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Macroinvertebrate Production and Waterbird Use of Natural Ponds and Impoundments in the Prudhoe Bay Oil Field, Alaska

by Kenneth Kertell

LGL Alaska Research Associates, Inc.

Prepared for

BP Exploration (Alaska) Inc.

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MACROINVERTEBRATE PRODUCTION AND WATERBIRD USE OF NATURAL PONDS AND IMPOUNDMENTS IN THE PRUDHOE BAY OIL FIELD, ALASKA

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This report was prepared under contract to BP Exploration (Alaska) Inc. Inquiries about this report may be addressed to:

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Executive Summary

In 1991, LGL Alaska Research Associates, Inc. (LGL) initiated a program to study invertebrate productivity in impoundments in the Prudhoe Bay oil field. The small permanent impoundments we studied were found to contain higher mean biomasses of chironomids and oligochaetes (2x and 3x for chironomids and 3x and 10x for oligochaetes in June and August, respectively) than similarly sized natural ponds. In one water body pair, there was also a greater diversity of chironomids (17 versus 13 taxa) in the impoundment than the pond.

During 1992 we continued invertebrate sampling and determined waterbird use of impoundments and ponds. Invertebrates in emergent vegetation were sampled in June, July, and August at four pairs of impoundments and ponds (eight total water bodies). Analysis was limited to plecopterans (stoneflies), trichopterans (caddisflies), and gastropods (snails). Waterbird abundance was measured during June and July at 15 pairs of impoundments and ponds (30 water bodies). Behavior of common waterbirds was sampled following surveys of abundance. Waterbird studies focused on the following species: King Eider (*Somateria spectabilis*), Spectacled Eider (*Somateria fischeri*), Northern Pintail (*Anas acuta*), Oldsquaw (*Clangula hyemalis*) and Pacific Loon (*Gavia pacifica*). Aspects of the breeding biology of Pacific Loons was determined at 24 ponds and 22 impoundments.

During 1992 we determined the following:

- Mean numbers of aquatic invertebrates (all taxa combined) were greater in impoundments than natural ponds in June, July, and August; however, differences were not significant. High variability in invertebrate production among individual water bodies apparently resulted from differences in water chemistry, water body surface area and depth, and hydrology.
- Trichopterans were significantly more abundant in impoundments in July. Impoundments contained more plecopterans in July and August, but in June ponds were more productive. Differences in plecopteran abundance were not significant. Gastropods were significantly more abundant in impoundments in June. Within ponds and impoundments, Shallow-*Arctophila* water bodies were consistently more productive than Shallow-*Carex* water bodies.
- Ducks (all species combined) were more abundant on impoundments than ponds during all periods, but differences were not significant. Northern Pintails were consistently more abundant on impoundments during all periods. Oldsquaws were more abundant on ponds during all periods. Eiders (King and Spectacled combined) were more abundant on ponds in early and mid-summer.
- Ducks and Pacific Loons foraged similar lengths of time on impoundments and ponds. However, there were differences among waterbirds in method of foraging on the two water body types. For male and female King Eiders, diving accounted for a much greater percentage of total foraging time on ponds than impoundments. Dives were also longer on ponds for Pacific Loons and Oldsquaws.

- Number of young Pacific Loons per nesting pair averaged 0.83 and 0.63 on ponds and 0.73 and 0.41 on impoundments at hatch and at the end of the study, respectively. However, the proportion of pairs that produced 0, 1, and 2 young was not significantly different between ponds and impoundments at hatch or at the end of the study.
- Impoundments with Pacific Loon nests averaged larger (>3x) in surface area than ponds with nests. A variety of factors, including water body size, may have contributed to high interpair variation in foraging habits of loons on impoundments and ponds.
- The majority of impoundments we studied were subject to water level drawdowns which may have resulted in greater use by surface-feeders relative to divers, and lower productivity for breeding loons. We suggest that the long-term impact of drawdowns, acting in association with ongoing thermokarst, may be continued high invertebrate productivity 10 to 20 years after initial impoundment creation.
- Because waterbird species vary in the extent to which they respond to different wetlands and wetland habitats, modification of wetland habitats may benefit some species at the expense of others.

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INTRODUCTION

Human activities in the Arctic can cause long-lasting changes in tundra landscapes (Truett and Kertell 1992). Within oil fields in arctic Alaska, water impounded beside gravel roads and pads constitutes one of the major human-induced landscape disturbances in terms of acreage affected (Walker et al. 1987). In an intensively developed portion of the oil field, impoundments covered approximately 20% of the landscape, compared with 11% covered by gravel roads and pads (Walker et al. 1986). In the entire oil field (area = 300 km^2 or 186 mi^2), 2.8% of the landscape was covered by impoundments (Walker et al. 1987).

