Helminthological Comparison of Subpopulations of Bering Sea Spotted Seals, *Phoca largha* Pallas

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ABSTRACT

The population of spotted seals in the Bering Sea appears to consist of three major groups, which concentrate at the time of giving birth and mating in Karaginskii Gulf, the Navarin-Anadyr region, and in southeastern Bering Sea from the Pribilof Islands to Bristol Bay, respectively. As part of an investigation of the biological characteristics of the seals in each group, their helminth faunas were compared. Samples consisted of 122 seals from the Karaginskii region, 130 from the Navarin-Anadyr region, and 57 from the Pribilof-Bristol Bay region. Of 22 species of helminths isolated from these seals, only 10 were common to all three regional samples, and most differed to a significant degree among regions in both prevalence and intensity of infection. The seals of the Karaginskii and Pribilof regions had fewer species of helminths in common (11) than either had with the Anadyr group (13), but were significantly more similar in the prevalences of the respective helminths. In numbers of helminths per host, the Anadyr and Pribilof seals were much more similar than either was to the Karaginskii seals. The differences between regional samples appear to be attributable in part to the somewhat different assemblages of prey available and, perhaps in part, to regional food preferences derived from learned, traditional, or inherited behaviors.

РЕЗЮМЕ

Популяция ларги в Беринговом море по-видимому состоит из трех главных групп, которые сосредоточиваются во время рождения и спаривания в Карагинском заливе, в Наварин-Анадырском районе, и в юго-восточной части Берингова моря от Прибыловских островов до Бристольского залива. В связи с исследованием биологических особенностей этих тюленей в каждой группе сравнивалась их гельминтофауна. Пробы получены от 122 ларг из Карагинского залива, 130 из Анадырского залива, и 57 из Прибылово-Бристольского района. Только 10 из 22 видов гельминтов являются общими для всех трёх районов; однако степень интенсивности и экстенсивности инвазии значительно изменяется в каждом из этих районов. Карагинская и Прибыловская популяции имели 11 общих видов гельминтов, но каждая из этих популяций имела 13 видов гельминтов общих с анадырской группой. Анадырские и прибыловские тюлени наиболее сходные по интенсивности инвазии. Разница между региональными пробами отчасти может быть обусловлена локальными особенностями питания, а с другой стороны - рационом, определяемым приобретенным, традиционным или унаследованным поведением тюленей.

INTRODUCTION

Spotted or larga seals, *Phoca largha*, inhabit the seas bounding the northern part of the Pacific Ocean, wherever pack ice is a dominant physical feature in winter (Mohr 1965; Chapskii 1969; Shaughnessy and Fay 1977). During their breeding season in early spring, the spotted seals of the Bering Sea are associated with the southern part of the pack ice, within about 100 km of its edge. Surveys of their distribution in April to early May, at the time of parturition and mating, repeatedly have disclosed a consistent pattern of varying abundance in different sectors of the ice (Tikhomirov and Kosygin 1966; Gol'tsev et al. 1975,[3] 1978; Burns and Harbo 1977[4]). The seals tend to concentrate at that time principally in three regions: 1) In Karaginskii Gulf, 2) south of Cape Navarin to St. Matthew Island, and 3) in southeastern Bering Sea, from the Pribilof Islands to outer Bristol Bay (Braham et al. 1984). Later in the spring, with melting and recession of the pack ice, the Karaginskii seals apparently disperse to Kamchatkan and Koryak nearshore waters, the Navarin-St. Matthew seals move northward into Anadyr Gulf, while the others continue through the Bering Strait, into the Chukchi Sea. They summer principally in coastal and estuarine habitats.

Because the three concentrations appear to be semi-isolated during the breeding season, they may warrant separate consideration in the formulation of management procedures. In order to assess the degree of their isolation, series of specimens have been collected from each group in recent years, for comparison of their craniological and helminthological characteristics. The results of the helminthological investigations are presented in this report.

MATERIALS AND METHODS

Helminthological data from the Karaginskii Gulf breeding concentration were obtained from 122 seals taken there between 6 and

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[3]Gol'tsev, V. N., V. N. Popov, and M. V. Yurakhno. 1975. On the localization of stocks of Bering Sea largas. *In* Marine mammals. Materials 6th all-union conf. 1:100-102. [Abstr.] Naukova Dumka, Kiev.

