical ranges of pods J, K, L8 and L10 off eastern and southern Vancouver Island.

and spring made field studies difficult. Movements of the three pods were essentially the same because they often travelled together. They entered Juan de Fuca Strait from the west coast and travelled into either Puget Sound or Georgia Strait and eventually back to the west coast by the reverse route. Their ranges thus include areas on the west coast although we do not know the extent. On one occasion pod L8 was seen at Chatham Pt., just north of Campbell River. However, this pod is only transient here. Of the three pods, K was the most independent, occasionally travelling alone or with pod J, while pods L8 and L10 travelled primarily together and as previously mentioned (p. 5) may be a single large pod.

The movements of pods A5, E, G, M, N, O and Q are poorly known in this subregion. None were seen in Puget Sound. Pod A5 periodically visits central Georgia Strait from regions north of Campbell River. Pod E was seen only once off Barkley Sound and once in northern Johnstone Strait, some 250 miles away. Pod G occurred once off Nanaimo, although it generally inhabited areas north of Campbell River. Pod M was seen from Victoria to Comox, pod N twice off Nanaimo and pod O from Victoria to Chatham Pt. Pod Q may frequent the west coast of Vancouver Island, having been seen off Victoria, Barkley Sound, Tofino and Bella Bella, but not off eastern Vancouver Island. During 6 days this pod travelled from Bella Bella to Victoria, some 330 miles.

c. Campbell River -- Bella Bella

We are less certain about which pods comprise this community territory because the area is less accessible for year-round studies. Assuming that pods which travelled together were members of the same community, it contained six pods A1, A5, B, C, D and G totalling about 75 whales. While not all pods were seen travelling together at one time, each was seen travelling in some combination with the others. Pods A5, A1, C and D totalling about 50 whales, formed the largest group seen here. Three other pods, I, P and R totalling

about 45 whales, similarly travelled with one another but not with the previous six. However, we had so few encounters with them that comment on the social relationships is reserved. An additional five pods, E, F, L8, O and Q totalling about 35 were seen but not in association with any others. These appear to be transients. Pods E, L8, O and Q were discussed earlier.

Figure 10 summarizes the movement routes of pods A1, A5, B, C, D and G. While in general the southern range of these pods off eastern Vancouver Island was northern Georgia Strait, we do not know the northern or western limits. Pod A5 was the only pod to be seen during all months of the year. It ranged from central Georgia Strait to Bella Bella some 250 miles. For most of the year it travelled alone but periodically travelled with pods A1, B, C, D and G. Pod A1 was seen from Chatham Pt. to Bella Bella and travelled with A5, B, C and D. Pod B travelled primarily alone but occasionally with A1 and A5 and was seen from Campbell River to Alert Bay. Pod C was seen only three times, twice in northern Johnstone Strait and once near Bella Bella during which time it was associated with A5, A1 or D. Pod D was occasionally sighted from Chatham Pt. to northern Johnstone Strait and travelled variously with A1, A5, C and G. Finally, pod G travelled between Campbell River and Bella Bella and joined with A5 or D. It was also sighted as a transient off Nanaimo.

Pods I and P were seen near Bella Bella, the former also in northern Johnstone Strait and the latter at Chatham Pt. Pods R and F were seen only once, the former just north of Alert Bay and the latter near Chatham Pt.

##### 5. Large groups off southern Vancouver Island

Several people involved with capture and research of killer whales reported larger groups of whales off southern Vancouver Island than we observed or can explain from our results. Don Goldsberry is Manager of