A goal of the U.S. Fish and Wildlife Service is "to maintain overall wildlife habitat productivity" (FWS 1989). Because habitat value for a given species is considered to be equivalent to the carrying capacity of the environment for that species (FWS 1981), a number of scientists have voiced concern about the potential negative effects of impoundments on wildlife populations (Walker et al. 1987). Options for mitigating potential negative effects are being investigated by the oil industry, but it is not clear how or which mitigation approaches should be used. For example, draining impoundments would not necessarily improve habitat value or increase carrying capacity.

To meet the need for more information, LGL initiated a program in 1991 to study invertebrate production in impoundments as one measure of their potential value as waterbird habitat. The small impoundments we studied were found to contain higher mean biomasses of chironomids and oligochaetes (2x and 3x for chironomids and 3x and 10x for oligochaetes in June and August, respectively) than similarly sized natural ponds. It was suggested that these impoundments may benefit some waterfowl populations, but may represent a net loss of habitat quality for waders (with the exception of phalaropes) due to loss of tundra nesting and feeding areas.

Although greater invertebrate productivity should be beneficial to waterfowl, the extent to which it was being utilized was unknown. Until actual bird use was determined, the potential benefits of high invertebrate productivity could only be hypothesized. Therefore, during 1992, we studied waterfowl and Pacific Loon use of impoundments and natural ponds and, to increase confidence in our 1991 findings, sampled additional invertebrate taxa important as food for breeding waterbirds. Differences in invertebrate production and waterbird use between ponds and impoundments could have implications relative to types and costs of future impoundment mitigation.

OBJECTIVES

Objectives of the study were as follows:

(1) Determine waterbird abundance in impoundments and natural ponds.

The purpose of measuring waterbird abundance was to see if one water body type was being selected over the other.

(2) Document types of waterbird use of impoundments and natural ponds.

The purpose of documenting types of waterbird use was to determine how ponds and impoundments were being used, and to test the feasibility of using Pacific Loons as an indicator species. An indicator species is an organism whose life-history characteristics are used as an index of habitat attributes too difficult, inconvenient, or expensive to measure for other species or environmental conditions of interest (Landres et al. 1988).

(3) Sample macroinvertebrates associated with emergent vegetation in impoundments and natural ponds.

The purpose of invertebrate sampling was to supplement information collected in 1991 by emphasizing additional invertebrate taxa important as food to waterbirds (i.e., plecopterans, trichopterans, and gastropods).

BACKGROUND AND RATIONALE

Although impoundments constitute one of the major human-induced landscape disturbances in arctic Alaska (Truett and Kertell 1992), few investigators have studied the effects of impoundments on waterbirds. The relevant studies that have been done suggest that impoundments have varying effects on waterbird species, depending on the species and type of use in question (see Kertell and Howard 1992, Table 1), and that invertebrate production is high in some impoundments (Kertell and Howard 1992). However, there is almost no information available for establishing a direct link between waterbird use and invertebrate production, for determining how habitat (e.g., water depth and amount of emergent vegetation) may affect invertebrate availability and use by different waterbird species, and for understanding why some impoundments are highly productive.

Invertebrate abundance is widely recognized as an important measure of habitat quality for waterbirds (Whitman 1976, Joyner 1980, Murkin and Kadlec 1986, Rosenberg et al. 1986, Belanger and Couture 1988, Kaminski and Weller 1992, Krapu and Reinecke 1992), particularly in arctic areas, where high levels of animal protein are required by breeding waterbirds (Weller 1988). Female ducks, for example, consume a high proportion of invertebrates (Weller 1988, Krapu and Reinecke 1992). These highly digestible sources of protein and energy, and essential amino acids, are critical for egg laying and incubation (Serie and Swanson 1976, Swanson et al. 1979, Weller 1988). They are also important to ducklings, which depend on high-energy and high-protein-quality foods for rapid growth and feather development (Driver et al. 1974, Sedinger 1992). Consequently, secondary productivity is often used as an indicator of habitat quality (or wetland type) for birds that consume large quantities of invertebrates (Howard 1974, Klopatek 1988, Kertell and Howard 1992).

Chironomids dominate the biomass of arctic freshwater habitats (Butler et al. 1980, Hobbie 1984), and large numbers of larvae are consumed by pond-feeding shorebirds (Holmes 1966) and waterfowl (Krapu and Swanson 1975, Swanson et al. 1979, Taylor 1986). Zooplankton are also eaten by birds (Wetzel 1983, Hobbie 1984), but because zooplankton are temporally and spatially more variable in abundance (Hobbie 1984), they are difficult to accurately sample. For this reason, sampling in 1992 was focused on several groups of invertebrates associated with emergent vegetation: trichopterans (caddisflies), plecopterans (stoneflies), and gastropods (snails). Availability of a variety of invertebrate taxa for breeding female waterfowl increases the probability that they will obtain a balance of essential nutrients not provided by a single food source (Sugden 1973).