[4]Burns, J. J., and S. J. Harbo, Jr. 1977. An aerial census of spotted seal, *Phoca fulina largha*, and walruses, *Odobenus rosmarus*, in the ice front of Bering Sea. *In* Environmental assessment of the Alaskan continental shelf. Quarterly reports of principal investigators, April-June 1977, Vol. 1, p. 58-132. NOAA Environ. Res. Lab., Boulder, Colo.

28 May 1972 (examined by Popov). In the Navarin-Anadyr concentration, data were obtained from 116 seals taken in Anadyr Gulf between 8 April and 16 June 1967 (Yurakhno), and from 14 taken there between 5 May and 11 July 1972 (Popov). Data for the Pribilof-Bristol Bay concentration were obtained from 26 seals taken in the vicinity of the Pribilof Islands between 17 and 28 April 1976 (Yurakhno), 15 in southern Bristol Bay between 25 March and 25 April 1976 (Shults); 8 about 275 km north of the Pribilof Islands between 22 March and 26 April 1977 (Shults); and 8 about 450 km north of the Pribilofs between 26 May and 4 June 1977 (Shults). The geographic position of each sample is shown in Figure 1.

For each seal, the contents of the heart, lungs, gall bladder, stomach, and both the large and the small intestines were examined thoroughly. All helminths from them were then washed in fresh- or seawater and fixed in 10% Formalin.[5] Later, in the laboratory, they were examined and identified by conventional methods.

The resultant data were treated statistically, following Beklemishev (1970) and Breev (1976), by Student's t-test for significance of difference between sample means:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{S_1^2 + S_2^2}}$$

where $\bar{x}$ = sample mean, assuming binomial distribution
S = standard deviation about the sample mean.

When the value of t was > 2.0, the differences between regional samples were considered to be significant at the 0.95 level; when $t > 3.03$, the difference was accepted as significant at the 0.999 level.

[5]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

RESULTS

The qualitative and quantitative characteristics of the helminths from spotted seals in the samples from the three compared concentrations are presented in Tables 1 to 3 and in Figures 2 and 3.

The results of comparison of the helminth faunas of the Karaginskii and Anadyr populations already have been published (Gol'tsev et al. 1978). Therefore, we confine ourselves here principally to comparison of the helminths of the southeastern Bering Sea seals with those from the Anadyr and Karaginskii regions. Larval forms of helminths were excluded from the comparison.

From Table 1, one can see that the species composition of the helminths in the seals from each of the three regions was similar; nevertheless, only 10 of the 22 species were shared. These included several widely prevalent parasites of marine mammals (Delyamure et al. 1979): The trematode *Phocitrema fusiforme*; the cestode *Anophryocephalus* sp.;[6] the acanthocephalans *Corynosoma semerme, C. strumosum, C. validum*, and *C. villosum*; and the nematodes *Anasakis simplex, Phocascaris cystophorae, Terranova* sp. (footnote 6), and *Dipetalonema spirocauda*.

The qualitative similarity of the helminth fauna of the seals from southeastern Bering Sea to those in the Karaginskii and Navarin-Anadyr regions lay almost exclusively within those 10 species. The only other resemblances were 1) to the Karaginskii seals in the presence of the cestode *Diplogonoporus tetrapterus*, and 2) to the Navarin-Anadyr seals in the presence of the trematode *Orthosplanchnus arcticus*, the cestode *Diphyllobothrium* sp., and the nematode *Contracaecum osculatum*. The remaining species did not occur in common.

[6]The authors are not in full agreement as to the specific identification of cestodes of the genus *Anophryocephalus*, nematodes of the genus *Terranova* (=*Phocanema*), and acanthocephalans of the genus *Bolbosoma*, hence these are indeterminate species ("sp."), pending further study.