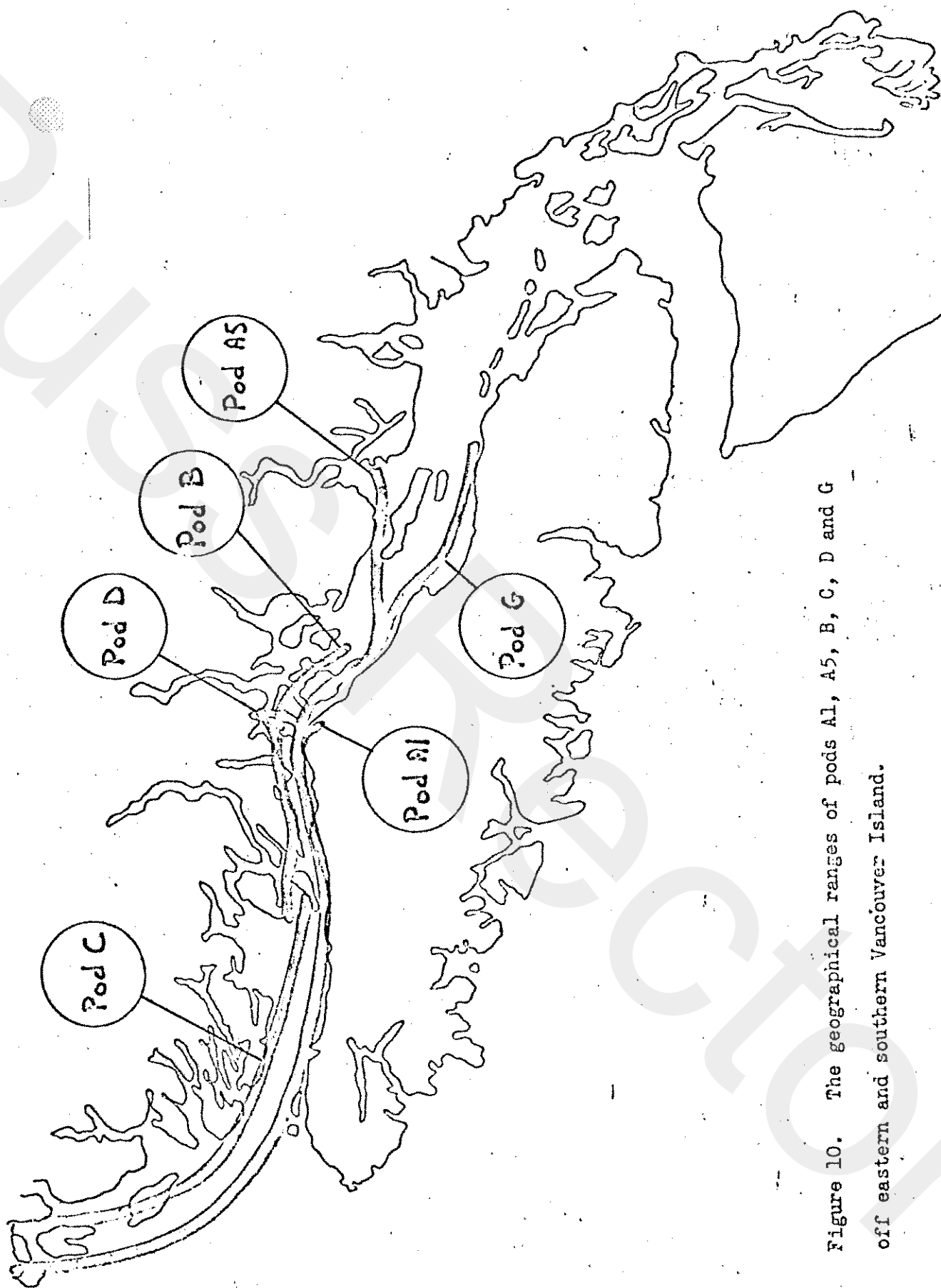


Figure 10. The geographical ranges of pods A1, A5, B, C, D and G off eastern and southern Vancouver Island.

