Restoration notebook

November 1998 *Exxon Valdez* Oil Spill Trustee Council

Pigeon Guillemot

Cepphus columba

Photo courtesy USFWS

By Katherine J. Kuletz
U.S. Fish and Wildlife Service

Pigeon guillemots (*Cepphus columba*) are medium-sized seabirds in the Family Alcidae, close cousins to auklets, murres, murrelets, and puffins. The pigeon guillemot nests along rocky coastline from California to Alaska in the North Pacific and along eastern shores of Siberia.[1] Other members of the genus Cepphus are: black guillemots (C. grylle), which inhabit the North Atlantic and the Bering Sea coast of Alaska, and spectacled guillemots (C. carbo), in the Sea of Okhotsk and Japan.[1] Pigeon guillemots, like all auks, forage by swimming underwater in pursuit of their prey. They nest mostly in small scattered colonies or in solitary pairs. The estimated world population of pigeon guillemots is about 235,000 and most (50%-80%) breed in Alaska. Surveys conducted by the U.S. Fish and Wildlife since 1989 estimated the population of pigeon guillemots at 3,500 in Prince William Sound (PWS),[2] 9,000 in lower Cook Inlet,[3] [FIG.1] and 19,000 in southeastern Alaska.[4]

In PWS the guillemot population has declined by 67% since the 1970s.[2] Detailed counts at study colonies confirm this decline. Pre-spill counts of about 2,000 guillemots breeding at the Naked Island complex in central PWS were twice as high as post-spill counts.[5] Although guillemots in PWS show clear spill-related effects, the reason for the magnitude of the decline is not well understood, and counts in 1985 suggest that the decline began prior to the spill.[5] Local threats to guillemots include gillnet bycatch mortality, oil pollution, and predation. Changes in marine ecosystems could affect food availability and regional population trends.

Vital Statistics

Population
Approx. 3500 PWS;
9000 lower Cook Inlet

Population Trend
67% decline in PWS since the '70s, some areas show trend of continued decline since 1989

Lifespan
14+ years

Adult Size
Length, 32-33 cm; wing span, 175-188 cm; weight, 445-565 g.

Breeding Season
Lay eggs May-June;
fledging July-August

Incubation/Fledging
Eggs hatch in 26-33 days;
chick fledges in 29-54 days.

Clutch size
One or two eggs per season;
some replacement clutches

Chick weights
Hatch at 24-50 g, semiprecocial;
fledge at 350-550 g.

Maturity
Age at breeding approx. 3-4 yrs

Plumages
Winter and juvenile, gray above / white below; breeding, blackish-brown iridescent with white wing patch

Diet
Gunnels, pricklebacks, ronquils, sculpins, flatfish, rockfish, small crustacea, squid, sand lance, smelt, juveniles of cod, herring, pollock, and salmon

Annual Cycle and Nesting Habitat

Little is known about the winter range of pigeon guillemots, but exposed coastlines appear to be deserted in favor of more sheltered inshore waters.[1,6,7] Low numbers of guillemots remain in southcentral Alaska throughout the winter.[6] Guillemots begin to return to their breeding grounds in April, usually sporting their summer plumage. Breeding plumage is a startling change from their winter plumage of mostly white head and belly and dark gray back. Adults of breeding age are a sleek black, with white wing patches and bright red feet that match the red lining of the mouth. Younger birds have faint white streaking mixed with the black feathers.

In May, maximum numbers of birds are present at the colonies and courtship begins in earnest. The guillemots gather in groups on the water and on rocks near the colonies where they socialize and establish pair bonds. Compared to other alcids, guillemots have the widest array of vocal calls and behaviors to affect pair bonding and establish dominance hierarchies. Calls include various hunch-whistles, trills, and alarm screams to signal perceived dangers.[8,9] Lively duet flights and chases over land and water, often continuing underwater, can be observed during this time. The distinctive red legs and interior of the mouth may also play an important role in courtship and social interactions. Pairs tend to be monogamous and generally retain the same mate and defend the same nest site in successive years.[1,10]

Pigeon guillemots are found along rocky coastlines during the breeding season, which in southcentral Alaska is May through August. Guillemots are flexible in nest selection and will use isolated offshore islands or onshore sites. Nest predation by birds and mammals can be intense, so nest site selection is vital to a pair's breeding success. River otter and mink prey on adults, eggs and chicks while ravens, crows, jays and magpies take unattended eggs or chicks if they can reach them. Nests can be found by the smell and presence of chick feces on the rocky cliffs. The high-pitched peeping of chicks begging for food, or the adult delivering fish to their young, also help predators (and researchers) to locate nests.