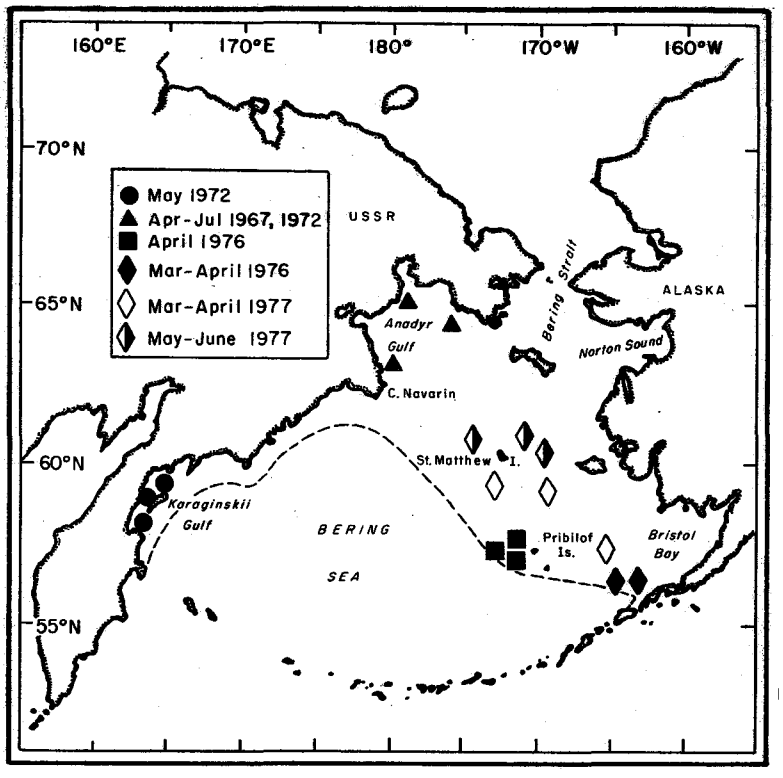

Figure 1.—Locations in which samples of spotted seals were taken for helminthological investigation in the Bering Sea. Dashed line marks approximate maximal extent of winter pack ice.

Table 1.—Comparative percentage frequency of occurrence of species of helminths in spotted seals taken in Karaginskii and Anadyr Gulfs and in the Pribilof-Bristol Bay region of Bering Sea.

Species of helminth	1 Karaginskii (n=122) $\bar{x} \pm S$	2 Anadyr (n=130) $\bar{x} \pm S$	3 Pribilof (n=57) $\bar{x} \pm S$	t_{1-2}	t_{1-3}	t_{2-3}
Orthosplanchnus arcticus	—	8.5±2.43	1.8±1.73	—	—	2.25
Orthosplanchnus pygmaeus	0.8±0.81	—	—	—	—	—
Phocitrema fusiforme	29.5±4.11	10.8±2.72	1.8±1.73	3.78	6.22	2.81
Microphallus orientalis	—	—	1.8±1.73	—	—	—
Anophryocephalus sp.[1]	24.5±3.76	23.8±3.74	56.1±6.56	0.13	4.18	4.28
Diphyllobothrium sp.	—	2.3±1.32	7.0±3.38	—	—	1.29
Diplogonoporus tetrapterus	1.7±1.15	—	8.8±3.78	—	1.80	—
Pyramicocephalus phocarum	—	—	1.8±1.73	—	—	—
Diphyllobothriidae gen. sp.	3.3±1.61	—	1.8±1.73	—	0.05	—
Corynosoma semerme	45.8±4.51	54.6±4.36	[2]88.1±4.99	1.40	6.30	5.07
Corynosoma strumosum	87.0±3.05	81.6±3.39	93.0±3.38	1.19	1.32	2.39
Corynosoma validum	8.2±2.48	4.6±1.18	3.5±2.44	1.31	1.35	0.40
Corynosoma villosum	2.5±1.40	3.0±1.50	3.5±2.44	0.28	0.37	0.16
Corynosoma wegeneri	6.2±2.24	8.5±2.43	—	0.58	—	—
Bolbosoma sp.[1]	—	—	5.3±2.96	—	—	—
Anisakis simplex	36.1±4.35	2.3±1.32	7.0±3.38	7.44	5.29	1.31
Contracaecum osculatum	—	2.3±1.32	31.6±6.30	—	—	4.54
Phocascaris cystophorae	54.9±4.50	72.3±3.93	52.6±6.60	2.92	0.29	2.57
Terranova sp.[1]	65.3±4.31	33.1±4.12	50.9±6.61	5.40	1.82	2.29
Terranova decipiens[1]	1.6±1.15	4.6±1.84	—	1.37	—	—
Anisakidae gen. sp.	—	0.8±0.77	—	—	—	—
Otostrongylus circumlitus	—	—	1.8±1.73	—	—	—
Parafilaroides krascheninnikovi	2.4±1.38	0.8±0.77	—	1.04	—	—
Dipetalonema spirocauda	4.0±1.77	8.5±2.44	1.8±1.73	1.47	0.92	3.41

[1]Species in question; authors disagree on identifications.
[2]Based on sample size of 42 seals.

