Exxon Valdez Oil Spill Restoration
Project Annual Report

Pigeon Guillemot Restoration Research at the Alaska SeaLife Center

Restoration Project 99327
Annual Report

This annual report has been prepared for peer review as part of the Exxon Valdez Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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April 2000

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Study History: Post-spill (EVOS) studies (project beginning in FY95 with APEX subproject 95163F and APEX subproject 95163M) have identified three potential factors preventing recovery of Pigeon Guillemots in Prince William Sound, including the reduction in high quality fishes in their diet, exposure to residual oil, and predation. EVOS Restoration Project 99327 is the second year of a 3-year project to study captively reared Pigeon Guillemots to determine viability of raising and fledging them in conjunction with a social attraction project at the Alaska SeaLife Center. During captive rearing, additional studies are being performed on food and crude oil ingestion to help address the questions of recovery. The project began as EVOS Project 98327. This is the second annual report initiated under the project.

Abstract: Pigeon Guillemot (*Cepphus columba*) populations in Prince William Sound were injured by the *Exxon Valdez* Oil Spill (EVOS) and have failed to recover from declines occurring before and after the spill. Three factors have been proposed for the lack of recovery: (1) increased predation on eggs and chicks, (2) decreased availability of high-quality schooling forage fish prey (e.g., herring, sand lance), and (3) stress associated with exposure to residual oil. In 1999 we continued the second year of a three year study on these three factors. We constructed nesting platforms with nest boxes and decoys at the Alaska SeaLife Center in Seward, Alaska and in Prince William Sound to examine the utility of artificial nest cavities in reducing nest predation. We also examined the effect of prey quality on chick growth and survival by hatching eggs in captivity and raising chicks on two restricted and one unrestricted diet treatments comprising low- and high-energy diets. Growth (body mass) of guillemot chicks fed equivalent biomass diets of different prey was positively correlated with the energy density of those prey. Captive-raised chicks (n = 60) were allowed to fledge into the wild from the SeaLife Center and subsequent resightings or recruitment at the nesting platforms could demonstrate the effect of pre-fledging diet on post-fledging survival, and the utility of captive-rearing as a direct restoration technique. In 1999-2000, small numbers of chicks were and will continue to be dosed with oil to allow identification of blood biomarkers of oil ingestion.

Key Words: pigeon guillemot, *Cepphus columba*, social attraction, captive rearing, fledging, diet, lipid, hatching, proximate analysis, energy content, growth rate, fledging period, physiological ecology.

Project Data: Data collected to date include pigeon guillemot chick growth rates and fledging times for chicks raised on differing lipid diets. Data on collection and captive rearing success is also included.

Introduction: Pigeon Guillemots are pursuit-diving, semi-colonial, cavity-nesting alcids that feed in the nearshore and utilize a wide range of cavities found in shoreline habitats, such as rock crevices, tree roots, talus, burrows, and man-made structures (bridges, docks). The Pigeon Guillemot population in Prince William Sound (PWS) decreased from approximately 15,000 in the 1970's to less than 5,000 in the 1990's (Laing and Klosiewski 1993). While mortality from the 1989 *Exxon Valdez* Oil Spill contributed to the decline, the population was apparently decreasing before the spill. Unlike most other avian species affected by the spill, Pigeon Guillemot populations in PWS have not recovered to pre-spill numbers. Censuses at other northern Gulf of Alaska breeding colonies indicate that the decline in guillemots may have occurred over a wide region.

Post-spill studies have identified three potential factors preventing recovery: 1) a change in prey base, 2) increased nest predation, and 3) continued exposure to oil.

1) Change in prey base. Guillemots are the most neritic members of the Alcidae family and, like other members of the family, dive in pursuit of prey. Pigeon Guillemots prey on a wide variety of fishes, including schooling forage fish (e.g., herring, sand lance, and pollock) and nearshore demersal fish (e.g., gunnels, blennies, sculpins; Drent 1965, Kuletz 1983). The proportion of high-quality schooling forage fish in the diet has decreased at some PWS colonies (Oakley and Kuletz 1996). The percentage of high-lipid forage fish in the diet is a pivotal factor affecting guillemot reproduction (Golet et al. 2000a). A decline in the availability of high-quality forage fishes (sand lance, herring, capelin) in the last two decades (Hatch et al. 1993, Piatt and Anderson 1996) may be decreasing growth rates, fledging success, post-fledging survival, and adult recruitment rates.

2) Increased nest predation. Predation on guillemot eggs and chicks in some areas of PWS is higher than prior to the spill and could be contributing to the decline or impairing recovery (Hayes 1995). Sub-optimal nest cavities that allowed successful reproduction in the past may no longer do so due to increased numbers of predators at some sites.

3) Continued exposure to oil. Exposure of seabirds to crude oil has been demonstrated to have a variety of deleterious effects. External physical exposure has been shown to decrease buoyancy, inhibit flight, increase basal metabolic rate, and cause inflammation (Hartung and Hunt 1966, Lee et al. 1985, Lambert et al. 1982). In addition, oil can be ingested during preening of oiled plumage (Hartung 1963). Ingestion of oil can cause a myriad of problems for birds, including reduced rate of growth (Szaro et al. 1978, Peakall et al. 1982), lowered reproductive success (Grau et al. 1977, Trivelpiece et al. 1984), Heinz-body hemolytic anemia (Leighton et al. 1983), and damage to internal organs or death with chronic or high level exposure (Fry and Lowenstine 1985, Khan and Ryan 1991).

Ten years after EVOS, levels of cytochrome P4501A (CYP1A) in adult Pigeon Guillemots in PWS were elevated in liver samples taken from birds breeding in oiled sites when compared to those breeding in unoiled sites (Golet et al. 2000b). CYP1A is a xenobiotic-metabolizing enzyme that can be induced by crude oil components such as polycyclic aromatic hydrocarbons. This indicates a possible link between oil contamination and biochemical effects on guillemots living in area of the spill.