Although guillemot colonies may be limited by nest sites in some locations, the adequacy of local food supplies may be equally important, because guillemots forage within 7 km of their nests,[7] and usually much closer.[10,11,12,13] Nesting density probably varies due to the availability of both suitable nest sites and food abundance. Perhaps because they feed nearshore and near their nests, guillemots can be found nesting as isolated pairs or in small colonies scattered along the coastline, although in a few locations there are colonies of more than 1000 pairs.[14]

One or two eggs are laid in natural cavities, often in rock crevices in talus boulders or on cliff faces or in labyrinth tree root systems. Some birds nest in artificial structures. Occasionally a bird will construct a nest-scrape if soil, sand, or gravel is present. The eggs are the size of chicken eggs and vary in color from white to slightly bluish or pale green, with variable gray and brown blotches concentrated in a band at one end. Incubation is intermittent after the first egg is laid until the clutch is completed, usually 3 days later, after which full-time incubation begins.[10] Both adults have a two-lobed brood patch and share incubation of the eggs, exchanging incubation duties approximately every 4-8 hours.

Photo by Greg Golet

A guillemot chick at 6-8 weeks is ready to leave the nest.

Chicks hatch after an average of about 32 days, with the first-laid egg usually hatching 1-2 days before the second.[7,15,16] The size advantage of the 'alpha' chick can become critical

if food is scarce, resulting in many single-chick broods later in the season. The chicks are semi-precocial and able to stand after only a few hours. Because the chicks cannot thermoregulate for the first few days, they are brooded by adults during this period. At hatching the chicks are covered by a thick black-brown down that later becomes gray. Feathers begin to appear about day 12 and chicks are fully feathered by day 20-25, although tufts of down persist. Juvenile plumage after fledging is similar to adult winter plumage, but with more gray on the head, throat, and belly.

Chicks are fed by both parents, each carrying one fish or invertebrate at a time in their bill back to the nest throughout daylight hours. Chicks eat the fish whole, head-first, and gain weight rapidly, tripling their mass within 10 days.[10,17] After this rapid start, growth rates can vary greatly between chicks, and fledging age may range from 29 to 54 days.[1] Sometimes chicks exceed adult weights, but lose some weight just prior to fledging. Fledglings usually depart from the nest at night or early in the evening. The young, which are independent from their parents, are capable swimmers and divers, but do not fly for several weeks.

Guillemot pairs, even within the same colony, exhibit a wide range in breeding phenology. In Alaska, fledging occurs from July to September. Most guillemots in southcentral Alaska fledge from late July to mid August, with the peak occurring during the first two weeks in August.[6,11] The numbers of adult guillemots at the colonies gradually decrease as the chicks fledge.

Little is known about the movement of immature birds in the fall, but estimated chick survival is around 40%. Starvation is the most likely cause of first year mortality.[1,18] The winter population of guillemots was about 30% of the summer numbers in lower Cook Inlet,3 and 25%-50% of summer numbers in PWS.[1] Among those birds that remain throughout the winter, it is not known whether they are juveniles or breeding birds or both.

Feeding and Marine Habitat Use

Pigeon guillemots are "generalists" in foraging behavior, pursuing more than 50 species of small fish and invertebrates found throughout the water column and on the sea floor. Important benthic species include gunnels, pricklebacks, sculpins and shrimp.[1,19] In Alaska, such schooling fish as Pacific sand lance, herring, smelt, and gadids are also significant prey species.[11,20,21] [FIG.2]. Individual guillemots, however, often show distinct diet preferences, even in the presence of apparently abundant alternative prey species.[10,11,12,22] For example, some birds would catch and feed their chicks only blennies, while others at the same colony would use sand lance or Pacific herring. In Kachemak Bay, diet appeared to vary with location of the colony, suggesting that prey use was a function of local habitat (Litzhow and Piatt, unpubl data). At Naked Island, however, there were no significant differences in the diet preferences among colonies.[22]