Table 2.—Comparative abundance (number per host) of each species of helminth in spotted seals taken in Karaginskii and Anadyr Gulfs and in the Pribilof region[1] of Bering Sea.

Species of helminth	1 Karaginskii (n=122) $\bar{x} \pm S$	2 Anadyr (n=130) $\bar{x} \pm S$	3 Pribilof (n=26) $\bar{x} \pm S$	t_{1-2}	t_{1-3}	t_{2-3}
Orthosplanchnus arcticus	—	1.5± 0.97	0.3± 0.26	—	—	1.25
Orthosplanchnus pygmaeus	0.0± 0.01	—	—	—	—	—
Phocitrema fusiforme	p[2]	p	p	—	—	—
Microphallus orientalis	—	—	p	—	—	—
Anophryocephalus skrjabini[3]	10.2± 3.47	p	1.7± 0.81	—	2.38	—
Diphyllobothrium sp.	—	0.0± 0.05	p	—	—	—
Diplogonoporus tetrapterus	0.1± 0.06	—	1.9± 1.84	—	0.99	—
Pyramicocephalus phocarum	—	—	0.2± 0.15	—	—	—
Diphyllobothriidae gen. sp.	0.1± 0.10	—	0.1± 0.08	—	0.08	—
Corynosoma semerme	2.7± 0.48	14.4± 3.26	8.5± 1.43	2.71	3.85	1.65
Corynosoma strumosum	119.0±87.60	835.0±208.00	397.0±103.00	3.18	2.04	1.89
Corynosoma validum	0.2± 0.08	0.1± 0.08	0.1± 0.08	1.10	0.83	0.28
Corynosoma villosum	0.1± 0.06	0.0± 0.02	0.2± 0.09	0.67	0.73	1.44
Corynosoma wegeneri	0.3± 0.24	0.6± 0.30	—	0.76	—	—
Bolbosoma nipponicum[3]	—	—	p	—	—	—
Anisakis simplex	11.9± 1.13	0.1± 0.10	0.4± 0.14	10.4	10.1	1.45
Contracaecum osculatum	—	0.1± 0.06	p	—	—	—
Phocascaris cystophorae	7.0± 0.62	16.9± 3.03	7.7± 1.32	3.18	0.47	2.79
Terranova azarasi[3]	13.0± 2.31	4.3± 1.10	3.4± 1.02	3.14	3.80	0.56
Terranova decipiens[3]	0.2± 0.19	0.6± 0.53	—	0.71	—	—
Anisakidae gen. sp.	—	0.0± 0.01	—	—	—	—
Otostrongylus circumlitus	—	—	0.3± 0.31	—	—	—
Parafilaroides krascheninnikovi	0.1± 0.10	0.0± 0.02	—	0.99	—	—
Dipetalonema spirocauda	0.8± 0.69	0.8± 0.63	p	0.05	—	—

[1]Includes only the April 1976 (Yurakhno) sample; comparable data not available from others.
[2]Present but not counted.
[3]Species in question; authors disagree on identifications.

Table 3.—Comparative diversity of species of helminths in spotted seals of different ages, taken in Karaginskii and Anadyr Gulfs and in the Pribilof region[1] of Bering Sea.

	1 Karaginskii			2 Anadyr			3 Pribilof					
Age of seals	n	$\bar{x} \pm S$	C.V.[2]	n	$\bar{x} \pm S$	C.V.	n	$\bar{x} \pm S$	C.V.	t_{1-2}	t_{1-3}	t_{2-3}
Newborn	8	—	—	7	—	—	2	—	—	—	—	—
Yearlings	18	1.4±0.27	102.0	18	0.4±0.26	286.0	—	—	—	2.66	—	—
1-4 yr	46	4.5±0.23	34.5	45	3.8±0.18	31.6	5	3.8±0.16	9.5	2.28	2.36	0.00
5-12 yr	27	4.4±0.38	23.2	44	4.3±0.20	31.4	12	4.4±0.28	21.5	0.40	0.04	0.44
13 yr and older	23	4.6±0.21	23.6	14	4.1±0.46	41.8	7	4.7±0.28	20.6	0.92	0.27	1.06
Age unknown	—	—	—	2	3.5±0.35	14.3	—	—	—	—	—	—
Total	122	3.7±0.18	52.1	130	3.3±0.17	59.0	26	4.0±0.28	35.9	1.71	0.90	2.19

[1]Includes only the April 1976 (Yurakhno) sample; comparable data not available from others.
[2]C.V. = coefficient of variation about the sample mean.