Seattle Marine Aquarium and captures killer whales in Puget Sound. On January 9, 1976 he stated the largest groups seen by him occurred during the summer months off San Juan Island, located about 7 miles east of Victoria. He felt that the largest group here occurred during the late 1960's and contained about 500 whales. During the last 2 to 3 years the largest group was 225-250 and the largest in 1975 was about 200. In August, 1970 he captured a group of about 80 whales in Puget Sound. Bob Wright is owner of Sealand of the Pacific, Victoria and captures killer whales near Victoria. On January 7, 1976 he stated that the largest group seen by him was 75-90 whales captured by Goldsberry during August 1970 in Puget Sound. The largest group reported to him which he felt was reliable was about 200 whales at Swiftsure Bank at the western entrance to Juan de Fuca Strait. Dale Rice is a whale biologist for the National Marine Fisheries Service in Seattle. He stated on November 21, 1975 that he counted a group of about 130 whales at Tacoma in Puget Sound during October 11-12, 1975.

The largest group seen by us was 65-70 whales composed of pods J, K, L8 and L10. During 1975 we observed this group on four occasions in southern Georgia Strait, three times in September and once in October. It is important to explain how we determined group size because the method differs from that used by others. Usually observers estimate group size by counting individual whales. While we used this method to establish pod size and on special occasions, large group size, we found this produced highly variable estimates as group size increased. The reason for this is that large groups are usually dispersed widely with individuals or small groups surfacing independently. Because each whale spends only about 5% of the time on the surface, dives for varying periods of time and often changes direction of travel, the difficulties in keeping track of all



individuals during a count increase in an exponential fashion with an increase in group size.

We believe the best method for determining the size of large groups is to sum the sizes of pods identified as present. This requires prior knowledge of each pod size which is best determined when encountered separately. However, once pod size is established, subsequent encounters generally require the recognition of only the identifiable individuals in order to determine the total number of whales present. Our data indicate that pods are permanent family units in which the same individuals almost always travel together. All large groups encountered by us contained pods which we had already identified.

Goldsberry's report of a group of 200 whales in the summer of 1975 off San Juan Island and Rice's report of 130 in October 11-12, 1975 at Tacoma are of particular interest because these groups apparently formed while we were censusing off southern Vancouver Island. Unfortunately, neither person took photographs of these encounters. Our observations of large groupings in this locality involve only four pods, J, K, L8 and L10. Table 3 gives the pod composition of 14 groups encountered off San Juan Island during the summer of 1974-75 and two in southern Puget Sound during September-October, 1975. The four pods were seen in both areas. Fortunately, we located a boater, Winifred Brown of Tacoma, who photographed the large group seen by Rice. His photographs indicate the presence of at least pods J, L8 and L10. Pencil sketches made by Rice of two well-marked individuals resembled two males from pod L8. It is noteworthy that we observed the four pods travelling together on October 15, 1975 off Vancouver, British Columbia.

While it is possible for the seven transient pods, A5, E, G, M, N,

Table 3. The identification of 14 groups encountered off San Juan Island during the summer of 1974-75 and 2 groups in southern Puget Sound during September - October, 1975.

Area	Date	Group		
		Number	Pod composition	Size
San Juan Is.	Jul. 1974	1	K, L8, L10	50-55
	Aug. 1974	1	K, L8, L10	50-55
	Aug. 1974	1	K	12
	Aug. 1974	3	L8, L10	40
	Jul. 1975	1	K, L8, L10	50-55
	Aug. 1975	4	K, L8, L10	50-55
	Aug. 1975	1	J	15
	Sep. 1975	2	K, L8, L10	50-55
Carr Inlet	Sep. 1975	1	K, L8 + ?	32 + ?
Tacoma	Oct. 1975	1	J, L8, L10 + ?	55 + ?

O and Q to have joined with pods J, K, L8 and L10 to make a group of up to 115, the irregularity and rarity of visits (Table 2, Fig. 8) from transient pods make this circumstance unlikely. We have never seen these travelling with pods J, K, L8 or L10. Also, the additional 95 whales which we identified between Campbell River and Bella Bella have never been seen south of Campbell River and thus would most likely, not form part of the large groups reported. If the concept of two-community territories off eastern Vancouver Island is valid, large additions to the known whales present are difficult to explain.

Goldsberry's capture of about 80 whales in Penn Cove during August 1970 could have involved pods J, K, L8 and L10. In fact, a photograph taken at the capture site identifies pod L8 as being present (details p.13).