Exposure to residual oil by consuming nearshore demersal and schooling fish contaminated with oil could increase Pigeon Guillemot adult mortality or decrease

Restricted diet and dosing experiments. Due to the uncertain nature of chick/egg acquisition, chicks were assigned to diet groups on the basis of acquisition date for chicks collected in the wild or hatch date for eggs collected in the wild. Further complicating matters was that the juvenile walleye pollock (*Theragra chalcogramma*) for the pollock diet treatment was not available at the start of the experimental treatments. Thus, the first 30 chicks either hatched or acquired as chicks were assigned to restricted juvenile herring (*Clupea harengus pallasii*). These first 30 chicks were then assigned randomly, by drawing assignments out of a hat, to one of three diet treatment groups: a) restricted, control, b) restricted, 1.0 ml crude oil dosed (by gel cap within prey) on two days (day 20 and day 25 post hatch), c) restricted, 2.0 ml crude oil dosed (by gel cap within prey) on two days (day 20 and day 25 post hatch). The next 10 chicks hatched or taken in as chicks were assigned to restricted diets of juvenile pollock (after the pollock shipment arrived). The remaining chicks were assigned to ad lib (unlimited food availability) diets of juvenile herring. The treatment group assignments of guillemot chicks are shown in Table 2.

TABLE 2. Assignments of guillemot chicks to experimental diet and dosing groups.

N	Diet (age class)	Restricted 160 g/day (R) or Ad lib (A)	Total oil dose (ml)
8	Herring (1+)	R	Control
12	Herring (1+)	R	1.0
9	Herring (1+)	R	2.0
12	Herring (1+)	A	None
10	Pollock (1+)	R	None

Newly hatched Pigeon Guillemots destined for restricted diet treatments were fed on an unrestricted diet of silversides, juvenile pollock, and juvenile herring eight times per day until 10 days post-hatch. On day 11, chicks in restricted diet treatments were switched to 160 g/day of juvenile Pacific herring (*Clupea harengus pallasii*) or juvenile walleye pollock (*Theragra chalcogramma*). On day 11, all chicks were switched to four feedings per day. All chicks in the *ad libitum* herring treatment were fed only herring from day 1 post hatch and were continually monitored to ensure that fish were always present after day 11 post-hatch. All restricted diet birds were fed 100 g on day 11, 125 g on day 12, and 160 g on day 13 and thereafter. After day 30, all birds were fed *ad libitum* at each of their four daily feedings until they fledged.

The oil used in dosing experiments was Prudhoe Bay Crude Oil (PBCO). It was weathered in the lab to remove the highly toxic volatile components. This was done by

mixing a 1:1 ratio of oil and 3.5% NaCl solution with a magnetic stirrer for a one week period prior to the experimental treatments (Fry and Lowenstine 1985).

The SAS (version 7.0) program was used for all statistical analyses.

Measurement of blood biomarkers. Measurement of specific biomarkers in blood or excreta may be useful in determining the direct exposure of wild Pigeon Guillemots to oil. Blood was drawn from chicks on day 20, 22, 25, and 28 post-hatch as part of the oil dosing study. Approximately 0.8 ml was collected at each blood draw from a tarsal vein using 25- or 26-gauge syringe needles, except on day 22 when 0.3 ml of blood was collected. All blood samples were collected in sodium heparin-containing tubes to prevent clotting, placed immediately on ice, and centrifuged for 10 minutes at 1000x *g* to collect plasma and stored at -70°C until ready for analysis.

The acute phase protein, haptoglobin, will be measured from plasma samples. Western blot analysis will be used to quantify free haptoglobin (Duffy et al. 1994) in the laboratory of Dr. Larry Duffy at the University of Alaska Fairbanks. Other acute phase proteins, including fibrinogen, C-reactive protein, and serum amyloid P may be analyzed (S. Newman, pers. com.). Work is currently being performed at the University of California-Davis on these potential biomarkers to oil exposure by Dr. Scott Newman. Further information from Dr. Newman's studies may allow us to focus on other biomarkers as well.

Measurement of biomarkers in excreta. Excreta samples were obtained from the artificial nest sites at time intervals following oil dosing. Samples were stored in plastic bags at -20°C until ready for analysis. Analysis will include fecal porphyrin levels or possibly corticosterone levels (which will also be measured in plasma; A. Kitaysky, pers. com.) to show a time course response. Fecal porphyrins may be expected to increase as a result of interference in heme biosynthesis by exposure to certain xenobiotics (Akins et al. 1993). Corticosterone levels are a general measure of stress in chicks (Etches 1976). Both excreta and blood plasma samples are currently in freezer storage awaiting analysis.

Nest-site provisioning and social attraction. As in 1998, a nesting and social attraction platform was erected on the remnants of a breakwall adjacent to the Alaska SeaLife Center in 1999. The platform consisted of four nest boxes sandwiched between two 4x8 sheets of plywood. The two sheets of plywood provided an area where prospecting guillemots could examine nest sites with sufficient overhead cover to allow protection from aerial predators. Six Pigeon Guillemot decoys were bolted on top of the platform. A wireless speaker was placed on the shore approximately 30 meters from the platform and Pigeon Guillemot calls, recorded at a PWS breeding colony, were played from approximately 0600 until 2100 each day.

The platform was visible from the project office, as well as from most other offices in the ASLC, public observation decks, and viewing areas. From May until September, project personnel routinely checked the platform and surrounding waters for the presence of guillemots, and other ASLC personnel would also observe bird activity on or near the platform.

Results and Discussion

Hatching and fledging success. In 1999, 28 chicks and 70 eggs were collected from Pigeon Guillemot nest sites in the wild and transported to the Alaska SeaLife Center. Forty-nine chicks were successfully hatched from artificially-incubated eggs, for a 70.0% hatching success. Egg candling indicated that nearly all the collected eggs were fertile and had gone through some development during incubation. This compares to only 52% hatching success in 1998 (n = 44 eggs). There were significant differences in hatching success by year and collection area (Fig. 1), and these differences were likely due to differences in egg-handling protocols, including a decrease in vibration and other unintentional mishandling of the eggs in 1999 compared to 1998. Also, in 1999 eggs were transported in the horizontal position as compared to transportation of eggs in the vertical positon in 1998. Differential hatching success from some sites may have been directly related to egg handling as the eggs with the worst hatching success in 1999 came from nests located in crevices high on cliffs (Kachemak Cliffs), which required technical climbing to access (Table 1).

