PROJECT RATIONALE, DESIGN, AND SUMMARY

by

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1984

BACKGROUND

The Chirikof Basin is generally delineated by the Seward Peninsula and Norton Sound in the east, the Chukotka Peninsula and a shallow sill in the west, St. Lawrence Island and a sill in the south, and the Bering Strait sill in the north. Water depths in the central basin range from about 30 to 50 m. Sediments are silty sand over much of the basin, with gravely sand and sandy gravel predominating in the area off northwestern St. Lawrence Island (Sharma 1974).

The marine environment of much of the Chirikof Basin is classed as Pacific Subarctic (Dunbar 1968). Bottom temperatures are near O°C (Takenouti and Ohtani 1974). Salinity is reduced through the influence of large rivers that empty into the Bering Sea (Stoker 1978). The general flow of water in the Chirikof Basin is northward to the Bering Strait (Takenouti and Ohtani 1974)0

Large numbers of marine mammals inhabit the northern Bering Sea (see Braham et al. 1977). Some, like the bearded and ringed seal, are year-round residents, whereas others (bowhead whale, white whale) use it as wintering grounds. The gray whale (*Eschrichtius robustus*) frequents the northern Bering Sea in summer.

Gray whales calve and mate primarily in the lagoons of Baja California. Most have begun their northward migration along the North American west coast by early March (Rice et al. 1981), and they summer mainly in the northern Bering and southern Chukchi seas (Braham et al. 1977). One of the main areas of concentration in summer is the Chirikof Basin (Votrogov and Bogoslovskaya 1980; Zimushko and Ivashin 1980). Gray whales start to arrive in the St. Lawrence Island area in May (Pike 1962), and some remain there until October (Pike 1962, Votrogov and Bogoslovskaya 1980). Migration out of the Bering Sea summering areas is completed by mid December (Rugh and Braham 1979).

During migrations and in their summering range, gray whales are generally found in coastal areas or in shallow offshore areas (Pike 1962; Votrogov and Bogoslovskaya 1980; Zimushko and Ivashin 1980). In the summering areas, food consists almost entirely of the benthic amphipods Pontoporeia affinis, P. femorata, Anonyx nugax and particularly ampeliscids, especially Ampelisca macrocephala (Pike 1962; Zimushko and Ivashin 1980; Bogoslovskaya et al. 1981).

The present population of gray whales is approximately 17,600 (Reilly et al. 1983). It appears that most of the population utilizes the Bering Sea area at least as a migration route (Rugh and Braham 1979). However, it was not known what proportion of the animals summer in the area between St. Lawrence Island and the Bering Strait, or how many utilize the Chirikof Basin. Considerable numbers of gray whales occur along the Soviet coasts of the Bering and Chukchi seas (Zimushko and Ivashin 1980), and some move northeast along the Alaskan side of the Chukchi Sea. Many of these animals must move through the Chirikof Basin at least once or twice during the open-water season.

APPROACH USED IN THE STUDY

The present stock of gray whales is believed to be at or near its historic pre-exploitation level (Reilly et al. 1980). Reilly et al. (1983) have calculated that the population of gray whales showed a net increase of 2.5% per annum between 1967 and 1980. If the Russian catch is included, total net production was 3.8% (Reilly et al. 1983). Under these conditions natural factors may eventually act to regulate gray whale populations. One potentially important factor is the carrying capacity of the summer habitat. The general objective of this study was to determine the 'carrying capacity' of the Chirikof Basin for gray whales, in order to evaluate the importance of this area to gray whales and to estimate the effect on gray whales of any serious adverse impact on this habitat.

In order to address these objectives, information was obtained on (1) the numbers and distribution of gray whales utilizing the Chirikof Basin, (2) food consumption by gray whales in summer, (3) biomass and distribution of prey species, and (4) productivity of prey species.

The study encompassed four components:

1. Numbers and distribution of whales utilizing the Chirikof Basin were estimated based on the literature, and upon ship surveys and aerial surveys conducted during this project.

2. Food consumption by gray whales was estimated by two independent methods: a theoretical estimation based on energetic requirements, and an estimate based on direct observations of feeding behavior and observations of pits and furrows made by feeding gray whales.

3. Biomass and distribution of gray whale prey species in the Chirikof Basin were estimated through examination of samples collected by surface- and diver-operated gear, and video and still photography.

4. The productivity of the infaunal prey of the gray whale was estimated using commonly accepted methods (e.g., Wildish and Peer 1981). This required year-round sampling at a location chosen at the beginning of the field study.