#### 6. Pod composition

Table 4 gives the proportion of individuals judged to be either bulls or young in each pod. Bulls were individuals with erect dorsal fins estimated to be at least 3' high and young were the obviously small whales. Young probably included newborn to those several years of age. One whale which we classified as young was later captured in Pedder Bay on August 16, 1975. It was a female measuring 13'6" in length. Calves are apparently born at 6'-9' in length with females maturing at 16' (p.4).

In 17 pods, bulls averaged about 19% of all whales and young about 20%. The remaining 62% were presumably females and immature males. The variation in pod composition was relatively small. Only one pod (Q) did not have a bull and one (O) did not have any calves. Another pod, (N) consisted of only a bull.

#### 7. Pods cropped

Tables 5 and 6 list data on the captures of killer whales in British Columbia and Washington during 1962-75. In British Columbia whales were

Table 4. Composition of 17 pods. Pods E and F are excluded because of incomplete data. Composition of pod Q is prior to capture in Aug. 1975.

Pod	A1	A5	B	C	D	G	I	J	K	L8	L10	M	N	O	P	Q	R	Total
size	16	10	8	10	12	19	16	15	12	20	20	3	1	7	10	6	19	204
Bulls	No. 4	1	2	3	3	3	3	3	2	3	4	1	1	1	1	0	3	38
%	25	10	25	30	25	16	19	20	17	15	20	33	100	14	10	0	16	19
Young	No. 3	4	1	1	3	4	4	4	3	3	4	1	0	0	2	1	2	40
%	19	40	25	10	25	21	25	27	25	15	20	33	0	0	20	17	11	20
Females and immature males	No. 9	5	5	6	6	12	9	8	7	14	12	1	0	6	7	5	14	126
%	56	50	75	60	50	63	56	53	58	70	60	33	0	86	70	83	74	62

Table 5. Number and pod identity of killer whales captured in British Columbia, 1964-75 and the size and sex of those cropped. See text p. 4. for assumptions on sizes at maturity.

\* Number differs from that given in Bigg and Wolman (1975) because of revised information.

Date	Place	Pod	No. captured	No.	Cropped							
					Immature				Mature			
					8-11'		12-15'		12-18'		16'+	
					F	M	F	M	F	M	F	M
Jul./64	Saturna Is.	-	1	1				1				
Jun./65	Namu	-	2	1								1
Jul./66	Steveston	-	1	1		1						
Jul./67	Port Hardy	-	1	1				1				
Jul./68	Malcolm Is.	-	11	1				1				
Feb./68	Pender Hbr.	-	1	0								
Apr./68	Pender Hbr.	-	7	6		1	1	1			3	
Dec./69	Pender Hbr. A5		13*	6	1		2	2			1	
Mar./70	Pedder Bay M		5	3	1		1				1	
Aug./73	Pedder Bay K		2	1							1	
Aug./73	Pedder Bay	-	2	2				1				
Aug./75	Pedder Bay Q		6	2			1	1				
Total			52	25	3	1	5	8			7	1

Table 6. Number and pod identity of killer whales captured in Washington, 1962-73 and the size and sex of those cropped. See text p. 4 for assumptions on sizes at maturity. \* See text p. 13.

Date	Place	Pod	No. captured	Cropped									
				Immature					Mature				
				8-11'		12-15'		12-18'		12-15'		16'+	19'+
				F	M	?	F	M	?	F	M	F	M
Sep./62	Bellingham	-	2									1	1
Oct./65	Carr Inlet	-	15				1					1	
Feb./67	Yukon Hbr.	K	15	1	2		1		2			1	1
Feb./68	Vaughn Bay	-	12		1							1	
Oct./68	Yukon Hbr.	J	25		1			3					1
Apr./69	Carr Inlet	-	11										1
Oct./69	Penn Cove	-	7										
Feb./70	Carr Inlet	-	6						1				
Aug./70	Penn Cove	L8*	80	1	4	2	1	2				1	
Aug./70	Port Madison	-	1				1						
Aug./71	Penn Cove	L8	15				2	1					
Nov./71	Carr Inlet	-	19										
Mar./72	Carr Inlet	J	11					1					
Mar./73	Ocean City	-	1									1	
Total			220	39	3	2	5	9	1	6	4		