Nestling survival for chicks collected in the wild was 89.3%, whereas it was only 71.4% for chicks hatched from eggs that were artificially incubated. All mortality of chicks collected in the wild (n = 3) occurred soon after collection, either in the field or during transport. All mortality for chicks hatched in captivity (n = 14) occurred in the first 11 days post-hatch and was apparently due to either brooder equipment malfunction (n = 9), lower GI tract blockage of unknown causes (n = 3), or microbial infections of the lower GI tract (n = 2). Thus, 61% of all eggs and chicks collected for captive-rearing in 1999 were successfully fledged into the wild.

Timing of fledging. The majority of fledging occurred during a short period after sunset (Figure 2). Of the 49 chicks for which we obtained the timing of fledging, 45 fledged during twilight hours within two hours after sunset. The advancement of the time of fledging with calendar date indicated that chicks were fledging in response to light levels. Lacking a continuous recording of ambient light levels at the SeaLife Center, we relied on the time of sunset and civil, nautical, and astronomical twilight at Seward as computed by the U.S. Naval Observatory.

Sunset is defined as the time when the top of the sun disappears below an ideal horizon.

Civil twilight is defined to begin in the morning, and to end in the evening when the center of the Sun is geometrically 6 degrees below the horizon. Twilight illumination is sufficient, under good weather conditions, for terrestrial objects to be clearly distinguished; at the beginning of morning civil twilight, or end of evening civil twilight, the horizon is clearly defined and the brightest stars are visible under good atmospheric conditions in the absence of moonlight or other illumination.

Nautical twilight is defined to begin in the morning, and to end in the evening, when the center of the sun is geometrically 12 degrees below the horizon. At the beginning or end of nautical twilight, under good atmospheric conditions and in the absence of other illumination, general outlines of ground objects may be distinguishable, but detailed outdoor operations are not possible, and the horizon is indistinct.

Astronomical twilight is defined to begin in the morning, and to end in the evening when the center of the Sun is geometrically 18 degrees below the horizon. Before the beginning of astronomical twilight in the morning and after the end of astronomical twilight in the

evening the Sun does not contribute to sky illumination; for a considerable interval after the beginning of morning twilight and before the end of evening twilight, sky illumination is so faint that it is practically imperceptible.

The time of these events at Seward during the period of chick fledging are presented in Figure 3. Because of the high latitude of Seward, nautical and astronomical twilight do not begin until after the period of fledging is underway.

While it was previously known that guillemots generally fledge under the cover of darkness, our observations are the first to show that fledging occurs in a restricted time period shortly after sunset and before complete darkness. This suggests that predation levels during this time are typically low and that no advantage is gained by fledging later in the night. In nature, guillemot chicks are fed up until twilight and for fledglings ready to leave the nest there may be advantages to maximizing the period between sea-going and sunrise. Post-fledging darkness may allow fledglings to swim some distance from the colony, where the density of avian predators may be expected to be lower compared to inshore.

Diet composition and chick growth rates. Analysis of specimens of the two fish species used in diet treatments resulted in estimates of energy density for juvenile pollock (n=5) of 3.27 kJ/wet g wet mass (95% CI: 2.81-3.72) and for juvenile herring (n=20) of 4.24 kJ/ g wet mass (95% CI: 3.81-4.67). A Satterthwaite t-test was performed on these two energy densities due to unequal variance in the samples, which indicated that there was a significant difference in energy density between the two fish diets ($t_{17.7}$=3.68, p=0.0017). The principle cause of the difference in energy density was the difference in lipid content of these two fish species (Fig. 4).

One-way ANOVA was performed on the body mass of chicks in the three dietary treatments on day 10 post-hatch to determine if the starting point was the same for all treatment groups. The assumption of normality was met for this data set (Shapiro-Wilk W=0.973713, p=0.3255) and the residual plot shows a constant variance of residuals. The 95% confidence intervals are shown in Figure 5. Least square mean (LSM) comparisons between the chicks on restricted herring diets and those on restricted pollock diets indicated that there was no difference in mass at the outset of the experiment (t_{47}=0.53, p=0.6012). LSM comparisons indicated that the chicks on the ad lib herring diet had significantly lower mass than those on the restricted herring diet at day 10 (t_{47}=3.56, p=0.0009).

One question of importance was whether ingestion of low level doses of weathered PBCO (to mimic chronic low level exposure) would have any effect on growth of guillemot chicks. ANOVA of chick growth in mass between days 20 to 30 (oil dosing period) as a function of PBCO doses (1.0 ml, 2.0 ml and negative control) was used to test for oil dose effects. Diet type (herring vs. pollock) was responsible for highly significant differences in growth ($F_{1,51}$=14.27, p=0.0004). Doses of PBCO, however, did not appear to have an influence on chick growth ($F_{1,51}$=1.26, p=0.2925). All chicks on restricted herring diets were grouped together for further analysis, because the PBCO dosing did not appear to influence chick growth. A confounding factor in the oil dosing studies were that at least 25% of the doses were partially or completely regurgitated after feeding. Because traces of oil showed up in excreta as well as in regurgitations, and because some of the regurgitated fish were swallowed again, it was hard to accurately

assess how much of the oil dose each chick consumed and digested. For this reason, dosing will be altered during the 2000 study year in order to reduce the daily dosing amount and to spread the doses out over the 10-day dosing period.

Due to differences in the initial masses of chicks at the start of treatments on day 10, further comparisons were performed to detect potential differences in chick growth increment on different diet regimes during the dietary treatments. Comparisons were made at the end of the period of highest growth rate ("linear phase") at day 20 and at the end of the experimental treatments (day 30) (see Figure 6 for growth curves). One-way ANOVA and LSM analysis of the differences in mass between the initiation of dietary treatments (day 10) and day 20 indicated that chicks on the ad lib herring diet accumulated more mass than the chicks on the restricted herring diet (t_{49}=2.57, p=0.0133) and chicks on the restricted herring diet accumulated more mass than chicks on the restricted pollock diet (t_{49}=5.73, p<0.0001; Figure 7). Mass accumulation in the next growth phase (day 20 to day 30) indicated a different pattern between the chicks on the pollock and herring diets (Figure 8). Chicks on the pollock diet gained more mass during days 20-30 than the chicks on the restricted herring diet (t_{49}=2.97, p=0.0046) and chicks on the ad lib herring diet continued to gain more mass than the chicks on the restricted herring diet (t_{49}=4.09, p=0.0002). When these mass increments over the course of the entire diet treatment period (day 10 to day 30) were compared (Figure 9), the chicks on the ad lib herring diet clearly displayed greater growth than the chicks on the restricted herring diet (t_{49}=5.54, p<0.0001), but the chicks on the restricted herring diet displayed only slightly greater growth than the chicks on the restricted pollock diet (t_{49}=1.70, p=0.0954).