Total food consumption by gray whales in the Chirikof Basin was estimated from our knowledge of the frequency of feeding dives, the amount of food removed per dive, and our estimate of the number of whales in the area. Food availability was determined by applying productivity to biomass ratios of prey species to the biomass of prey species in the area used by gray whales as foraging grounds.

STUDY DESIGN

Distribution and abundance of gray whales in the Chirikof Basin during the summer of 1982 were estimated from results of aerial surveys supplemented with information obtained from shipboard transect counts. Aerial surveys were flown along 10 transect lines across the Chirikof Basin. Additional lines to sample distribution of gray whales in coastal waters were also flown. Surveys were flown in mid July and early September.

Shipboard work was conducted from 16 stations in the central Chirikof Basin and 11 stations near St. Lawrence Island. An area off Southeast Cape, St. Lawrence Island, was studied intensively. At each station, we collected data needed to determine the extent of feeding by gray whales, kinds of potential prey organisms present, and nature of the substrate. This information, coupled with data on whale distribution as determined by aerial and shipboard surveys, enabled foraging grounds to be identified and characterized.

At each station a 500 kHz side-scan sonar was towed to detect the presence, number and outlines of feeding features made by foraging gray whales. These data were subsequently coded and/or digitized. The digitized records were corrected for ship speed and height of towfish. These data were used to produce corrected plots of the outlines of features, plus data on size of features and amount of sea floor covered by the features. The coded records were used to determine the density of feeding features in various parts of the study area.

Five Van Veen grab samples were taken at each station. Abundance, biomass and species composition of animals were recorded for each sample. Subsamples were analyzed for grain size, caloric content, and carbon and nitrogen content of the substrate. A video camera was used to typify the sea floor at each station and to provide data on homogeneity of bottom types in the vicinity of grab sampling locations.

Information about numbers of gray whales near sampling stations was obtained by 'station scans' while the ship was on station and transect counts while it was en route between stations.

off Southeast Cape, St. Lawrence Island, divers investigated features in areas that had been marked by a boat towing the side-scan sonar, or marked by observers within a group of feeding whales. Airlift samples were taken inside and outside features made by feeding whales to determine the amount of food that had been removed. The size and shape of the features were measured and photographs were taken, A station for the estimation of amphipod productivity was established and sampled in August, September, January, March and May.

At each station where there were whales, and in the intensively studied nearshore area, we obtained observations and video recordings of the behavior of the whales. Observers recorded the breathing rate, durations of surfacings and dives, distance traveled, and whether or not dives were accompanied by evidence of feeding such as the presence of mud plumes and/or seabirds. These observations were made from small boats and from elevated positions on the ships and shore.

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Distribution, Abundance and Productivity of Amphipods

The areal extent of amphipod dominated benthic communities was as described by Stoker (1978). High biomass of amphipods was found in the central Chirikof Basin and off the south and west coasts and Southeast Cape, St. Lawrence Island. The ampeliscids Ampelisca macrocephala, A. eschrichti and Byblis gaimardi were the most abundant amphipods in three of four of the above areas. Photis fischmanni was dominant in areas off Southeast Cape.

Mean grain size and its square were significant predictors of the density of all three ampeliscid species in multiple regression analyses. The equations predicted maximum density of all three species at a mean grain size of between 2.9 and 3.1 Φ . Both Byblis gaimardi and Amplisca macrocephala were more abundant in sediments with a high caloric content. Niche separation between the three ampeliscid species with the same apparent grain size preference may be as follows. Ampelisca macrocephala was more abundant in poorly sorted substrates while A. eschrichti was more abundant in well sorted substrates. All three ampeliscid species ingested sediment, but Byblis gaimardi appeared to be the only species that ingested diatoms. Perhaps because of this preference for algal material it was the only one of the three species that was more abundant in shallow water than in deep water. Ampelisca eschrichti was most abundant in sediments with a high carbon content and low carbon/nitrogen ratio. The other two species exhibited no such relationship.

Photis fischmanni was the dominant benthic animal on the shallow shelf off Southeast Cape, St. Lawrence Island, where mean density was 95,000 indiv./m^2. Overall, its density was highest in shallow water in well sorted substrates with a high caloric content and a low carbon to nitrogen rat io.

Detailed analyses of seven other common species of amphipod also showed niche separation on the basis of depth, substrate, organic composition of the sediment and food habits.

Sampling was carried out off Southeast Cape, St. Lawrence Island, in July, September, January, March and May to determine productivity of **Ampelisca macrocephala** and **Photis fischmanni,** the two dominant species.