Several species of arctic waterfowl consume trichopterans, plecopterans, and gastropods. At West Long Lake in the National Petroleum Reserve-Alaska (NPR-A), adult Oldsquaws collected from shallow ponds ate primarily plecoptera nymphs (51% of aggregate volume) during June (Taylor 1986). Gastropods and trichopterans were taken in lesser amounts (8.6% and 3.5% of aggregate volume, respectively) during this period. At Point Storkersen (Bergman et al. 1977), a male and a female Oldsquaw collected in early summer contained large numbers of trichoptera larvae (80.2% and 39.2% of total volume). An Oldsquaw pair was also observed in early summer eating plecoptera larvae from the ice surface at the edge of a shallow pond at Point Storkersen, but plecopterans were not found in any of the birds collected. Trichoptera larvae were the most important food of King Eiders at Point Storkersen, and gastropods and trichoptera larvae were eaten in small quantities by Northern Pintail (Bergman et al. 1977). An adult female and three young Pacific Loons collected at Prudhoe Bay had eaten trichoptera larvae (Bergman and Derksen 1977). In western Chukotka, female King and Spectacled eiders fed mainly on trichoptera and chironomid larvae in the spring (Kondratev and Zadorina 1992).

Although invertebrates are important in determining wetland use by waterbirds, a variety of other factors may also influence use. They include: (1) amount of emergent vegetation (Kadlec 1962, Hudson 1983, Rumble 1989, Weller 1990, Kadlec and Smith 1992, Payne 1992), (2) wetland surface area (Rumble and Flake 1983, Weller 1988, Kaminski and Weller 1992), (3) water depth (see Payne 1992), (4) shoreline characteristics (Rossiter and Crawford 1983, Uresk and Severson 1988), and (5) the habitat needs and foraging patterns of waterbirds (Weller 1988, Krapu and Reinecke 1992). Therefore, direct measurements of bird abundance and habitat use are often needed to evaluate the relative importance of invertebrate production in different wetland types.

A variety of waterbirds eat invertebrates, but we selected the following species of waterfowl for study: King Eider (*Somateria spectabilis*), Spectacled Eider (*Somateria fischeri*), Northern Pintail (*Anas acuta*), Oldsquaw (*Clangula hyemalis*) and Pacific Loon (*Gavia pacifica*). These species employ a variety of foraging techniques, are abundant in the Prudhoe Bay oil field, or are currently of interest to regulatory agencies. Spectacled Eider populations are declining in arctic and subarctic regions (Kertell 1991), and the Spectacled Eider may soon be included on the federal List of Threatened and Endangered Species (FWS pers. comm.). There is concern that King Eider populations may also be declining (FWS, pers. comm.). The Northern Pintail is an important game species and its numbers have declined precipitously in the last decade. Although the Arctic Coastal Plain is not an important breeding area for pintails, it attracts large numbers of non-breeding birds, and it has been suggested that many of these birds may breed in the southern prairies when conditions there are favorable (Derksen and Eldridge 1980, Derksen 1992). Oldsquaw may be the most abundant breeding duck in the Beaufort Sea area (Johnson and Herter 1989), and extensive food habit and wetland use data have been collected along the coastal plain (Bergman et al. 1977, Taylor 1986). Loons have recently received considerable attention from agencies and the public (McIntyre 1986).

Determination of the value of wetlands to waterbirds by direct measurement of bird abundance is often difficult because of methodological and interpretational problems (Johnson 1980, Weller 1988, Hobbs and Hanley 1990). These problems are particularly apparent in arctic Alaska, where waterbird densities may be low and distributions patchy. Therefore, we also studied interactions between birds and their habitats, including foraging behavior for species listed above and aspects of the breeding biology of Pacific Loons.

The Pacific Loon appears well suited for use in assessing the comparative values of ponds versus impoundments in arctic Alaska. Loons typically use one water body during incubation and brood-rearing (Davis 1972, Bergman and Derksen 1977); thus, if they use impoundments, it would suggest that nest site and food requirements are being met. We suggest that foraging efficiency is an important measure of the comparative health of ponds and impoundments. The relationship between prey availability and the foraging tactics of vertebrate consumers in aquatic systems has been previously used to assess habitat quality for loons and sea otters (*Enhydra lutris*) (Alvo 1986, Estes et al. 1986).

Pacific Loons exhibit other attributes which make them a potentially excellent indicator of wetland habitat change at Prudhoe Bay. First, Pacific Loons are easy to observe while feeding their young, appear to respond to differences in food supply in ways detectable by observers, and are relatively easy to relocate following dispersal from nest sites. Second, they are abundant in arctic wetlands, providing resource managers with the opportunity to conduct comparative studies in a variety of geographic locations.

STUDY AREA

The study area was located in the Prudhoe Bay oil field on the Arctic Coastal Plain of Alaska (Fig. 1). Potential impoundments for study were selected prior to the field season based upon a 1984 map depicting impoundment locations (Lederer et al. 1984). Large-scale color infrared (CIR) photographs taken in late summer of 1991 were used to determine which impoundments were likely to still be present in 1992. Impoundments selected for study were located in both alkaline and acidic soils (see Walker et al. 1980) and ranged in age from 10 to 20 years (Lederer et al. 1984). Final selection of study sites was made during visits to the field on 26–27 May and 1–4 June 1992. Following final impoundment selections, nearby natural ponds of similar surface area were selected. However, individual ponds sometimes differed in size and shape from their impounded counterparts.