All the above data were tested for normality using normal probability plots and the Shapiro-Wilk test for normality, and for constant variance using residual plots. All groups of data analyzed met the assumptions of normal distributions and constant variance of residuals.

Nest-site provisioning and social attraction

No prospecting Pigeon Guillemots were observed associated with the artificial nest platform in 1999. Chicks released in 1998 would not be expected to be returning to the ASLC until 2000 or 2001. Members of the genus *Cepphus* do not typically breed until three years of age and subadults are typically found more distant from the natal colony in their first summer than in subsequent years.

The failure of the social attraction techniques and nesting platform to attract prospecting guillemots for the second year and our observations of few guillemots north of Cain's Head in Resurrection Bay indicates that the northern end of Resurrection Bay is not regularly frequented by foraging or prospecting guillemots. This could be due to a number of factors, including:

1) Poor foraging conditions due to the input of fresh and turbid water from the Resurrection River

2) The coast north of Cain's Head has few rocky headlands adjacent to deep water as does much of the southern and central Bay. Guillemots entering Resurrection Bay prospecting for nest sites likely would be attracted to rock cliff colonies well south (>10 km) of the ASLC breeding platform.

3) The number of guillemots prospecting for nest sites in Resurrection Bay may be low. The three guillemot colonies in central Resurrection Bay are not large (all <20 pairs) and the number of nonbreeding guillemots philopatric to Resurrection Bay would be expected to be small. Prospectors would likely have to come from colonies elsewhere in the northern Gulf of Alaska. The decreased size of these colonies in the last two decades would be expected to result in fewer nonbreeding prospectors in northern Resurrection Bay.

If the chicks being released as part of this project are philopatric to their fledging location, they may prospect the nest boxes at the SeaLife Center. Their ability to recruit and breed successfully will depend on whether foraging conditions in northern Resurrection Bay are suitable for provisioning chicks with adequate food.

Conclusions

Chick growth experiments

1) The growth of chicks fed from day 0 (hatch date) to day 10 post-hatch with just herring (ad lib herring group) was significantly less than the growth of chicks fed a combination of herring, pollock, and silversides (all restricted diet chicks). This difference may have been due to differences in prey size, or the lack of randomness in the assignment of chicks to the ad lib herring diet. These chicks were the latest to hatch of all the chicks.

2) PBCO dosing resulted in no apparent differences in growth compared to controls during the dosing period. This may be due to two principle factors: 1) the doses administered were too small to result in a physiological response, or 2) the timing of administration of the dose may have been too late to see an effect because most growth had been completed by the day of first dosing (day 20).

3) Chicks fed restricted diets of herring accumulated body mass more slowly in comparison to chicks fed an ad lib diet of herring. These differences were apparent during all phases of the diet treatment.

4) The chicks fed restricted diets of pollock or herring displayed no overall difference in mass accumulation during the dietary treatment. However, there was a biphasic growth response by diet type: the chicks on the restricted herring diet had significantly higher growth rates in mass during the first 10 days of the diet treatments, while the chicks on the restricted pollock diet had higher growth rates during the last 10 days (day 20 to day 30) of the diet treatments.

These differences in growth between diet treatment groups were sufficient to be biologically significant. The most interesting differences were chicks on the restricted herring diet and those on the restricted pollock diet. There was a 21.1% greater increase in mass of chicks on the herring diet than those on the pollock diet between day 10 and 20 (191.3 g vs. 157.6 g) and conversely a 21.4% greater increase in mass of chicks on the pollock diet than those on the restricted herring diet (119.3 g vs. 98.0 g) between days 20 and 30. The explanation and underlying physiology behind these differences is unknown, but may be a result of greater assimilation efficiency in chicks that are lagging in growth. The differences in mass growth after the full experimental period (day 10 to 30) did not result in any biologically significant differences in herring chicks vs. pollock chicks results. There was, however a biologically significant difference in mass growth between

chicks on restricted herring diets (289.8 g) and chicks on ad lib herring diets (330.5 g, 14.0% difference).

Causal conclusions can not be drawn about differences in dietary treatments because of the lack of random assignments for the diet groups due to problems in procuring the pollock in 1999. However, causal conclusions can be drawn from the effects of PBCO on mass growth due to the random assignment of PBCO treatments in the restricted herring group.

Clearly, random assignment of chicks to all treatment groups is needed for the next year of this study, so that more causal conclusions can be made. To help overcome the constraints of small sample sizes, chicks will be assigned to treatments using a serial random method that will complete each series of treatments before beginning the new set of complete random treatments (e.g., 1,4,3,2,5...3,2,4,5,1...). To eliminate some of the variability and availability problems due to annual catch of fish, herring will be obtained and a second dietary group will be established by supplementing the herring with a known quantity of lipid. In this manner, food with a known energy density can be fed to the diet groups, which will allow us to reduce the chicks' energy intake to a level that may produce a biologically significant difference at the end of the treatments. In the last year of the study, collection on growth rate data will be secondary to collection of hematological data on stress levels and biomarkers for oil exposure. Thus, it is critical to ensure random sampling design and that diets of known lipid content and energy density are used in this upcoming year of the study.

Captive rearing and release

The increase in hatching success of eggs incubated in captivity is promising because it indicates hatching success in captivity can be similar to that recorded in the wild. Problems with regulating the nestling environment during the first five days after hatching when chicks are developing the ability to thermoregulate, resulted in most of the chick mortality. In 2000, we will utilize techniques used at the Oregon Coast Aquarium for raising guillemot chicks, which allow the chick to control ambient temperature by proximity to the heat source. Our method of releasing and monitoring the release of chicks in 1999 was a major improvement over 1998 and indicates that captive-raised chicks need to be exposed to ambient conditions for 24 hours a day for at least a few days prior to fledging. In 2000 we will attempt to monitor immediate post-fledging movements and short-term survival of the released fledglings.

