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Winter Species in Prince William Sound, Alaska, 1989-2016

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The opinions expressed in this PWSRCAC-commissioned report are not necessarily those of PWSRCAC.

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Appendix 1: Bibliography of winter research in Prince William Sound, Alaska, from 1989-2016. Microsoft Excel Document: 910.16.01 Appendices.

Appendix 2: Complete list of species documented in Prince William Sound, Alaska during winter from 1989-2016. Microsoft Excel Document: 910.16.01 Appendices.

Abstract

We conducted a literature search and developed a bibliography of research conducted on biological resources during winter in Prince William Sound (PWS) since the 1989 *Exxon Valdez* oil spill. The literature search returned 133 unique results documenting the presence of 188 species, including 61 zooplankton, 1 mollusk, 1 echinoderm, 7 crustaceans, 61 fish, 50 birds, and 6 mammal species. However, the species list included with the bibliography is by no means a comprehensive list of all species present in PWS during winter. We were unable to find any published studies or reports documenting sea cucumbers, sea urchins, jellyfish, octopus, and several marine mammal species known to occur in PWS throughout the year. Our bibliography is useful for identifying sensitive biological resources in the Sound and can be used as a tool to inform and update oil spill contingency plans.

Introduction

In March 1989, the *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound (PWS), Alaska. The spill released approximately 11 million gallons (257,000 barrels) of crude oil into the Sound and contaminated over 1000 miles of shoreline (Alaska Oil Spill Commission 1990). The estimated mortality from the spill included approximately 250,000 seabirds (Piatt et al. 1990), 2,600 sea otters (Garrot et al. 1993), 300 harbor seals (Loughlin 1994), 250 bald eagles (Bowman et al. 1993), as many as 22 killer whales (Loughlin 1994), and countless salmon and herring eggs.

Following the oil spill, Congress passed the Oil Pollution Act of 1990. This act requires oil storage facilities and vessels to develop and submit oil spill prevention and response plans detailing their responses in the event of accidental discharge. The PWS Subarea Contingency Plan (PWSSCP) documents the response plan for the PWS area and identifies sensitive areas, biological resources, and human-use resources within PWS that may be particularly sensitive to the effects of an oil spill. However during oil spill response drills, the staff of the PWS Regional Citizens' Advisory Council (RCAC) has at times noted response actions that perhaps demonstrate an under-appreciation of the biological resources that may be present in PWS during winter months.

To address these issues, we developed a bibliography documenting the presence of biological resources in PWS during the winter since the *Exxon Valdez* oil spill in 1989. This information is useful for the PWS RCAC to identify sensitive biological resources in the Sound, to identify gaps in knowledge of winter species, and to inform and update oil spill contingency plans such as the PWSSCP.

Methods

We used a variety of methods to identify research activities since 1989 that pertain to biological resources in PWS during winter months. First, we defined winter as the period occurring between November 1 and March 31. We then performed a literature search using the Web of Science and Google Scholar databases. The search parameters used were “Prince William Sound winter” with the time span restricted to 1989-2016. We also used the Exxon Valdez Oil Spill Trustee Council’s Restoration Project Search using the following parameters: Geographic Regions- Prince William Sound; Professional Activities- Field research and data management. Additionally, we searched final reports submitted by the Alaska Department of Fish and Game (ADFG), U.S. Forest Service (USFS), PWS RCAC, and the National Oceanic and Atmospheric Administration (NOAA) directly on the agency websites. Additionally, we contacted 25 researchers from 10 agencies and organizations that conduct research or manage biological resources in PWS during winter. Of the 25, all but two responded to our inquiries. Researchers were contacted primarily by email, but were also interviewed over the phone or in person.

All applicable results were organized into a searchable bibliography using Microsoft Excel. All entries were completed as fully as possible. See Table 1 for a complete list of the data categories and definitions.

Results

Our search returned a total of 133 unique records of 188 species for the bibliography (See Appendix 1 for the complete list of records and Appendix 2 for list of species). In some cases, the bibliographic citations may have more than one entry associated with them if the research investigated more than one taxonomic grouping.