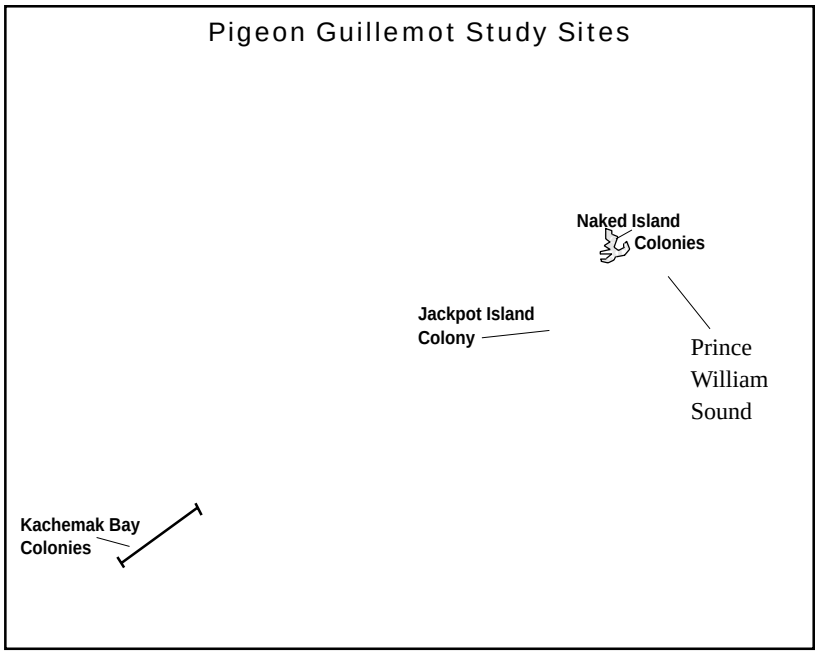

FIG. 1. Colonies of pigeon guillemots can be found throughout the oil spill region. Monitoring of colonies has taken place in Kachemak Bay and in Prince William Sound at Jackpot Island and at Naked Island. Naked Island has five distinct colonies included in the study.

Because different fish are not equal in nutritional value, the feeding preferences of adults could have implications for chick growth and reproductive success of pairs.[22,23] At Naked Island the use of forage fish, particularly sand lance, is positively correlated with guillemot chick growth, breeding success,[22] and even population size.[21] Thus, one hypothesis for the decline of pigeon guillemots is the apparent decline of key forage species in PWS.[24]

Pigeon guillemots generally feed inshore, usually alone. Being at sea does not keep them entirely safe from predation; adult guillemots have been observed taken on the water by bald eagles, killer whales and even a large octopus. Guillemots mainly feed in water less than 20 m deep,[1,25] but are probably capable of diving to depths of 50 m. Using their wings for propulsion, they dive to the sea floor to search crev-