Nest-site provisioning and social attraction

The low density of guillemots in northern Resurrection Bay and the lack of prospectors at the nesting platform at the SeaLife Center prevents using that location to assess the utility of nest-site provisioning as a restoration technique. While the SeaLife Center nesting platform and social attraction array will be maintained in 2000, most of our work on artificial nest-sites will consist of installation of sites in PWS and central/southern Resurrection Bay. Observations of the activities of prospecting guillemots at artificial nest sites will also be conducted in these two locations. The high rate of adoption of artificial nest sites by Pigeon Guillemots in Puget Sound and the use of man-made sites elsewhere strongly argues for pursuing the utility of this approach in the Gulf of Alaska.

Acknowledgments

Cindy Anderson, Eli Bridge, and Rebecca Kagle provided invaluable assistance in the field and laboratory. Dede Bohn (Alaska Biological Science Center, USGS) has been very helpful with contract administration and project oversight, and we are very grateful for her skillful and professional assistance. The staff and volunteers of the Alaska SeaLife Center, especially Susan Inglis, John French, and Michelle Miller provided logistical support and encouragement throughout. We very much appreciate the help of the following individuals who provided critical assistance with acquisition of guillemot eggs and chicks in the field: Julian Fisher (USFWS), Adrian Gall (USFWS), Dan Garner, Greg Golet (USFWS), Mike Litzow (Alaska Biological Science Center, USGS), Rich MacIntosh (NMFS), Angela Palmer (USFWS), John Shook (ABR, Inc.), Oliver Sternicki (USFWS), Kelsey Sullivan (USFWS), Kathy Turco (Alaska's Spirit Speaks), Gus Van Vliet, Mike Walgren (USFWS), and Bruce Wright (NMFS). Jim Blackburn and Larry Byrne (Alaska Department of Fish and Game), Bob Otto (Alaska Fisheries Science Center, NMFS), and Scott Smiley and Loren Buck (Fisheries Industrial Technology Center, UAF) provided logistical assistance on Kodiak Island, for which we are very grateful. We are also very grateful to the following individuals for logistical assistance in the Juneau and Anchorage areas: Ken Taylor, Chow Taylor, Dave Hunsaker, Annie Calkins, and Diana Lloyd. We are very much indebted to Paul Anderson and Cynthia Tynan, who helped supply us with juvenile Pollock collected on NMFS survey cruises in the Bering Sea. Drs. Scott Newman and Pam Tuomi provided valuable veterinary assistance. Dr. Larry Duffy provided Prudhoe Bay crude oil for use in the dosing experiments. To these individuals and many others who helped this project in 1999, we express our sincere appreciation.

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Figure 1. Survival of Pigeon Guillemots raised at the ASLC (1998-1999). *Hatching success* = percentage of eggs that hatched from collected eggs. *Chick survival (hatchlings)* = percentage of chicks that fledged from total number of hatchlings from collected eggs. *Chick survival (collected chicks)* = percentage of chicks that fledged from collected chicks. *Overall survival* = percentage of chicks that fledged based on total collected eggs and chicks.

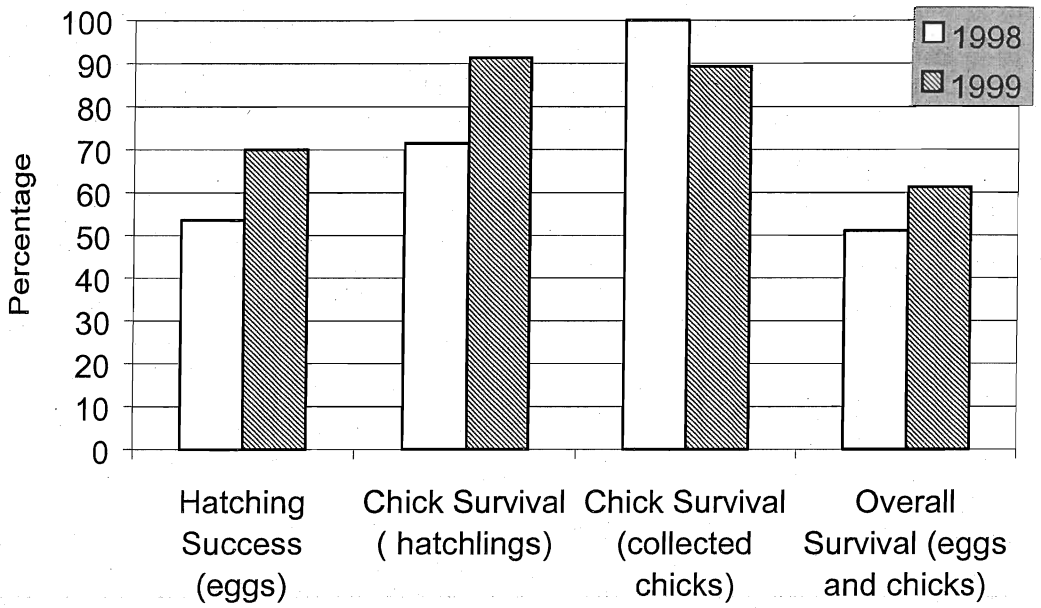

Figure 2. Timing of fledging of captive-reared Pigeon Guillemots in Seward, Alaska, 1999.