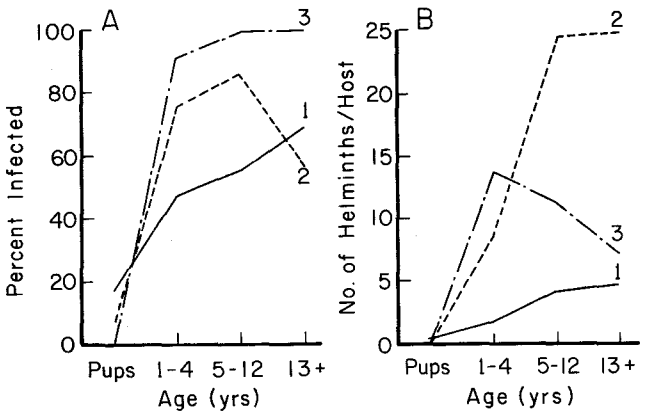

Figure 2.—Percentage of seals infected (A) by *Corynosoma semerme*, and mean numbers per host (B) in relation to age of spotted seals taken in the Karaginskii (1), Anadyr (2), and Pribilof (3) regions of the Bering Sea.

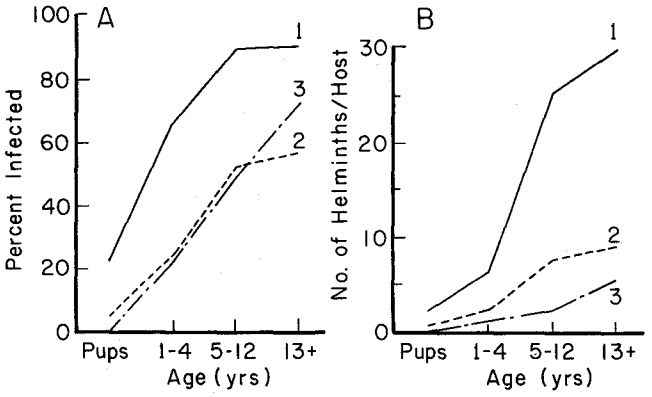

Figure 3.—Percentage of seals infected (A) by *Terranova azarasi*, and mean numbers per host (B) in relation to age of spotted seals taken in the Karaginskii (1), Anadyr (2), and Pribilof (3) regions of the Bering Sea.

The seals from the southeastern Bering Sea differed from the others in that they alone had the trematode *Microphallus orientalis*, the acanthocephalan *Bolbosoma* sp. (footnote 6), the cestode *Pyramicocephalus phocarum*, and the nematode *Otostrongylus circumlitus*. Only the Karaginskii seals had the trematode *Orthosplanchnus pygmaeus*, and only they and the Navarin-Anadyr seals had the acanthocephalan *Corynosoma wegeneri* and nematodes identified as *Terranova decipiens* and *Parafilaroides krascheninnikovi*.

Quantitative comparison between regional samples could be done only with the species of helminths which they had in common. Those, of course, were the ones which most frequently and most intensively infected these seals. The data obtained indicate substantial differences in frequency of occurrence of the helminths between samples (Table 1).

The southeastern and southwestern (Karaginskii) samples differed significantly to highly significantly in infection rate by four species [*Phocitrema fusiforme, Anophryocephalus* sp. (footnote 6), *Corynosoma semerme*, and *Anasakis simplex*]; the mean numbers per host (Table 2) also differed significantly to highly significantly for five species [*Anophryocephalus skrjabini* (footnote 6), *Corynosoma semerme, C. strumosum, Anasakis simplex*, and *Terranova azarasi* (footnote 6)]. Significant differences in infection rate were not indicated for the cestode *Diplogonoporus tetrapterus*; the acanthocephalans *Corynosoma strumosum, C. validum*, and *C. villosum*; or for the nematodes *Phocascaris cystophorae, Terranova* sp. (footnote 6), and *Dipetalonema spirocauda*. Most of those [excepting *C. strumosum* and *T. azarasi* (footnote 6)] also did not differ significantly in numbers per host.