caught on 12 occasions and in Washington on 14. Each capture involved 1-80 individuals with the cumulative total for all captures of 272 whales. As summarized in figure 11, 64 whales were removed, 22 from Georgia Strait and Juan de Fuca Strait, 38 from Puget Sound and 4 from other regions. The largest number, 48 was taken during 1967-70 while only 7 were cropped during 1962-66, and 10 in 1971-75. Cropping was primarily on immature whales (71%). Of the adults taken most were females because of their smaller, more manageable size.

If, as our data suggest, we have identified most or all pods which commonly occur off eastern and southern Vancouver Island, then most or all cropping occurred from the 19 pods identified. Photographic identification of whales from 8-9 captures from 1967-75 support this contention. As indicated in Tables 5 and 6, pods A5, K, Q and M were identified as captured in Georgia Strait and Juan de Fuca Strait and pods J, K and L8 were cropped in Puget Sound. Thus, of the 11 pods known to occur in Georgia Strait -- Juan de Fuca Strait -- Puget Sound, six were cropped, three of which were transients and three residents. If our estimate of the population size in Georgia Strait-- Juan de Fuca Strait -- Puget Sound is correct and there are 115 whales, some must have been caught several times because the cumulative catch here was 258 whales (Table 6). Our data indicate that pod J, K and possibly L8 were captured twice. Pod L8 was present at the capture site in Penn Cove during August 1970 when some 80 whales were entrapped. We are not certain whether L8 was recently released or was just a curious pod near the capture operation.

#### 8. Recruitment

We have few data on recruitment rates and none are available from studies on this species in other regions. Young whales comprised about 20% of