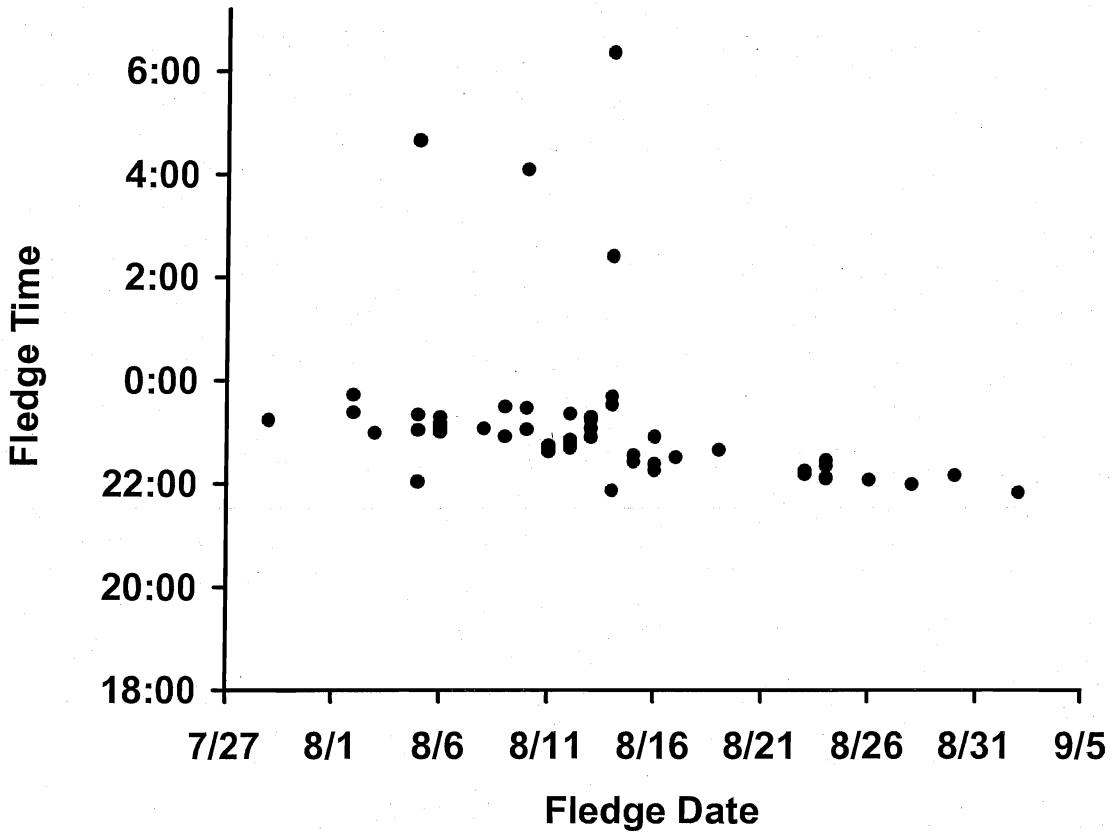

Figure 3. Timing of illumination events at Seward, Alaska during the period of Pigeon Guillemot fledging, 1999.

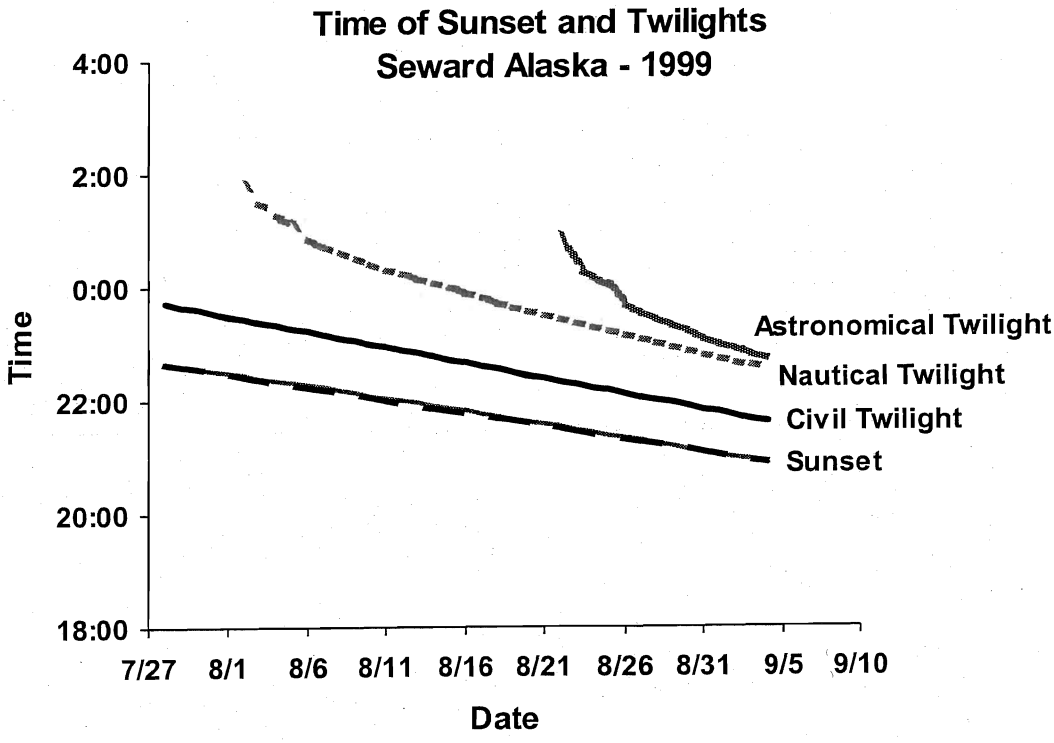

Figure 4. Proximate composition and energy density of diet fish (± SE).