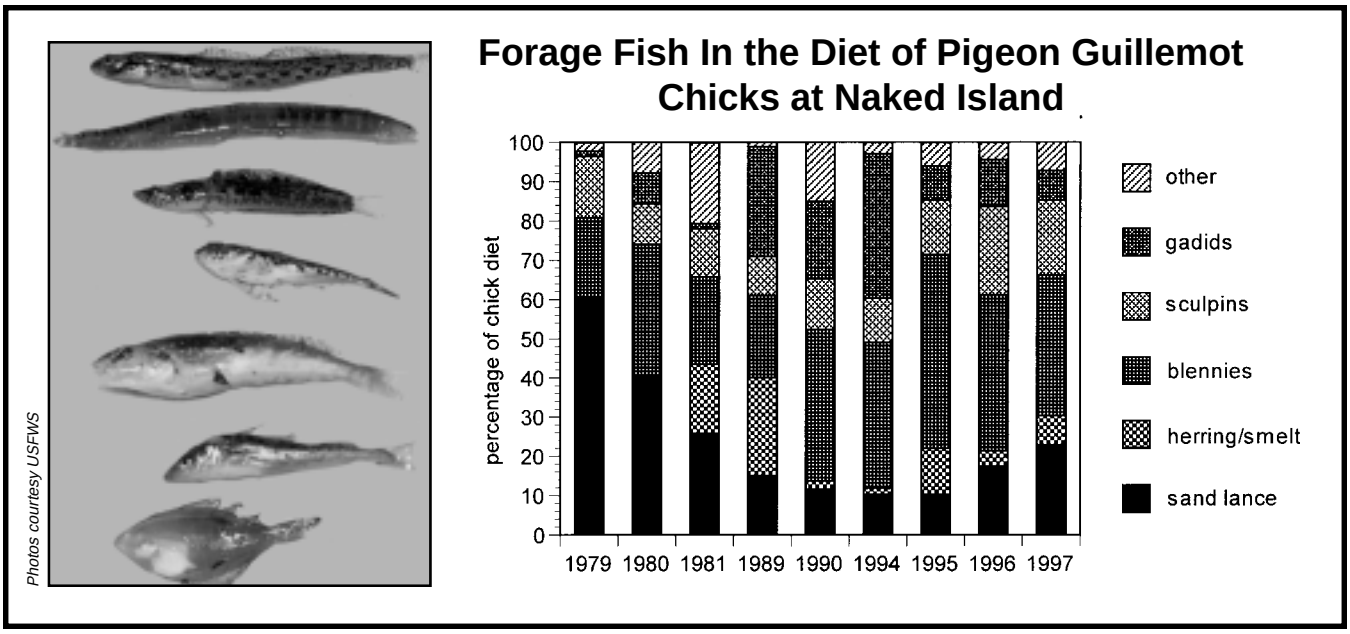

FIG 2. A study of diets of pigeon guillemot chicks shows a swing in the dominant prey species. In 1979, sand lance dominated the chick's diets, but as waters warmed and sand lance became more scarce, other less nutritious species such as blennies, sculpins and gadids became the main food source for the chicks. Inset photo: prey species used by pigeon guillemots to feed their chicks include, from top to bottom, blennies, sculpin, gadids, and flatfish. Below, sand lance are a fatty fish providing more energy for growth of chicks.

ices and algae patches for demersal prey or schooling fish near the surface. Fish ranging in mass from 2 to 40 g are often brought to the surface by the bird to subdue, which can take up to 10 minutes for a large blenny.[11]

Because demersal fish typically take longer to catch and subdue than sand lance, the chick-feeding rate of bottom-feeding birds is often low compared to their surface-feeding neighbors.[11,22] Low feeding rates, together with low nutritional value, would seem to make demersal feeding less advantageous for guillemots, yet this behavior persists even when schooling fish are present. Bottom-feeding parents may be betting on the sure thing for long-term productivity, since demersal fish may be more consistently and predictably available than surface-schooling fish.[11,22]

Effects of the Oil Spill

Because they forage by diving in nearshore habitats guillemots are highly vulnerable to oil spills.[26] The Exxon Valdez oil spill occurred on March 24, before most of the pigeon guillemots had returned to breeding areas in PWS and Gulf of Alaska (GOA). However, oil from the spill eventually traveled over 750 km from Bligh Reef through PWS, out to the Kenai Peninsula, Kodiak, and the Alaska Peninsula. Guillemots returning to their breeding sites encountered the oil as it progressed southwest through the spill zone. More than 600 guillemot carcasses were recovered in the spill zone, including 135 from PWS. Based on carcass recovery rates, immediate mortality could have been as high as 6000 guillemots,[5,27] a substantial proportion of the population in the spill zone. Several studies have reported the sublethal toxic effects of oil on marine birds,[28,29] and declines in other guillemot populations have been attributed partially to oil pollution.[30,31]

Naked Island was the first land mass to be oiled in the Exxon Valdez spill. Oil surrounded Naked Island between March 29 and April 19, 1989, and remained on shoreline rocks at some guillemot colony sites throughout the 1989 and 1990 breeding seasons.[5] The beaches on Naked Island varied from heavily to lightly oiled and unoiled. The Naked Island area is an important guillemot breeding area where approximately 30% of the PWS guillemot population nests.[32] Fortunately, there were censusing, feeding and productivity data for guillemots at this area from 1978-81 to compare to post-spill data.[5]