Crop

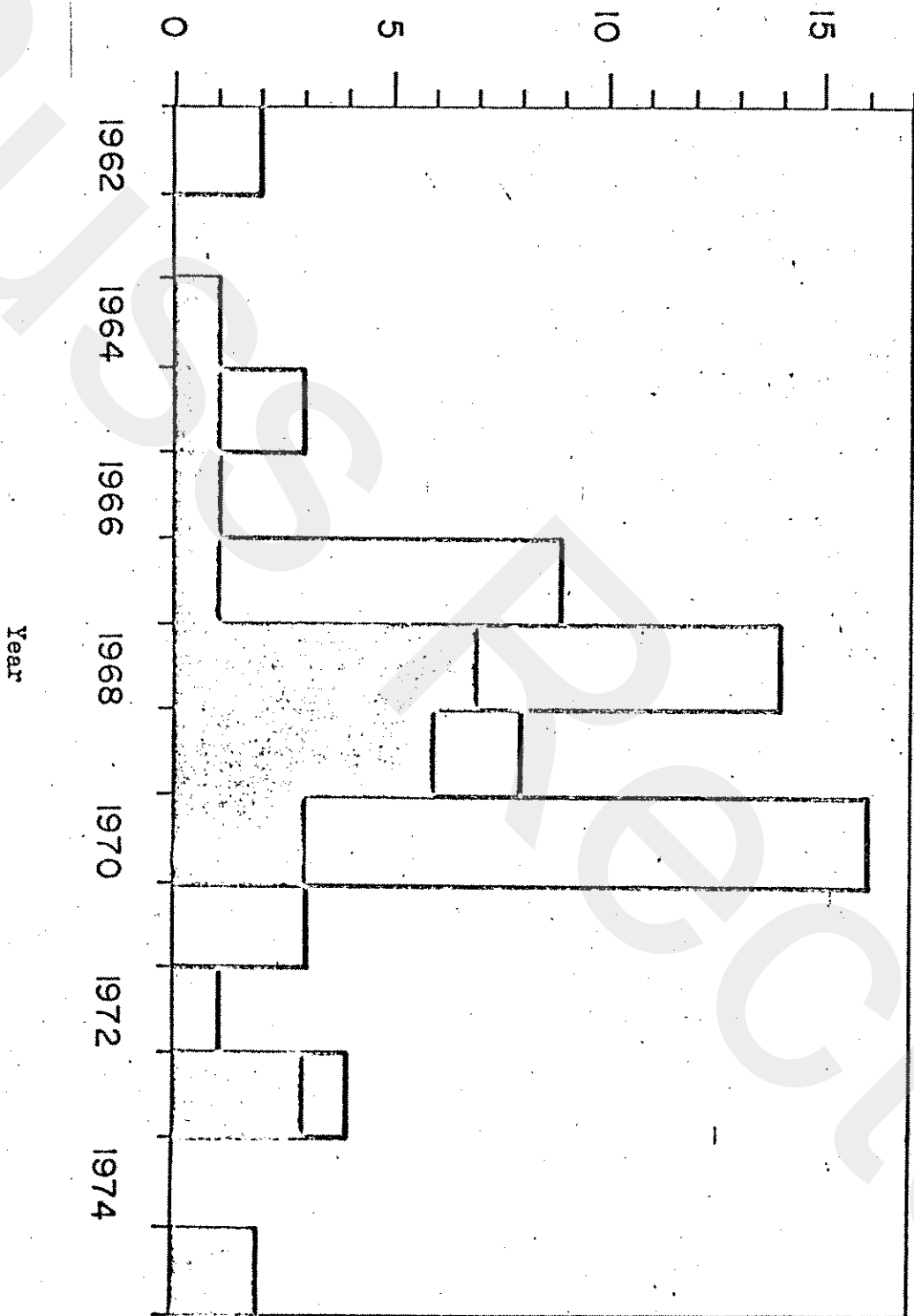


Figure 11. Crop by year of 64 killer whales from British Columbia (solid) and Washington (open), 1962-75. Data from Tables 5 and 6.



the population. However, because this figure included newborn whales to those several years of age, the annual birth rate must be considerably less than 20%.

Two lines of evidence suggest that the net recruitment rate (births less deaths) may be 5% or somewhat less per year. The first evidence comes from known increases in size of two pods, A5 and M, which were cropped 5 years ago. Pod A5 was captured in Pender Harbour during December 1969 and initially contained 13 whales. From these, five immature whales and one cow were cropped and seven were released including two bulls, three cows, one cow or small bull and one very young calf. From May 1974 to August 1975 this pod contained 10 individuals including one bull and four young. This pod thus increased by three young for an average annual increase of 7.6%. Pod M was captured in Pedder Bay during March 1970, and contained five whales. From these, two immature whales and one cow were cropped and an adult male and female released in October 1970. From September 1974 to October 1975 this pod consisted of three individuals including one bull and one young for an average annual increase of 10.0%. The combined average annual increases in pods A5 and M was 8.1%. However, caution must be placed on this figure. It is an artificially high rate to apply to the whole population because immatures were removed. While a rate which includes immatures cannot be derived exactly it might be reduced to 5%. Also the rate was derived from only two small pods. An increase or decrease of one individual in either pod would change the rate considerably.

The second method for estimating net recruitment rate is to eliminate the unreasonably high rates which when combined with the known number of whales cropped each year, produces lower original population sizes than currently exist. The original population size probably existed up to 1966, because of the small numbers cropped up to this time. Prior to 1967 in

British Columbia and Washington one whale was taken in 1955 (Pike and MacAskie, 1969 p. 30) and seven during 1962-66 (Table 5 and 6). In other west coast localities 10 were taken off California during 1961-67 and one off Alaska in 1960 (Rice, 1968, p.2-3; Bigg and Wolman 1975 p.1214). Table 7 gives the derived population sizes for 1966 in Georgia Strait -- Juan de Fuca Strait -- Puget Sound when net recruitment rates were varied from 1 to 10%. We assume a current population size of 115 whales, all cropping from this stock and the net recruitment rate did not change annually. Rates larger than 5% result in original population sizes which are lower than the current level - an unlikely possibility. It thus appears that while some net recruitment is occurring it may not exceed 5% annually.