The helminth fauna of the sample from the southeastern Bering Sea also differed significantly to highly significantly from that of the Navarin-Anadyr sample in infection rate by nine species of helminths [*Orthosplanchnus arcticus, Phocitrema fusiforme, Anophryocephalus* sp. (footnote 6), *Corynosoma semerme, C. strumosum, Contracaecum osculatum, Phocascaris cystophorae, Terranova* sp. (footnote 6), and *Dipetalonema spirocauda*]. For only *P. cystophorae*, however, did the numbers per host differ significantly.

Some differences between regional samples also were apparent in the species diversity of helminths in seals of different age classes (Table 3). The clearest tendency toward increased diversity in relation to the age of the hosts was evident in the seals from the southeastern Bering Sea. In the Anadyr sample, conversely, a tendency toward diminution in number of species was indicated in the oldest age group of seals. The coefficient of variation of species diversity also was least overall (35.9%) in the southeastern sample and lower for each age group than in the other regional samples.

DISCUSSION

The great similarity between the three samples of seals in the composition of their helminth faunas indicates a high degree of uniformity in the diets of the spotted seals in all regions. The greater similarity in some respects between the helminths of the southeastern and Karaginskii seals than between those of the southeastern and

Navarin-Anadyr concentrations is notable and may be attributable to the greater similarity of habitats occupied by the seals in Karaginskii Gulf and the Pribilof-Bristol Bay regions, with consequent availability of similar, subarctic prey. The waters of the Navarin-Anadyr region, conversely, are appreciably deeper and colder than those of the southeastern and southwestern shelves of the Bering Sea and support a predominantly arctic assemblage of organisms (Zenkevitch 1963).

Although the availability to the seals of somewhat different assemblages of prey in each of the three regions may account for some of the difference between their helminth faunas, other factors such as prey selection may be of equal or greater importance. That is, the spotted seals inhabiting each region may exhibit learned, traditional, or inherited preferences for different kinds or sizes of prey than those in the other regions, the result of which could be infection by different kinds and numbers of helminths. That this is a plausible factor is suggested by the distinct differences in helminth faunas between the southeastern Bering Sea spotted seals and their sympatric relatives, the Pacific harbor seals, *Phoca vitulina richardsi*, of the Pribilof Islands (Shults 1979,[7] 1982). The same kinds of prey were available to both species of seals at the same time (April) and some of those were eaten by both species (Lowry and Frost 1981). Nevertheless, the harbor and spotted seals were infected in common by only six species of helminths [*Anophryocephalus* sp. (footnote 6), *Diplogonoporus tetrapterus, Corynosoma semerme, C. strumosum, Contracaecum osculatum*, and *Dipetalonema spirocauda*]. The infection rates by each helminth also were markedly different in the two species of seals. Furthermore, the harbor seals lacked the other 12 species which were present in the spotted seals and were infected by one (*Corynosoma hadweni*) which was absent from the spotted seals. The contrasting results indicate that these two closely related species of seals, given access to the same food sources, have somewhat dissimilar dietary preferences as a consequence of learned or inherited behaviors. We suggest that the same may be true of the spotted seals in the three areas where breeding is concentrated. Since each is genetically differentiated to some degree, as indicated by their craniological variation (Fedoseev 1984), a corollary may be behavioral differentiation.

In our opinion, the helminthological findings reported here lend some support to the concept of three semidiscrete subpopulations of spotted seals in the Bering Sea, as has been indicated by the distributional and craniological data.

[7]Shults, L. M. 1979. Helminth parasites of the Pacific harbor seal, *Phoca vitulina richardsi*, from Alaskan waters. Unpubl. manuscr., 10 p. Institute of Marine Science, University of Alaska, Fairbanks, AK 99701.

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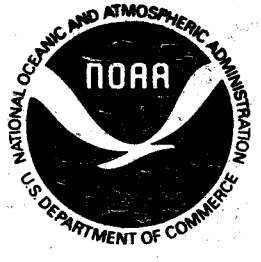

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