The bibliographic search returned studies documenting zooplankton, mollusks, echinoderms, crustaceans, fish, birds, and mammals (Table 2; Appendix 2). Most studies occurred either within a single winter month or throughout the entire winter period (Figure 1). March was the month in which the highest number of research activities occurred followed by November for all taxa except crustaceans (Figure 2).

Zooplankton

Five studies documented zooplankton presence, density, or distribution in PWS during winter. Two results were part of a long-term monitoring program that collected zooplankton samples all year round concurrent with oceanographic measurements (Campbell 2013; R. Campbell, PWSSC on-going project). Another project examined the influence of temperature on zooplankton, sampling in March (Foy and Norcross 2001). Sturdevant et al. (2001) conducted vertical zooplankton tows and assessed zooplankton presence in the stomachs of juvenile walleye pollock and Pacific herring to evaluate feeding habits and diet overlap between the two species. The fifth study sampled ballast water of tankers arriving to Port Valdez and examined variation in the biota of the water (Ruiz et al. 2000).

Mollusks

Mollusks were included in 14 studies, the majority of which involved collecting mussel tissues and sediments throughout PWS (Payne et al. 2010, 2008, 2006, 2005, 2003, 1998; Kinetic Laboratories Inc. 2003, 2000, 1999, 1998; Babcock and Short 1996) or within Port Valdez (Salazar et al. 2002) to test for hydrocarbon concentrations. Planktonic-state mussels were also documented in tanker ballast water (Ruiz et al. 2000). Bishop et al. (1998) tested the feasibility of using predator enclosures to assess direct avian predator and sea otter effects on mussel density and size distribution. Only in the Babcock and Short (1996) and Bishop et al. (1998) studies was species identified (*Mytilus trossulus*); otherwise mussels were referred to as bivalves or gastropods (Ruiz et al. 2000), or simply as intertidal mussels.

Echinoderms

Echinoderms were documented in one study wherein the biota of ballast water from tankers arriving to Port Valdez was sampled (Ruiz et al. 2000). Species were not identified, but echinoderms in their planktonic form were among the top ten most abundant species groups in the samples.

Crustaceans

There were seven projects documenting crustacean presence in PWS during winter. In the aftermath of the oil spill, ADFG evaluated the impact of the spill on spot shrimp (*Pandalus platyceros*; Trowbridge 1992). Additionally, ADFG manages the sidestripe shrimp trawl fishery in PWS, which is open from April-August and October-December (Wessel et al. 2012). However, due to very low commercial participation, catch numbers are not readily available. ADFG also manages the Tanner and king crab fisheries (Rumble et al. 2014) and documents personal and subsistence harvest rates and patterns (ADFG 2008). Carls et al. (2016) collected spot (*P. platyceros*), coonstripe (*P. hypsinotis*), and pink shrimp (*P. borealis*) samples from Port Valdez to test for hydrocarbon concentration. Pacific glass shrimp (*Pasiphaea pacifica*) were documented as bycatch during trawls sampling for walleye pollock (Guttormsen and Jones 2010). Planktonic crustaceans were also noted in ballast water of tankers arriving to Port Valdez (Ruiz et al. 2000); species were not identified, but crustaceans were the second most abundant species group in the samples.

Fish

Fish were the most extensively studied species group, with 59 returned search results documenting 61 species. The majority of winter fish research focused on Pacific herring (*Clupea pallasii*), specifically overwinter survival of juvenile herring. Pacific herring have been studied extensively since 1993 when their populations crashed in PWS (Thorne and Thomas 2008; Carls et al. 2002). Research activities included surveying and sampling herring using a variety of techniques such as midwater trawls (Thorne 2010; Foy and Norcross 2001; Stokesbury et al. 2000; Sturdevant et al. 2001; Lewandoski and Bishop in review), gillnets (M. Bishop, PWSSC, on-going project), purse-seines (Thomas and Thorne 2003; Stokesbury et al. 2000; Willette et al. 1999), and cast-nets (M. Bishop, PWSSC, on-going project), acoustic surveys (Thorne 2010; Frid et al. 2007; Thomas and Thorne 2003; Thorne and Thomas 2002; Foy and Norcross 2001; Stokesbury et al. 2000; Willette et al. 1999; Kirsch and Thomas 1998, 1997; Thomas et al. 1995; K. Boswell, FIU, on-going project; P. Rand, PWSSC, on-going project), and aerial surveys (Thomas and Thorne 2003; Thorne and Thomas 2002). Herring were also captured as part of a validation study of the acoustic survey techniques (M. Bishop, PWSSC, on-going project). Herring were also tagged with acoustic transmitters and their movements detected with acoustic arrays (Eiler and Bishop 2016; Bishop 2015).