METHODS

Data Collection

Water Body Description

Water bodies used for studies of invertebrate production, bird abundance, and Pacific Loon breeding biology were classified in the field according to a wetland classification system developed by Bergman et al. (1977). This system describes eight wetland classes based on size, water depth, emergent vegetation, basin geomorphology, and water chemistry. An important criterion in the system is the presence or absence of *Carex aquatilis* (water sedge) or *Arctophila fulva* (pendant grass), the dominant emergent plants in these wetlands.

Water bodies chosen for sampling of waterbird abundance and loon biology included Shallow-*Carex* (Class II), Shallow-*Arctophila* (Class III), and Deep-*Arctophila* (Class IV) wetlands (Bergman et al. 1977). Invertebrate study sites represented a subset of the water bodies used to determine bird abundance. The number of water bodies represented by each of these wetland classes is summarized in Table 1 (waterbird abundance and invertebrate production) and Table 2 (loon biology). Site numbers and wetland classifications for individual sites are provided in Appendix K (waterbird abundance and invertebrate production) and Appendices L and M (loon biology).

The amount of emergent vegetation was measured

Table 1. Wetland classification for water bodies used to determine bird abundance in 1992, Prudhoe Bay, Alaska. The classification system was developed by Bergman et al. (1977).

Wetland Class	Ponds (%)	Impoundments (%)
Shallow-*Arctophila* (III)	7 (46.7)	6 (40.0)
Shallow-*Carex* (II)	7 (46.7)	6 (40.0)
Deep-*Arctophila* (IV)	1 (6.6)	3 (20.0)

Table 2. Wetland classification for water bodies with Pacific Loon nests in 1992, Prudhoe Bay, Alaska. The classification system was developed by Bergman et al. (1977).

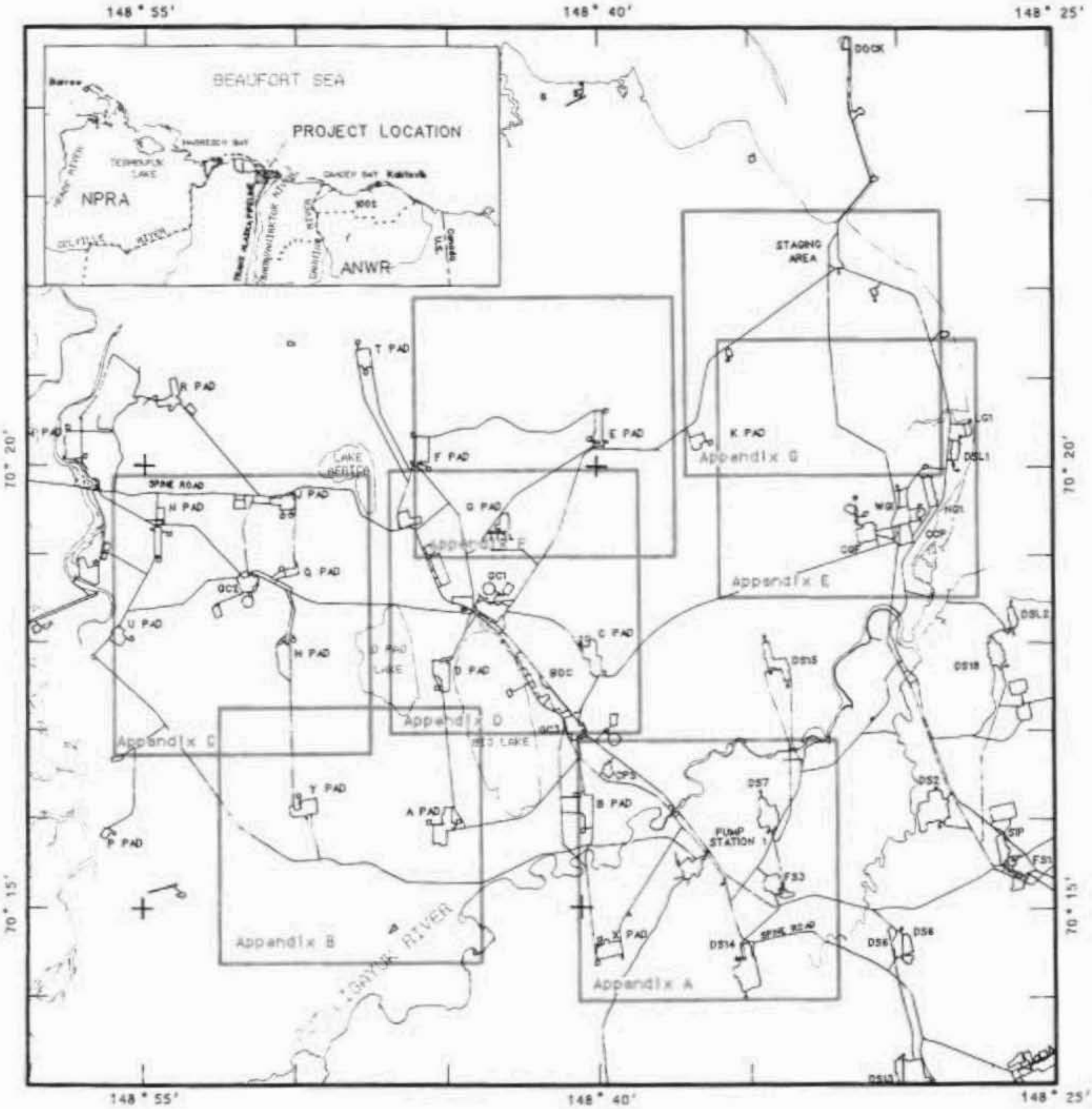
Wetland Class	Ponds (%)	Impoundments (%)
Shallow-*Arctophila* (III)	16 (69.6)	11 (50.0)
Shallow-*Carex* (II)	4 (17.4)	8 (36.4)
Deep-*Arctophila* (IV)	3 (13.0)	3 (13.6)