Most of the guillemots had not yet returned to the Naked Island area when the oil was present, so few adults likely died at those breeding sites immediately after the spill. In 1989 the guillemot population at the Naked Island complex was 43% of the pre-spill population, but there was also evidence that the population of PWS had declined already in the mid-1980s.[5] However, at the Naked Island complex the decline in numbers at the colonies was greater than expected along oiled shorelines, indicating that the spill did affect the population.[5] A higher rate of decline in guillemots in oiled areas also was found for PWS overall.[2]

One reason guillemots were probably more affected after the spill than other seabirds is because their daily social activity occurs on intertidal rocks at the breeding colony. At oiled sites, the guillemots would have been exposed to pools of oil caught in the nearshore rocks. Additionally, guillemots feed in shallow waters near their colonies, where they probe underwater rock crevices and seaweed for blennies and sculpins. In these cases, guillemots nesting along oiled sections of shoreline would be more likely to ingest oil while preening and by eating contaminated prey. Disturbance from cleanup efforts in 1989 and 1990 also may have had an effect on breeding birds in oiled areas.

Although reproduction and foraging of guillemots at Naked Island did not vary significantly from pre-spill measures (gathered from 1978-81), important effects on productivity could not truly be measured because of the lack of monitoring efforts between 1982 and 1989.[5]

Long-term Effects of the Spill

The guillemot population decline was still apparent in 1998, nine years after the spill. *(Greg Golet, USFWS, unpubl. data).* The lack of recovery has prompted researchers to take a broad-based, ecosystem approach. The downward population trend observed in guillemots also has been observed in other marine bird and mammal species of southcentral Alaska. One hypothesis links this trend to possible changes in prey types and fish abundance in the GOA in the early 1980s.[33] Guillemots have provided a measure of the change by shifting their diet from predominately high energy forage fish, such as sand lance and herring, to a greater portion of energy-poor food, such as cod, sculpin and blennies.[21,22] [FIG 2].

Another apparent change at Naked Island was the increase in nest predation after the spill. A substantial portion of post-spill nesting failures in PWS have been attributed to predation during the chick stage.[5,20] One hypothesis under investigation is that

Photo by James Hamon

At left, Greg Golet, a principal investigator for pigeon guillemot studies for the U.S. Fish and Wildlfe Service, wears a harness and climbs down a cliff to examine a guillemot chick at Naked Island. Below, a one week old guillemot.

Photo by Greg Golet

Photo by Bruce Wright

Dr. Hiromi Takanaga, left, and Sadie Wright hold pigeon guillemot chicks collected for research at the Alaska SeaLife Center. The chicks were raised at the SeaLife Center on different diets and were released in late August. It's hoped that they will return as adults to start a new colony in Resurrection Bay, visible from the SeaLife Center.

contamination of normal intertidal food supplies caused river otters and mink to shift to alternate prey, such as guillemots.[20]

Restoration Activities

Several oil spill studies are currently examining possible links between forage-fish abundance and seabird reproductive success. Since 1994, restoration studies for the pigeon guillemot have focused on the importance of food in the recovery of populations in the spill zone. Naked Island has remained a principal study site to follow pigeon guillemot productivity, diet and population size. Jackpot Island in southwestern PWS and Kachemak Bay in lower Cook Inlet were added to enable comparisons among breeding sites within the spill zone.

The change from historical dietary patterns of birds at Naked Island and current differences in diets among the three study sites have led to several hypotheses that are being tested. Other studies are examining the possible role of the toxic effects of oil and nutritional attributes of prey in relation to guillemot productivity.[23] The abundance and distribution of surface schooling fish are being quantified through the use of hydroacoustics, underwater video, beach seines and dipnets. Relative species composition of the demersal fish around the study colonies is being studied through use of scuba diving and fish traps.

Future efforts will be made to model the role of pigeon guillemots in the PWS ecosystem. This will require more detailed demographic data. To facilitate the modeling effort, individual guillemots are now being color-banded so that we can track their survival, foraging patterns, and productivity over many years.