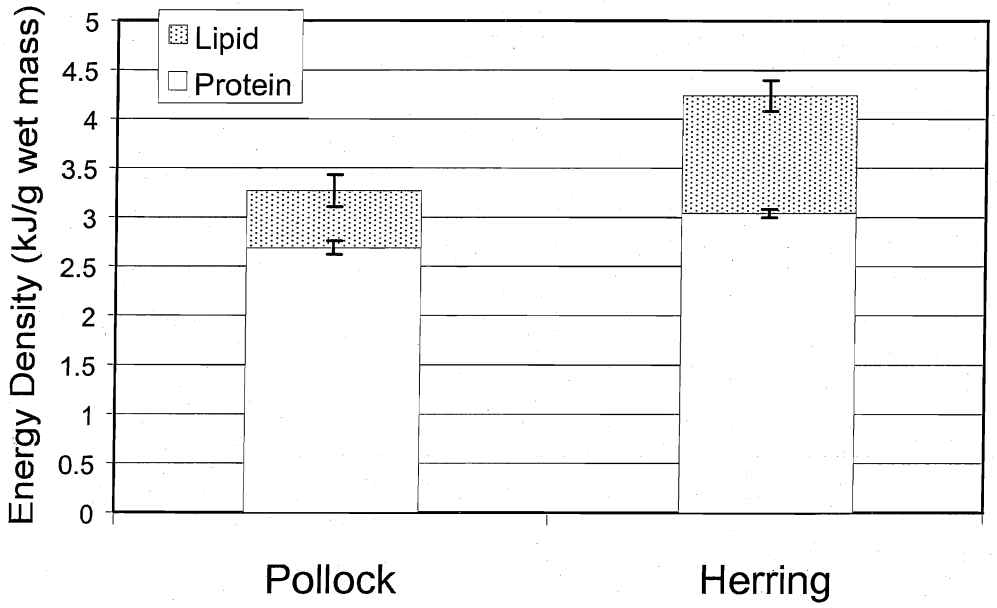

Figure 5. Mass of Pigeon Guillemots at day 10 post-hatch by diet (± 95% confidence intervals).

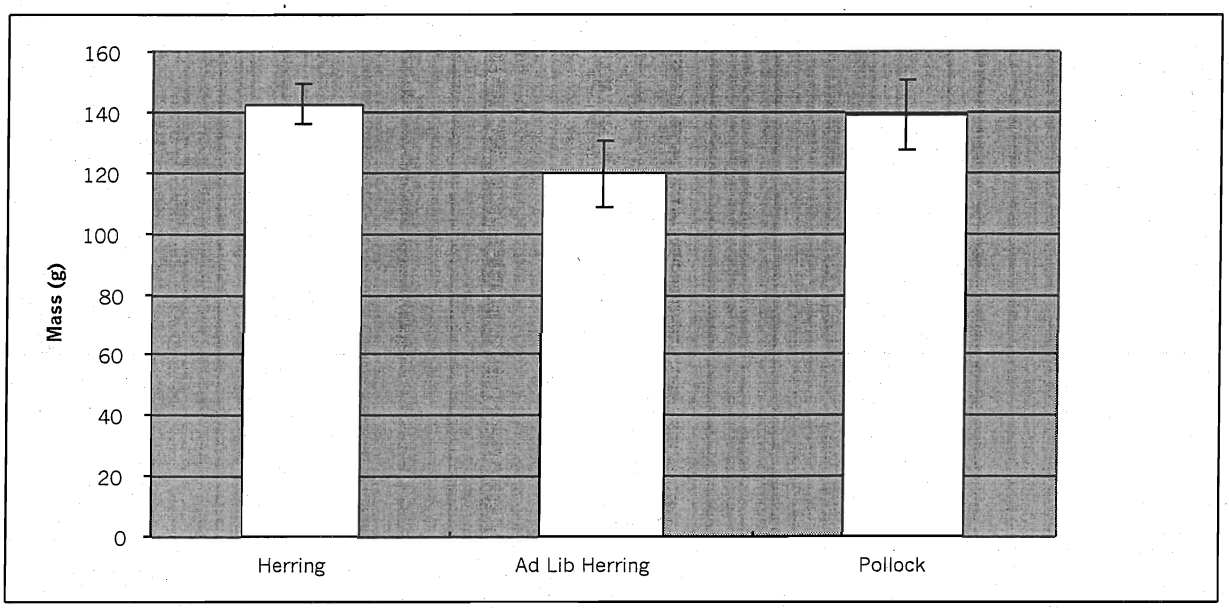

Figure 6. Pigeon Guillemot growth rates by diet.

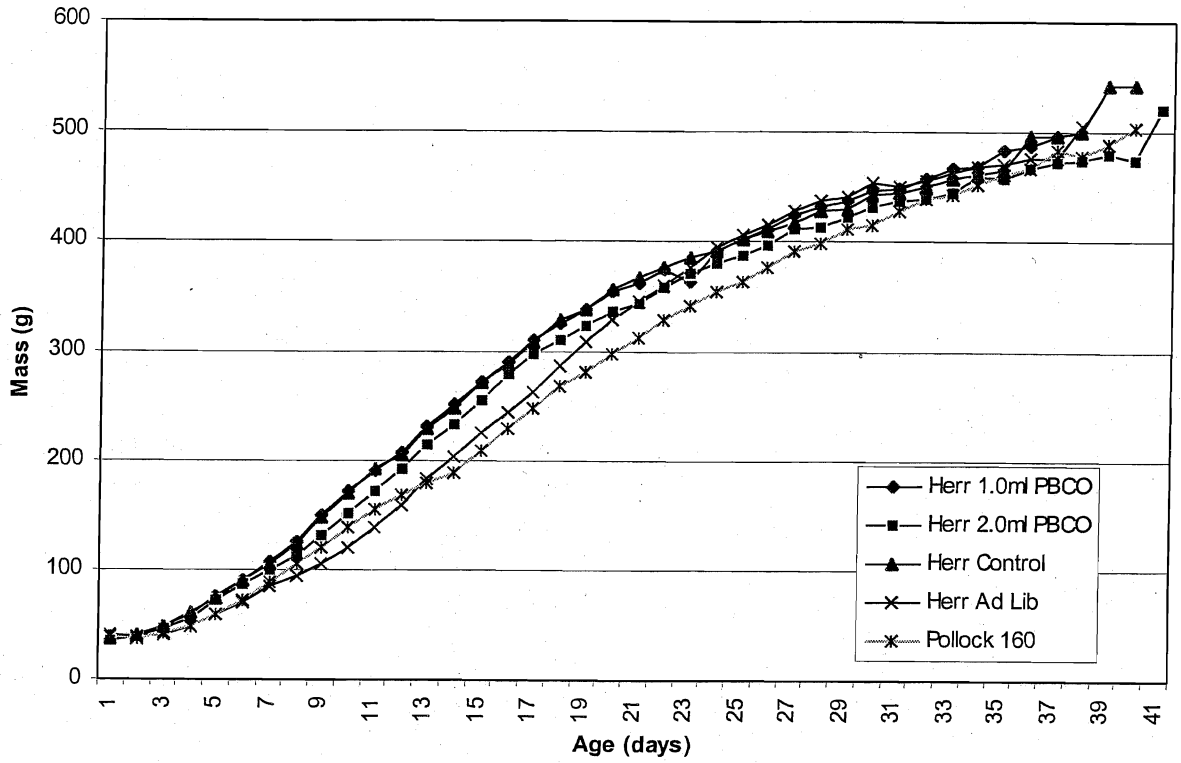

Figure 7. Incremental mass accumulation of Pigeon Guillemot chicks between days 10 and 20 by diet (± 95% confidence intervals).