The life cycle of **Ampelisca macrocephala** appears complicated because individuals require two and a half years to reach maturity and young are released around January and around July. Young released in June-July at a length of 3 mm reach 5 mm in length by September, 10 mm by the following March and 11 mm one year later. The following July (two years after release) they would be about 18 mm in length, reach maturity that fall and release young in winter. The productivity to biomass ratio of both the January and July cohorts over one year was about 1.8.

Photis **fischmanni** also appears to release young in summer and winter, but this small **amphipod** (7 mm maximum length) appears to require only six months to reach maturity. Annual productivity to biomass ratio was 3.7.

The growth rates of these two species were comparable to those recorded for other arctic and northern amphipod species.

There appeared to be no difference in the length/weight relationship between specimens of **Ampelisca macrocephala** taken in July and January; however, specimens taken in January had a lower caloric content and higher percentage of ash than those taken in July.

Distribution and Abundance of Gray Whales

Aerial surveys in July and September (Miller, this report) showed that gray whales were concentrated in a broad band extending (roughly) from Cape Prince of Wales on the Seward Peninsula south to Northeast Cape on **St.** Lawrence Island. Few whales were observed **within** the American **Chirikof** Basin to the east or west of this band. Gray whales were also numerous along the east and west coasts of St. Lawrence Island. During the two surveys, 46% of whales sighted within 500 m of the aircraft’s flight path were accompanied by feeding plumes.

The Fourier Series line transect method was used to estimate raw densities of gray whales. The resulting estimates were 0.0115 whales/km^2 in July and 0.0045 whales/km^2 in September. These raw estimates were then corrected for detectability of whales which is a function of the durations of surfacings and dives, and of the period of time during which each whale is potentially detectable from the passing aircraft. Separate correction factors were derived from behavioral data collected in July and September. Application of these correction factors to the raw density estimates for the 46,800 km2 under consideration yielded abundance estimates of 1929 whales in July and 601 whales in September.

The distribution of whales observed during shipboard transects and scans was similar to distributions observed during aerial surveys. In addition, approximately 100 whales were observed across the international boundary in the west-central part of the Chirikof Basin and 35 whales were observed off the south coast of St. Lawrence island. These two areas were not sampled by the aerial surveys.

Feeding Behavior

Blow intervals, number of blows per surfacing, durations of surfacings and durations of dives were recorded 3503, 1050, 1062 and 905 times, respectively (Würsig et al., this report). In July, most of the whales observed were solitary, while in September, the incidence of whales in social groups was higher and increased throughout the month. In July and September, whales spent an average of 20.8% and 23.2% of their time at the surface, respectively. Average blow rates were 0.997/min in July and 1.122/min in September.

Whale behavior was categorized as feeding, possibly feeding and not feeding. Blow rate did not vary with feeding category but was higher in September (1.186 and 1.288 blows/rein for non-feeding and feeding whales, respectively) than in July (0.976 and 0.974 blows/rein). In both months, number of blows per surfacing, durationa of surfacings and durations of dives were greater for feeding than for non-feeding whales. Blow intervals and number of blows per surfacing were greater in September than in July. In

July, the feeding dive cycle (including the surface interval) lasted 4.61 min and the non-feeding dive cycle 2.92 min. In September, the feeding dive cycle lasted 4.88 min and the non-feeding dive cycle 2.74 min. In July, gray whales were estimated to spend 79% of their time feeding, making about 198 feeding dives per day. In September, whales spent about 69% of their time feeding, making about 164 feeding dives per day. Observations of behavior indicate that the whales spent more time socializing and traveling and less time feeding in September than in July.

While feeding, whales traveled a mean distance of 69 m during surfacings in July and 33 m in September. During dives, they traveled net horizontal distances of 100 m and 93 m below the surface in July and September, respectively. Speed of movement while feeding was about 1.7 km/h underwater and 3.4 km/h at the surface for an average of about 2 km/h.

In July, dive duration was similar for all depths where whales were feeding; however, duration of surfacing, number of blows per surfacing, and the blow rate all increased with increasing depth.