Table 3. Characteristics of water bodies used to determine waterbird abundance and invertebrate production in 1992, Prudhoe Bay, Alaska. Invertebrate production was determined at West Beach State, Gasline, P-Pad, and GC2a ponds and impoundments only.

Water Body Pair	Area (ha)		Age (year)		Amount of Emergent Vegetation			
					%of Shoreline		% of Surface	
	Imp	Pond	Imp	Pond	Imp	Pond	Imp	Pond
Frontier/C-Pad	8.19	2.84	20	–	62.5	37.5	85.0	2.5
E-Pad	2.32	1.34	19	–	85.0	2.5	85.0	2.5
West Dock	3.73	5.07	15	–	2.5	2.5	15.0	2.5
West Beach State	4.09	2.23	15	–	85.0	15.0	2.5	2.5
DSLI	0.96	0.61	15	–	62.5	97.5	85.0	15.0
NGI	2.23	2.23	15	–	2.5	62.5	85.0	15.0
Gasline	3.68	4.32	18	–	62.5	15.0	15.0	15.0
DS7a	2.81	1.62	13	–	62.5	37.5	62.5	15.0
DS7b	2.28	2.12	13	–	15.0	37.5	37.5	2.5
A-Pad/X-Pad	8.36	12.82	13	–	37.5	15.0	2.5	2.5
P-Pad	2.04	1.78	10	–	62.5	2.5	62.5	2.5
GC2a	1.35	1.23	15	–	85.0	2.5	85.0	2.5
GC2b	2.04	2.04	15	–	15.0	15.0	37.5	2.5
H-Pad	2.68	1.67	20	–	85.0	2.5	62.5	2.5
CC2	3.62	3.12	18	–	62.5	62.5	62.5	2.5
Mean	3.36	3.00	15.6		52.5	27.2	52.3	5.8

FIGURE 1

MACROINVERTEBRATE PRODUCTION AND BIRD USE STUDY



Project location and oil field areas used for Macroinvertebrate Production and Bird Use Study in 1992, Prudhoe Bay, Alaska. Appendices A - G show water body locations.

1:126,720 (1"=2 MILES)

0 2 4 6 KM

0 2 4 MILES

UTM6/NAD27

BASE MAP FROM USGS 1:63,360 SERIES. FACILITIES UPDATED FROM AERIAL PHOTOGRAPHY THROUGH 1988.

RDI, FEB. 1993, FIGURE1

at those water bodies used to study bird abundance and invertebrate production (Table 3). Emergent vegetation was estimated visually according to cover categories developed by Daubenmire (Barbour et al. 1987) and expressed as percent of total shoreline and percent of total surface area. Mean percent cover was based on the midpoints of cover categories. Percent of total surface area covered by ice was also estimated daily until water bodies were 100% ice-free (Table 4).

A digital planimeter and color infrared (CIR) photographs (1" = 600' taken in July 1992) were used to measure surface area of water bodies used to study bird abundance and invertebrate production (Table 3) and those with loon nests (Appendices L and M). Surface areas were based on the amount of water present in early June. For impoundments, June water levels were clearly evident on July photographs by the color contrast between previously flooded vegetation and adjacent unflooded tundra.

Invertebrate Sampling

Invertebrate sampling was conducted at eight water bodies: two pond and impoundment pairs studied in 1991 (GC2 [nos. 1 and 2, Appendix C] and P-Pad [nos. 3 and 4, Appendix C]) and two new pairs of ponds and impoundments (Gasline [nos. 5 and 6, Appendix E] and West Beach State [nos. 7 and 8, Appendix G]). The GC2 and P-Pad sites were Shallow-*Carex* wetlands located in alkaline soil, while the Gasline and WBS sites were Shallow-*Arctophila* wetlands located in acidic soil within 4 km of the Beaufort Sea Coast.