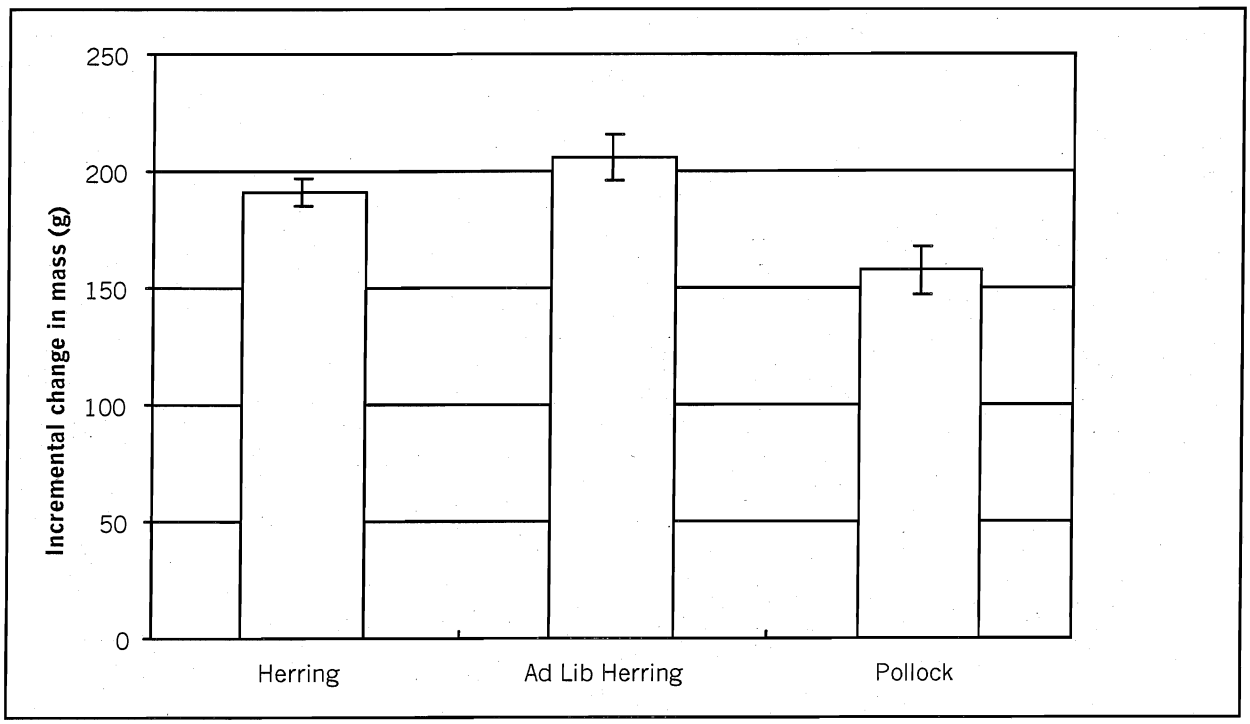

Figure 8. Incremental mass accumulation of Pigeon Guillemot chicks between days 20 and 30 by diet (± 95% confidence intervals).

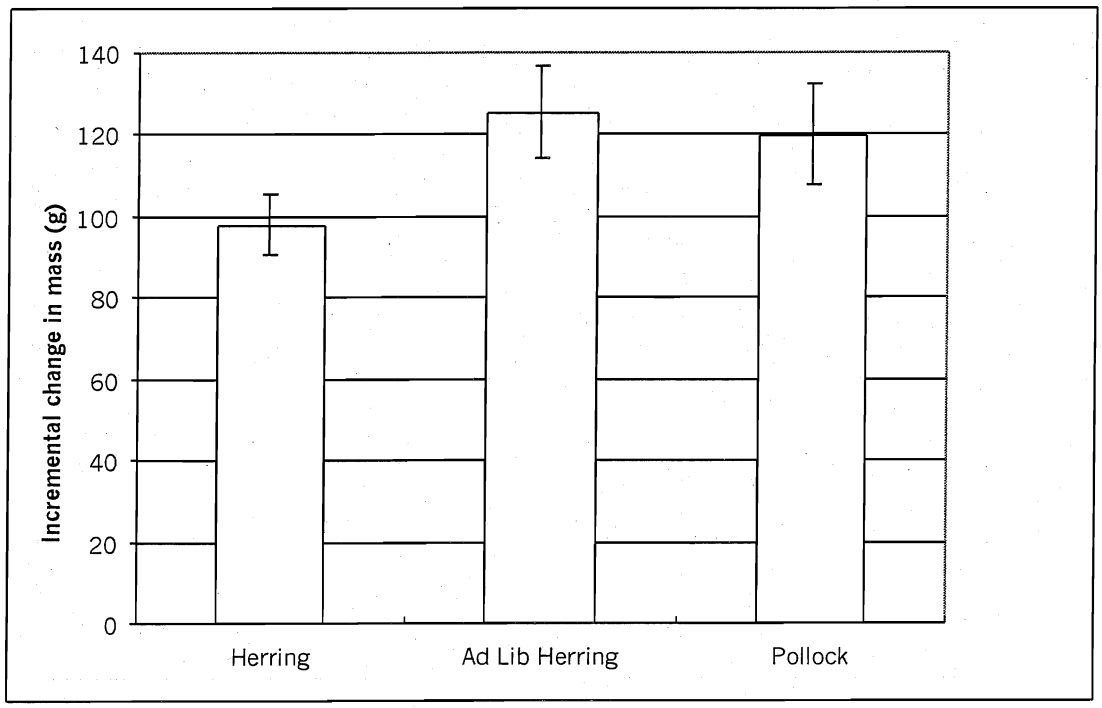

Figure 9. Incremental mass accumulation of Pigeon Guillemot chicks between days 10 and 30 by diet (± 95% confidence intervals).