#### 9. Original population size

Current data on net recruitment rates are insufficient to determine the original population size. However, as indicated in Table 7, if the average annual rate was 5% the population may have recovered to about the original size, but if the rate was 1%, the original size may have been 37% higher than the current figure. Additional difficulties in calculations arise if, as is likely, the net rate has changed with changes in population size. The net rate in animal populations tends to increase as the population size decreases from the unexploited level.

#### 10. Future research

It is important that the number and identity of pods which frequent Puget Sound be established with more certainty. This will probably be done in 1976 when the National Marine Fisheries Service, Seattle begins a photographic census in Washington.

There are still many captures for which the identity of the cropped pod is not known. We plan to continue a search for historical photographs of killer whale captures.

from annual net recruitment rates of .01-.10 and the known annual crop of whales.

Population size during 1966-74 was calculated from the equation

$$= \frac{N(x) + Z(x)}{1.00 + Y}$$

Population size (N)

Information on net recruitment rate can be collected by periodically censusing each pod. We hope that a large census can be conducted off eastern and southern Vancouver Island every 3-5 years. It could be done in 1 month, preferably August.

Data should also be collected on mortality rates of recognizable individuals in each pod. Greater attention to the identification of the smallest whales may provide more refined information on birth rates.

## 11. Management

### a. Fishery value

Bigg and Wolman (1975, p. 1218) reviewed the economic value of the fishery. Total revenue to killer whale netters in British Columbia and Washington was about \$1,000,000 from the sale of 48 whales during 1965-73. While the selling price of each whale was generally confidential information whales sold for \$8,000 in 1965, \$20,000 in 1970 and possibly \$70,000 in 1974.

It is difficult to judge the future prospects for the fishery. While there will always be some demand for the species in oceanaria, this may not be increasing as rapidly as during the late 1960's because of uncertainty in the supply of whales during recent years. Three organizations commercially net killer whales. The Seattle Marine Aquarium operates in Puget Sound, but despite intensive effort no whales have been caught here since 1972. Don Goldsberry, the whale netter for the aquarium feels this is because of restrictions on capture localities and a breakdown in his observer network to locate pods. While this aquarium used to sell whales to oceanaria in many parts of the world it is now owned by Sea World, San Diego. This will restrict the supply to other oceanaria. Messrs. Gooldrup, Reid and Gameron net in Pender Harbour, but none have been caught since 1969. B. Gooldrup feels that none have since entered Pender Harbour perhaps due to depletion of

local stocks or to more wary whales. Increased local boat traffic and public sentiment against killer whale netting has also reduced capturing effort. Sealand of the Pacific, Victoria nets in Pedder Bay and cropped eight whales during 1970-75. However, it kept four whales for its own exhibits and thus has not been a major supplier to other oceanaria.

b. Esthetic and recreational values

It is important to recognize the high esthetic and recreational value which many people from British Columbia and Washington place on seeing killer whales in the wild. This is particularly true in eastern and southern Vancouver Island, a region extensively used for marine recreation by residents and tourists. Here the whales generally travel slowly, close to shore and can be seen from boats or land. They are usually a spectacular sight being strikingly colored and frequently leaping out of the water or slapping their tails on the surface. They can be approached closely and appear unconcerned by normal boating activities. There are no known instances of attacks on humans. Throughout most of the area, pods are seen intermittently all year. In northern Johnstone Strait they are seen almost every day during the summer.

Eastern and southern Vancouver Island appear to be globally unique for observing killer whales in the wild. While the species occurs in all oceans it is not common. The relative abundance here is a localized phenomenon, perhaps related to concentrations of food. Killer whales have been caught for aquaria only in this area.