Invertebrates were sampled three times: 26–27 June, 15 July, and 1 August. The range of sampling dates provided information on the relative abundance of invertebrates through time.

Emergent vegetation was the only habitat where invertebrates were sampled. Macroinvertebrates were collected using a BioQuip (Gardena, CA), heavy-duty aquatic net ("D" shape, 12" diameter; Cat. No. 7412D). The net was lowered into the water and moved approximately 2 m in an arc through the emergent vegetation. The sample was discarded if bottom sediments were collected in the net. Invertebrates were removed from the net in the field and placed in plastic bags containing 70% alcohol. Sorting and identification were conducted at BPX offices at Prudhoe Bay.

Table 4. Thaw characteristics of ponds and impoundments used to determine waterbird abundance and invertebrate production in 1992, Prudhoe Bay, Alaska. Invertebrate production was determined at West Beach State, Gasline, P-Pad, and GC2a ponds and impoundments only.

Water Body Pair	Percent Open Water on 5 June		Approx. Date on which 100% Ice-Free	
	Imp	Pond	Imp	Pond
Frontier/C-Pad	100.0	0.0	5 June	17 June
E-Pad	85.0	5.0	10 June	12 June
West Dock	90.0	5.0	10 June	12 June
WBS	15.0	5.0	11 June	11 June
DSL-1	95.0	5.0	7 June	9 June
NGI	70.0	5.0	8 June	11 June
Gasline	5.0	10.0	8 June	14 June
DS7a	85.0	30.0	9 June	11 June
DS7b	70.0	5.0	8 June	10 June
X-Pad/A-Pad	40.0	5.0	12 June	20 June
P-Pad	30.0	20.0	9 June	9 June
GC2a	95.0	15.0	6 June	9 June
GC2b	40.0	5.0	11 June	1 July
H-Pad	80.0	0.0	7 June	12 June
CC-2	95.0	15.0	7 June	11 June
Mean	72.3	8.7	9 June	15 June

During each sampling period, six sweep samples were collected from each water body. Because the distribution of invertebrates within water bodies is extremely heterogenous (Wetzel 1983), three samples were collected at each of two locations. At the GC2 and P-Pad ponds and impoundments (Shallow-*Carex* water bodies), samples were collected only from emergent *C. aquatilis*. With the exception of WBS pond, which contained no *C. aquatilis*, samples at the Gasline and WBS sites (Shallow-*Arctophila* water bodies) were collected from both *C. aquatilis* (three samples) and *A. fulva* (three samples). This resulted in a total of 144 samples collected during the summer (8 water bodies x 3 sampling periods x 6 samples per water body). Numbers of invertebrates collected from ponds and impoundments during each sampling period are provided in Appendices H–J.

Waterbird Abundance

Waterfowl abundance was measured from 5 June through 29 July at 30 water bodies: 15 impoundments and 15 natural ponds (Appendices A–G). Observations were collected on all but seven days during this period. To evaluate changing levels of use, the breeding season was divided into three time periods, each with 16 observation days. These periods coincided with (1) the period prior to nest initiation in early summer (5–20 June), (2) the period when most nests are initiated in mid-summer (21 June–7 July), and (3) the post-nesting period in late summer after young have hatched (8–27 July).

Each water body was visited once during a sampling day for a minimum of 15 minutes, and all waterfowl were recorded by species. Only birds that were present at the beginning of the period or that arrived during the 15-minute period were recorded. Duck broods were classified by age category according to Gollop and Marshall (1954).

At the GC2b sites (nos. 25 and 26, Appendix C), it was determined that a large impoundment was actually a natural pond that had been joined to an impoundment to create a single water body. In this instance, the impounded portion of the water body was compared with a similarly sized portion of the adjoining natural pond.

Waterbird Activity Budgets

Activity budgets were determined for King Eider, Spectacled Eider, Oldsquaw, Northern Pintail, and Pacific Loon. Data were collected opportunistically at each water body following the census of bird abundance. Individuals and pairs were randomly selected from birds present on the water body, and activities were recorded at 20-second intervals for a duration of 15 minutes. Scoring an individual's behavior at predetermined points in time is referred to as "instantaneous sampling" (Martin and Bateson 1986). Instantaneous sampling gives a single score for each behavioral session.

The behavior of paired males and females was analyzed separately for eiders only. The majority of pair observations were collected during June when birds were feeding most actively prior to nesting; thus, behavioral information for pairs more closely reflects use of water bodies at that time.

Two major categories of behavior were recorded: foraging and other, which included all activities not associated with foraging (e.g., alert, swimming, resting, sleeping, body maintenance). Foraging was divided into:

(1) *Diving*. Diving included time spent underwater as well as pauses on the surface between dives. Dive lengths of eiders, Oldsquaw, and Pacific Loon were recorded during behavioral sessions.

(2) *Surface dabbling*. Surface dabbling included capturing prey from the water surface or from emergent vegetation above the water surface, or snatching insects from the air.