Herring samples have been collected and tested for disease (Hershberger et al. 2011; Marty et al. 2004). Researchers have also conducted energy content and diet analyses (Sturdevant et al. 2001; Foy and Paul 1999; Foy and Norcross 1999; J. Vollenweider, NOAA, on-going project), fatty acid analyses (R. Heintz, NOAA, on-going project), stable isotope analyses (Sewall et al. 2013; Kline and Campbell 2010; K. Gorman, PWSSC, on-going project), bomb calorimetry analyses (K. Gorman, PWSSC, on-going project), otolith microchemistry analyses (Otis et al. 2010; Otis and Heintz 2003), and genetic analyses (Wildes et al. 2011). The impact of upper trophic level predators on herring populations (Rice et al. 2011; Bishops and Powers 2013; Bishop et al. 2015) and ecosystem-level mechanisms influencing herring mortality (Cooney et al. 2001) have also been examined.

Walleye pollock (*Gadus chalcogrammus*) were documented in 15 studies. These studies involved hydroacoustic surveys (Guttormsen and Jones 2010; Frid et al. 2007; Thorne et al. 2002; Thomas and Thorne 2001; Stokesbury et al. 2000; Thorne and Thomas 2000; Kirsch and Thomas 1998, 1997; Thomas and Stables 1995; NOAA 1991) and aerial surveys (Thorne et al. 2002), and sampling using trawls, gillnets, seines, and longlines (Bishop and Powers 2013; Thomas and Thorne 2001; Stokesbury et al. 2000; Sturdevant et al. 2001; Bechtol 1999; NOAA 1991). Fish were sampled for gut content analysis (Bishop and Power 2013) and energy content analysis (Paul et al. 1998). ADFG manages the walleye pollock fishery, which is open from January until March, unless the catch limit is reached earlier. Since 1995, ADFG staff has conducted dockside sampling of pollock catches during the open season (Wessel et al. 2014).

Five studies documented lingcod (*Ophiodon elongates*) presence and movements during winter. From 2008 until 2010, Bishop et al. (2009, 2010) captured, acoustic-tagged, and tracked lingcod movements using an acoustic array. Lingcod were also captured for gut content analysis to evaluate the influence of predatory fish on herring populations (Bishop and Powers 2013). Additionally, ADFG manages the lingcod fishery in PWS, which is open from July-December. Since 2003, ADFG staff has performed dockside sampling of lingcod catches throughout the fishing season (Wessel et al. 2014) and documents recreational catches (Hochhalter et al. 2011).

Pacific cod (*Gadus microcephalus*) were documented in three studies. Cod were captured using pots and longlines and fitted with acoustic transmitters during the winters of 2013/14 and 2014/15. Their movements were monitored using acoustic arrays through May 2016 (Bishop

2015). Cod were also captured for gut content analyses to examine the effect of predatory fish on herring populations (Bishop and Powers 2013). ADFG manages the Pacific cod fishery in PWS, which is open all year round. Since 1994, dockside sampling of Pacific cod also has been conducted by ADFG throughout the entire winter period (Wessel et al. 2014).