Foxes introduced to two of the Shumagin Islands (Simeonof and Chernabura) are thought to be responsible for very low densities of pigeon guillemots on each island. Nearby islands that do not have fox populations have much higher guillemot populations. Foxes were eliminated from the two islands and though nesting birds have not been surveyed there since 1995, the removal of this predator should result in a large increase in the guillemot population.

Habitat protection will benefit pigeon guillemots along with many other species impacted by the spill. As nearshore feeders, the foraging habitat of guillemots is susceptible to any activity that degrades intertidal nearshore habitats. Nest sites, which may be located several meters into the forest near cliff edges, will be protected from logging or other coastal developments.

More direct methods of enhancing guillemot productivity also have been attempted. Although nest site availability was not a suspected cause of the population decline, predation has been detrimental to some colonies. Because guillemots have been known to use artificial nests, the U.S. Fish and Wildlife Service installed 50 predator-proof nest boxes in 1996 at Naked and Jackpot

islands. The boxes have not been used by the guillemots to date. Additionally, Dr. Dan Roby (University of Oregon) and Dr. George Divoky are attempting to establish a colony of guillemots in artificial nest boxes at the Alaska SeaLife Center in Seward. This will enable detailed diet and productivity studies to be carried out in a controlled environment. They are measuring the growth rates of chicks fed high-lipid prey, such as sand lance or herring, compared to chicks fed a low-lipid diet of cod or sculpin. As the marked chicks that fledge from the SeaLife Center return, their survival rates will help us determine post-fledging survival during the first critical year.

Conclusion

Pigeon guillemots continue to show evidence of oil effects in their nesting distribution. As subtidal and nearshore foraging birds that often use intertidal rocks, they were highly susceptible to oil long after the immediate mortality. There also is evidence that the PWS guillemot population was in decline prior to the 1989 spill. The population of pigeon guillemots at Naked Island and four neighboring islands has declined since the late 1970's similar to that of the entire PWS guillemot population. During this same period, the diet of pigeon guillemot chicks on Naked Island changed from one dominated by sand lance to one dominated by demersal fish. Our data suggest there may be a link between the change in chick diet and the population decline.

The productivity of pigeon guillemots was lower, but not significantly so, in the 1990s compared to the late 1970s. Lower numbers of birds attempting to nest may have been a factor. Additionally, since 1989, predation has been more prevalent at study colonies than it had been previously.[20] Although overall productivity is not significantly lower, guillemots at some colonies grow slower and fledge at lower weights than at others *(USFWS, unpubl. data)*, which may explain why some colonies have not recovered. Further studies will attempt to examine the reasons for differnt trends among colonies.

Long-term trawl data suggest that in the late 1970s there was a major change in the northern Gulf of Alaska ecosystem. Shrimp, crab, and forage fish were replaced by predatory bottom fish, such as pollock and cod, which are less available and less energy-rich as prey for seabirds. The GOA ecosystem shift may account for the observed long-term decline in populations of pigeon guillemots and other piscivorous marine birds. The use of demersal prey species allowed guillemots at Naked Island to continue raising chicks there, although perhaps at lower productivity. In 1996 and 1997, guillemot chick diets and EVOS sampling of forage fish indicated that sand lance increased around Naked Island. If this apparent trend continues, researchers will have the opportunity to track the response of the guillemot population. What we learn about guillemots and the marine ecosystems in southcentral Alaska will lead to more effective restoration efforts in the future.

Kathy Kuletz has been a wildlife biologist for the U.S. Fish and Wildlife Service for 10 years and has worked as a biologist in Alaska since 1976. Her work has included fisheries and wildlife diet and monitoring surveys. Most of her research has been on the distribution, habitats, feeding habits and breeding success of seabirds in southcentral Alaska. She is also the author of the Marbled Murrelet edition of the Restoration Notebook series.

Photo by Roy Corral

Kathy Kuletz

The Restoration Notebook series is published for educational purposes. Persons wishing to cite this material in scientific publications should refer to the technical reports and literature listed at the end of each account.

Photo courtesy USFWS

Adult guillemots rest on a rock in Prince William Sound. Guillemots can live 14 years or more. They mature in 3-4 years and can produce one or two chicks per year.