(3) *Subsurface dabbling*. Subsurface dabbling included capturing prey from below the water surface by submerging the bill or entire head.

Census and behavioral data were conducted from a parked vehicle using binoculars and a 20x Bushnell spotting scope mounted on the vehicle window. Field observations were made at various times of the day from 07:00 to 19:00.

Nesting Ecology of Pacific Loons

Pacific Loon nests were located by scanning water bodies from a parked vehicle. A total of 44 nests were located: 23 on natural ponds and 21 on impoundments. Two additional loon families (one on an impoundment and one on a pond) were located after hatch, for a total of 46 pairs. We referred to the impoundment map provided by Lederer et al. (1984) to confirm whether the nest was located on a pond or an impoundment. Nests were classified according to three substrate types: natural islands, mainland shorelines (including peninsulas), and platforms constructed by loons from emergent vegetation.

From 5 July to 4 August, loon nests were checked daily or every other day. Prior to hatch, the purpose of nest checks was to monitor nest status. A nest that appeared inactive was visited on foot to determine if it was still active or if it had been abandoned or preyed upon. To avoid disturbing nesting birds, we did not visit active nests to determine clutch sizes. When nesting was successful, we determined number of young, mortality of young, movements from the water body where the nest was located, and number of prey delivered to young by adults during 10-minute periods. A prey delivery period began when the observer first observed prey being exchanged.

Six ponds (nos. 6, 9, 22, 24, 33, and 35; Appendices A, B, C, F, and G) and six impoundments (nos. 2, 12, 21, 29, 38, and 46; Appendices A, C, D, and G) were selected for more detailed observations of loon foraging. At these sites, both number and duration of foraging "bouts" during 4-hour observation periods were recorded. Feeding behavior often occurs in temporal clusters, referred to as bouts, in which the same, relatively brief behavior is repeated several times in succession (Martin and Bateson 1986). Two loon pairs, one from a natural pond and one from an impoundment, were observed concurrently during morning and afternoon observation sessions. Concurrent sessions were conducted on pairs with an equal number of young. Each pair was observed twice, once in the morning and once in the afternoon; however, a second observation session was canceled at two sites because the adults could not be located at the start of the session resulting in three observation sessions at one pond/impoundment pair. Prey delivery rates (number of prey/10-minute period) also were recorded during 4-hour observation periods in order to estimate total prey delivered to young at each site.

Data Analysis

Analysis of variance (ANOVA) with repeated measures was used to compare invertebrate abundances between ponds and impoundments. The data were transformed [ln(x+1)] based on results of Bartlett's test for homogeneity and on examination of probability plots. The repeated measures analysis views the eight water bodies as subjects of which four received the impoundment treatment and four the pond treatment. We used *t*-tests for comparisons within ponds and impoundments (i.e., Shallow-*Carex* versus Shallow-*Arctophila* water bodies). For these comparisons, sample size (n) was based on the number of sweep samples rather than the number of water bodies which received the impoundment or pond treatment.

The Mann-Whitney *U* test was used to compare bird abundance data. Although mean values are presented in the text for ease of comparison, the Mann-Whitney *U* test compares rank sums (not means) to determine significant differences. Because a large number of comparisons will often result in some significant results through random chance alone, we computed Bonferroni-adjusted probabilities to guarantee that the probability of a Type 1 error would not be greater than 0.05 (Dunn 1961). The probability for each comparison was determined by dividing 0.05 by the number of comparisons.

Significance tests were not conducted on behavioral data because of large differences between ponds and impoundments in the number of behavioral observations per water body (i.e., data collection was constrained by the timing and distribution of birds for sampling). Consequently, comparisons between ponds and impoundments for each species are based on the number of observation sessions for that species rather than the number of ponds and impoundments at which observations were recorded, and results are presented for general comparison only.

Chi-square (χ^2) tests were used to compare Pacific Loon productivity on ponds and impoundments.

Standard errors (SE) are provided as the measure of variability throughout the report.

We tested four major hypotheses in this study. Hypotheses 1 and 2 refer to invertebrate data, Hypothesis 3 refers to bird use data, and Hypothesis 4 refers to Pacific Loon data.

Ho_1 = There are no significant differences between natural ponds and impoundments in numbers of plecopterans, trichopterans, and gastropods (by taxa and for all taxa combined) in early, middle, or late summer.

Ho_2 = There are no significant differences within natural ponds and impoundments (Shallow-*Carex* versus Shallow-*Arctophila* water bodies) in numbers of plecopterans, trichopterans, and gastropods (by taxa and for all taxa combined) in early, middle, or late summer.

Ho_3 = There are no significant differences between impoundments and natural ponds in numbers of ducks in early, middle, or late summer.

Ho_4 = There are no significant differences between impoundments and natural ponds in productivity of Pacific Loon pairs.