There has been public controversy, particularly since about 1970, from conflicts between esthetic and recreational values and the capturing of killer whales. These concerns include harassment of the whales during capture, the reduced population available for viewing in the wild, uncertainty in

scientific justification for harvesting and objection to the confinement of the species in small enclosures.

c. Regulations in 1975

In British Columbia during 1975 three permits were issued by the Federal Government for the capture of seven whales, either sex, of lengths 11'-16  $\frac{1}{2}$ ' from anywhere outside the important recreational area of Campbell River -- Alert Bay. Permits for three whales each were issued to Sealand of the Pacific, Victoria and Messrs. Gooldrup and Reid, Pender Harbour. A permit for one whale was given to Marineland and Game Farm, Ontario with Sealand of the Pacific the nominated catcher.

During October 1975 the Government of British Columbia legislated changes in its Wildlife Act which requires netters to apply to the provincial government for permission to capture killer whales in British Columbia territorial waters. The intent of the legislation was to place a moratorium on capturing until the population status was determined.

In Washington there were two permits issued to capture killer whales. One was given to Sea World, San Diego covering the period 1974-76 for the capture of four whales, either sex, lengths 11'-15' in regions outside Tacoma -- southern Whidbey Island in Puget Sound. The other permit was given to the University of Washington covering the period 1975-76 for the capture of 10 whales for experimental purposes. These whales can be either sex and any size.

d. Future considerations

Our key findings relevant to future regulations are now summarized. The most important management region is Georgia Strait -- Juan de Fuca Strait -- Puget Sound. About 115 whales occur here of which 65-70 whales are residents and the remainder transients. During 1962-75, 60 whales were probably cropped

from this stock, 45 of them during 1967-70. Uncertainty in net recruitment rate makes estimates of population reduction, recovery and yield speculative. However, these data can be collected over the next 3-5 years.

If captures are allowed in British Columbia during this time perhaps the management policy should limit cropping to the replacement of whales which die in Canadian oceanaria. With this policy cropping demand would remain relatively low. Currently there are three Canadian oceanaria with a total of seven killer whales. The Vancouver Public Aquarium has two killer whales, Sealand of the Pacific, Victoria has two, and Marineland and Game Farm, Ontario has three.

Any future cropping should consider changing the regulation on lengths to exclude adults. The survival of adults in captivity is considerably less than of immatures. The length regulation in 1975 was 11'-16  $\frac{1}{2}$ ' for both sexes. As maturity is thought to occur at 16' in females and 19' in males, cropping lengths would be better defined as 11'-15' for females and 11'-18' for males.

#### ACKNOWLEDGEMENTS

We express gratitude to Dr. W.E. Johnson, Director, Pacific Biological Station, Nanaimo for the use of Station facilities and the assistance of his support staff in carrying out this project.

We also thank Dr. W.E. Ricker, Nanaimo for comments on the manuscript.

Appreciation is acknowledged to the many other people and organizations, too numerous to list at present, contributing to the study.

REFERENCES

- Bigg, M. A. and A. A. Wolman. 1975. Live-capture killer whale (Orcinus orca) fishery, British Columbia and Washington, 1962-73. J. Fish. Res. Board Can. 32: 1213-1221.
- Cameron, W. M. 1941. Killer whales stranded near Masset. Fish. Res. Board Can. Pac. Prog. Rep. 49: 17.
- Carl, G. C. 1946. A school of killer whales stranded at Estevan Point. B. C. Prov. Mus. Nat. Hist. Anthropol. Rep. (1945): 21-28.
- Jonsgaard, A. and P. B. Lyshoel. 1970. A contribution to the knowledge of the biology of the killer whale Orcinus orca (L). Norw. J. Zool. 18(1): 41-48.
- Pike, G. C. and I. B. MacAskie. 1969. Marine mammals of British Columbia. Bull. Fish. Res. Board Can. 171: 54 p.
- Rice, D. W. 1968. Stomach contents and feeding behavior of killer whales in the Eastern North Pacific. Norsk Hvalfangst-Tid. 57(2): 35-38.