References

1. Ewins, P.J. 1993. Pigeon Guillemot (Cepphus columba). In A. Poole and F. Gill (eds.), The birds of North America, No, 49. Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union.

2. Agler, B.A., P.E. Seiser, S.J. Kendall, and D.B. Irons. 1994. Marine bird and sea otter populations of Prince William Sound, Alaska: population trends following the T/V/ *Exxon Valdez* oil spill. *Exxon Valdez* Oil Spill Restoration Project Final Report, U.S. Fish and Wildlife Service, Anchorage, Alaska.

3. Agler, B. A., P.E. Seiser, S.J. Kendall, and D.B. Irons. 1995. Estimates of marine bird and sea otter abundance in Lower Cook Inlet, Alaska during summer 1993 and winter 1994. OCS Study MMS 94-0063. Unpubl. Rep., U.S. Fish and Wildlife Service, Anchorage, Alaska. 138 pp. + appendices.

4 Agler, B.A., S.J. Kendall, P.E. Seiser, and J.R. Lindell. 1995. Estimates of marine bird and sea otter abundance in Southeast Alaska during summer 1994. Unpubl. Report., U.S. Fish and Wildlife Service, Anchorage, AK 87 pp.+ appendices.

5. Oakley, K.L., and K.J. Kuletz. 1996. Population, reproduction, and foraging 6 of pigeon guillemots at Naked Island, Alaska, before and after the *Exxon Valdez* oil spill. Pages 759-769 In: S.D. Rice, R.B. Spies, D.A. Wolfe, and B.A. Wright (eds.), Proceedings of the *Exxon Valdez* Oil Spill Symposium. American Fisheries Society Symposium 18.

6. Oakley, K.D. 1981. Determinants of population size of pigeon guillemots *Cepphus columba* at Naked Island, Prince William Sound, Alaska. Unpubl. M.Sc. thesis. Univ. Alaska, Fairbanks. 65 pp.

7. Ainley, D.G. and R.J. Boekelheide. 1990. Pigeon guillemot. Pages 276-305 In D.G. Ainley and R.J.Boekeheide (eds.), Seabirds of the Farallon Islands: ecology, dynamics, and structure of an upwelling-system community. Stanford Univ. Press, Stanford, CA.

8. Nelson, D.A. 1985. The syntactic and sematic organization of Pigeon Guillemot (*Cepphus columba*) vocal behavior. Z. Tierpsychol. 67: 97-130.

9. Storer, R.W. 1952. A comparison of variation, behavior, and evolution in the seabird genera Uria and Cepphus. Univ. Calif. Publ. Zool. 52:121-222.

10. Drent, R.H. 1965. Breeding biology of the Pigeon Guillemot *Cepphus columba*. Ardea 53:99- 160.

11. Kuletz, K.J. 1983. Mechanisms and consequences of foraging behavior in a population of breeding pigeon guillemots. Unpubl. M.Sc. thesis. Univ. California, Irvine. 79 pp.

12. Slater, E.B. and P.J. Slater. 1972. Behavior of the Tystie during feeding of the young. Bird Study 19:105-113.

13. Nelson, D.A. 1987. Factors influencing colony attendance by Pigeon Guillemots on Southeast Farallon Island, California. Condor 89: 340-348.

14. Ewins, P.J., H.r. Carter, and Y.V. Shibaev. 1993. The status, distribution, and ecology of inshore fish-feeding alcids (*Cepphus* guillemots and *Brachyramphus* murrelets) in the north Pacific. Pages 164-175 In K. Vermeer, K.T. Briggs, K.H. Morgan, and D. Siegel-Causey (eds.), The status, ecology and conservation of marine birds of the north pacific. Special Publ. Can. Wildl. Service and Pac. Seabird Group.

15. Drent, R.H. 1965. Breeding biology of the Pigeon Guillemot. Ph.D. thesis, Univ. British Columbia, Vancouver.

16. Thoresen, A.C., and E.S.P. Booth. 1958. Breeding activities of the pigeon guillemot *Cepphus columba columba (Pallas)*. Walla Walla Coll. Publ. Dept. Biol. Sci. 23:1-36.