Feeding Ecology

In the Chirikof Basin and near St. Lawrence Island, gray whales feed in two different ways (Thomson and Martin, this report). Both methods are described in the literature (Ray and Schevill 1974; Nerini in press) and involve suction of the bottom while the whale is on its side. (1) Furrows are made while the whale is in motion. Side-scan sonar records showed that furrows extended for a mean distance of 46 m. Furrows observed by divers were 42.6 ± s.d. 34.1 cm wide, 1 to 2 cm deep, and were usually discontinuous. Gaps between furrows were 25 to 50 cm long and furrowed portions were 4 ± 4 m long. The mean length of furrows recorded on side-scan sonar, exclusive of gaps, was 41 * 10 m and the mean furrowed area was 18 + 5 m^2. (2) Pits are apparently made while the whale is nearly stationary. Individual suction 'bites' averaged 1.1 m^2 in area and were sometimes coalesced into large shallow pits. The mean area of pits, including the component 'bites', was 13 + 3 m^2. Pits measured by divers were approximately 10 cm in depth.

In most areas there appeared to be a mixture of large and small pits and furrows. The side-scan sonar records indicated that the area around St. Lawrence Island and the central part of the Chirikof Basin were used extensively by feeding whales. The areas showing a high density of whale feeding features on the bottom had the following characteristics:

1. A high biomass of amphipods on the bottom.
2. A mean grain size of 3.1Φ (fine sand).
3* Sediment with very little gravel.
4. High densities of whales, as observed from the ship and during aerial surveys.
5. Presence of the ampeliscid amphipod community described by Stoker (1978).

Divers investigated five of the gray whales feeding features to examine the substrate communities. Animals other than amphipods appeared not to have been taken by the whales, most likely because they are deeper in the substrate, and the degree of recolonization, even in an apparently fresh feature, was considerable. Scavenging isopods, polychaetes and perhaps lyssianasid amphipods may move into denuded areas to take advantage of damaged animals. Amphipods appeared quick to respond to newly available substrate. Disruption of the 'mat', consisting mainly of animal tubes that give the surface layer of the bottom its cohesive nature, is not total and results in minimal changes to the grain size characteristics and organic makeup of sediments in feeding areas.

Analysis of the literature and aerial survey results indicates that annual utilization of the Chirikof Basin by whales migrating to and from the Siberian coast and Chukchi Sea may be about 100,000 whale-days. Utilization by the summer resident population may be about 265,000 whale-days.

Gray whale consumption was estimated using a mean of 198 feeding dives per day in July and 164 dives per day in September (Wursig et al., this report), a mean area cleared of 15.5 m^2 per dive, an average amphipod biomass in that portion of the Chirikof Basin used by feeding whales of 133 f/m^2, and a 95% baleen retention efficiency for amphipods (calculated using data from

from plankton tows taken through mud plumes). The average amphipod consumption per whale based on these parameters is 321 kg/day. However, it would appear that gray whales select areas of high amphipod density in which to feed. If gray whales were to selectively feed in areas containing an amphipod biomass equivalent to that in the 25% of benthic samples with the highest biomass they would consume an average of 678 kg/day.

Energetic requirements for a male gray whale weighing 23,000 kg, 12.5 m in length, and spending 150 days on its northern feeding range, was estimated using Sumich's (1983) respiration method. Assuming that such a whale fed enough during migration to account for energy utilized during migration, then it would have to consume about 800 kg/day in summer in order to store sufficient energy for a 62-day period of fasting" off" Baja in winter. However, this estimate is high when compared to Lockyer's (1981) energetic computations for large whales. Using Lockyer's assumptions, the feeding rate would be 445 kg/day.

Based on analysis of speed of movement over various parts of the migration route and evidence of feeding while migrating, it would appear that gray whales may feed considerably during approximately half of their migration but not during the remainder of the migration. If energy intake balances energy expenditure during half of the migration and if the remainder of the energy needed for migration and winter is accumulated in summer, then the male gray whale would need to consume about 604 kg/day while in the Chirikof Basin (using Lockyer's (1981) assumptions). This value is higher than that derived through analysis of feeding behavior and furrows. However, it appears that gray whales selectively feed in areas with a standing crop of amphipods higher than average. There was a significant positive correlation between amount of feeding, as shown on side-scan sonar, and biomass of amphipods. Using our data on size of feeding structures (e.g., furrows and other indentations) and feeding dive rates, feeding at a rate of 604 'kg/day requires the whales to feed in areas with a mean biomass of amphipods of 223 g/m^2. This value represents the mean biomass in the 35% of our samples that contained the highest biomass.

A comparison of (1) productivity and standing crop of the benthos with (2) consumption by gray whales showa that total consumption by gray whales utilizing the Chirikof Basin is roughly 7.5% of the standing crop and 4% of the annual productivity of amphipods in that part of the basin used as feeding grounds. These values are low. However, gray whales must feed in areas with a higher than average standing crop of amphipods. The extent of areas with a sufficient standing crop of amphipods to meet the requirements of gray whales is unknown.

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