RESULTS

Invertebrate Abundance

Between Sampling Periods

Mean numbers of plecopterans, trichopterans, and gastropods (all groups combined) increased from 31.5 ± 6.8/water body in June to 57.4 ± 16.4/water body in August for all sites pooled (Fig. 2). Trends in abundance for individual invertebrate groups are also shown in Fig. 2. Only trichopterans decreased in abundance between July and August. Plecopterans were the most abundant invertebrate during all periods, making up 47.3%, 39.5%, and 62.5% of total invertebrates during June, July, and August, respectively. The observed increase in invertebrate numbers, particularly plecopterans, from June to August may have resulted from (1) movement of instars to emergent vegetation from overwintering habitat in sediments, and (2) seasonal growth of instars to catchable size.

Within Sampling Periods

During June through August (Figs. 3–5), mean numbers of invertebrates (all groups combined) were greater in impoundments (35.2 ± 14.2, 54.4 ± 13.3, and 70.9 ± 27.4/impoundment, respectively) than natural ponds (27.8 ± 1.9, 31.6 ± 9.0, and 44.0 ± 19.5/pond, respectively). However, differences were not significant. Within both ponds and impoundments, Shallow-*Arctophila* water bodies consistently produced more invertebrates than Shallow-*Carex* water bodies. In impoundments, differences were significant in June (50.4 ± 13.6 versus 20.0 ± 4.7/sample; P<0.001), July (73.1 ± 10.2 versus 35.8 ± 2.5/sample; P<0.02), and August (104.2 ± 19.6 versus 37.6 ± 6.4/sample; P<0.001). In ponds, differences were significant in July (44.3 ± 7.9 versus 18.9 ± 4.7/sample; P<0.001) and August (61.7 ± 14.2 versus 26.3 ± 8.0/sample; P<0.001).

Plecopterans (*Nemoura* sp.) were more abundant in ponds (16.8 ± 0.9/pond) than impoundments (13.0 ± 11.9/impoundment) in June (Fig. 6), while during July and August (Figs. 7 and 8) mean numbers were greater in impoundments (20.8 ± 10.8 and 49,3 ± 26.1/impoundment, respectively) than ponds (13.2 ± 6.7 and 22.5 ± 11.2/pond, respectively). Again, differences were not significant. Differences were due to greater average plecopteran numbers in Shallow-*Arctophila* impoundments versus Shallow-*Arctophila* ponds; Shallow-*Carex* ponds were consistently more productive than Shallow-*Carex* impoundments. Within both ponds and impoundments, plecopterans were more abundant in Shallow-*Arctophila* than Shallow-*Carex* water bodies, and in five of six cases these differences were highly significant (P<0.001). A sample of plecopterans from all water bodies (ponds and impoundments combined) averaged 5.7 ± 0.1 mm (range 2–14 mm, n = 230) in length.

Trichopterans (*Limnephilus* sp. and *Micrasema* sp.) were more abundant in impoundments than ponds during all periods (Figs. 9–11), but only when they reached peak abundance within both water body types in July (Fig. 10) were differences significant (23.9 ± 6.4/impoundment versus 7.4 ± 2.5/pond; P<0.02). In two of three periods, production averaged slightly greater in Shallow-*Carex* ponds than Shallow-*Carex* impoundments. Comparisons within ponds and impoundments again showed that Shallow-*Arctophila* water bodies were consistently more productive than Shallow-*Carex* water bodies. In impoundments, differences were significant in June (14.6 ± 3.0 versus 3.8 ± 1.3/sample; P<0.001) and August (14.6 ± 4.2 versus 4.8 ± 1.7/sample; P<0.01). Trichopterans (both genera combined) averaged 9.8 ± 0.2 mm (range 4–17, n = 148) for ponds and impoundments combined. Cases were removed prior to measurement of larvae.

Gastropods (*Physa* sp.) were significantly more abundant (P<0.001) in impoundments (13.0 ± 3.5/impoundment) than ponds (4.2 ± 2.1/pond) in June (Fig. 12). In July (Fig. 13) and August (Fig. 14), they declined in abundance in impoundments (9.7 ± 4.5 and 11.9 ± 5.7/impoundment, respectively) relative to ponds (11.0 ± 4.4 and 15.6 ± 7.9/pond, respectively), but differences were not significant. Greater pond productivity in July and August was the result of greater productivity in Shallow-*Arctophila* ponds compared with Shallow-*Arctophila* impoundments. Although there were more gastropods in Shallow-*Arctophila* than Shallow-*Carex* ponds in July (16.8 ± 3.6 versus 5.3 ± 2.3/sample; P<0.001) and August (26.5 ± 5.0 versus 4.8 ± 0.9/sample; P<0.001), the reverse was true for impoundments. Within impoundments, gastropods were more abundant in Shallow-*Carex* compared with Shallow-*Arctophila* water bodies in June (15.5 ± 4.8 versus 10.5 ± 2.3/sample), and significantly more abundant in July (17.3 ± 1.7 versus 2.2 ± 1.0/sample; P<0.001) and August (19.3 ± 5.5 and 4.5 ± 1.8/sample; P<0.001).