17. Koelink, A.F. 1972. Bioenergetics of growth in the pigeon guillemot *Cepphus columba*. Unpubl. M.Sc. thesis, Univ. British Columbia, Vancouver. 71 pp.

18. Nelson, D.A. 1991. Demography of the Pigeon Guillemot on southeast Farallon Island, California. Condor 93:765-768.

19. Follett, W.I. and D.G. Ainley. 1976 Fishes collected by Pigeon Guillemots *Cepphus columba Pallas*, nesting on southeastern Farallon Island, California. Calif. Fish Game 62:28-31.

20. Hayes, D.L. and T. Spencer. 1997. The breeding and feeding ecology of pigeon guillemots at Naked Island in Prince William sound, Alaska. Appendix F in D.C.Duffy (compiler), APEX: Alaska Predator Ecosystem Experiment. *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 96163).

21. Hayes, D.L. and K. J. Kuletz. 1997. Decline of pigeon guillemot populations in Prince William Sound, Alaska, and apparent changes in distribution and abundance of their prey. Pages 699-702 In: Forage Fishes in Marine Ecosystems. Proc. of Intnl. Symp. on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report No.97-01.

22. Golet, G., K.J. Kuletz, D. D. Roby, and D.B Irons. Adult prey choice affects chick growth and reproductive success of Pigeon Guillemots. In review. Auk.

23. Anthony, J.A. and D.D. Roby. 1997. Diet composition, reproductive energetics, and productivity of seabirds damaged by the *Exxon Valdez* oil spill. Appendix G in D.C.Duffy (compiler), APEX: Alaska Predator Ecosystem Experiment. *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 96163).

24. Kuletz, K.J., D.B.Irons, B.A. Agler, J.F. Piatt and D.C. Duffy. 1997. Long-term changes in diets and populations of piscivorous birds and mammals in Prince William Sound, Alaska. Extended Abstract, Pages 703-706 In: Forage Fishes in Marine Ecosystems. Proc. of Intnl. Symp. on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report No.97-01.

25. Piatt, J.F. and D.N. Nettleship. 1985. Diving depths of four alcids. Auk 102:293-297.

26. King, J.G., and G.A. Sanger. 1979. Oil vulnerability index for marine oriented birds. Pages 227-239 In J.C. Bartonek and D.N. Nettleship (eds.), Conservation of marine birds of northern North America. U.S. Fish and Wildlife Service, Wildl. Res. Rept. 11:1-319.

27. Piatt, J.F., C.J. Lensink, W. Butler, M. Kendziorek, and D.R. Nysewander. 1990. Immediate impact of the *Exxon Valdez* oil spill on marine birds. Auk 107-387-397.

28. Peakall, J.F., D. Hallett, D.S. Miller, R.G. Butler, and W.B. Kinter. 1980. Effects of ingested crude oil on black guillemots: a combined field and laboratory study. Ambrio 9:28-30.

29. Peakall, D.B., D. Hallett, F.R. Bend, G.L. Foureman, and D.S. Miller. 1982. Toxicity of Prudhoe Bay crude oil and its aromatic fractions to nesting herring gulls. Environ. Res. 27: 206-215.

30. Ainley, D.G., and T.J. Lewis. 1974. The history of Farallon Island marine bird populations, 1854-1972. Condor 76:432-446.

31. Ewins, P.J., and M.L. Tasker. 1985. The breeding distribution of black guillemots *Cepphus grylle* in Orkney and Shetland, 1982-84. Bird Study 32:186-193.

32. Sanger, G.A., and M.B. Cody. 1994.Survey of pigeon guillemot colonies in Prince William Sound, Alaska. *Exxon Valde*z Oil Spill Restoration Final Report, U.S. Fish and Wildlife Service, Anchorage, Alaska.

33. Piatt, J.F., and P. Anderson. 1996. Response of common murres to the *Exxon Valdez* oil spill and long-term changes in the Gulf of Alaska Marine Ecosystem. Pages 720-737 in S.D. Rice, R.B. Spies, D.A.Wolfe, and B.A. Wright (eds.), Proceedings of the *Exxon Valdez* Oil Spill Symposium. American Fisheries Society Symposium 18.