Sharks and skates were included in six studies. Salmon sharks and Pacific sleeper sharks (*Somniosus pacificus*) were fitted with transmitters to study depth distribution, foraging ecology, and movement ecology (Carlisle et al. 2011; Frid et al. 2007; Hulbert et al. 2006; Hulbert et al. 2002) during winter. Big (*Raja binoculata*) and longnose skates (*R. rhina*) were also fitted with satellite tags to evaluate movement ecology of these species (T. Farrugia pers. comm). Gut contents from five species of skates (Big skates, longnose skates, Bering skates (*Bathyraja interrupta*), Aleutian skates (*Bathyraja aleutica*), and sandpaper skates (*Bathyraja kincaidii*) were also documented (Bishop and Powers 2013).

Pacific halibut (*Hippoglossus stenolepis*), spiny dogfish (*Squalus acanthias*), Chinook salmon (*Oncorhynchus tshawytscha*), yellowfin sole (*Limanda aspera*), and rockfish (*Sebastes* spp.) were documented as part of the study evaluating the impact of predatory fish on herring populations (Bishop and Powers 2013). Pacific halibut, Chinook salmon, and rockfish also were included in the ADFG Fishery Management Report for the Prince William Sound management area (Hochhalter et al. 2011). Sablefish (*Anoplopoma fimbria*) were tagged in March as part of an on-going study by ADFG that began 2011 (Wessel et al. 2014). Pink salmon (*Oncorhynchus gorbuscha*) were part of a study evaluating the influence of ecosystem-level mechanisms on mortality (Cooney et al. 2001). Bernard et al. (1995) conducted a mark-recapture survival study of individually marked Dolly Varden (*Salvelinus malma*). Finally, there were 46 other species documented as bycatch during trawl, gillnet, and longline surveys targeting other fish species (Appendix 2).

Birds

There were 43 studies documenting presence of 50 bird species in PWS during winter (See Appendix 2 for full list). Ship-based marine bird surveys, which were the dominant research activity (21 studies), have occurred relatively consistently since 1993. The majority of these surveys were conducted by the U.S. Fish and Wildlife Service (McKnight et al. 2008; Lance et al. 2001; Agler et al. 1998, 1997; Klosiewski and Laing 1994) and the Prince William Sound

Science Center (Bishop 2016, 2014; Bishop et al. 2015; Dawson et al. 2015; Bishop and Kuletz 2013, 2011), with additional surveys conducted by ABR, Inc. (Day 2006; Day et al. 1997, 1995) and researchers at Colorado State University (Wiens et al. 1996). These surveys documented all bird species encountered within a set strip-width from the survey vessel. Other projects focused on specific species, including marbled (*Brachyramphus marmoratus*) and Kittlitz's murrelets (*B. brevirostris*; Agler et al. 1998; Kendall and Agler 1998), harlequin duck (*Histrionicus histrionicus*; Rosenberg et al. 2005; Esler et al. 2000), Barrow's goldeneye (*Bucephala islandica*; Esler et al. 2000), and common murre (*Uria aalge*; Zuur et al. 2012; Piatt and Van Pelt 1997).

Levels of cytochrome P450 induction, which indicates oil exposure, were tested extensively in harlequin duck populations (Esler and Iverson 2010a, 2010b; Esler et al. 2010, 2002; Mulcahy and Esler 2010; Esler 2008; Trust et al. 2000; B. Ballachey, USGS, on-going project), and to a lesser degree, in Barrow's goldeneye populations (Esler et al. 2011; Trust et al. 2000).

Other research activities included tagging bald eagles (*Haliaeetus leucocephalus*), and harlequin ducks for survival analyses (Esler and Iverson 2010b; Esler et al. 2000; Bowman et al. 1995) and philopatry analysis (harlequin ducks only; Iverson and Esler 2006; Iverson et al. 2004), and satellite tagging of surf scoters (*Melanitta perspicillata*) and white-winged scoters (*M. fusca*; Rosenberg and Petrula 2001) and geolocator tagging of black-legged kittiwakes (*Rissa tridactyla*; McKnight et al. 2011) for movement analyses. Blood samples of harlequin ducks and Barrow's goldeneyes were surveyed for elements, antibodies, and hemoparasites (Heard et al. 2008), and also for genetic analyses (Lanctot et al. 1999). Foraging effort of marbled murrelets in Simpson Bay was observed (Morgan and Bishop 2011) and gulls were collected for diet analyses (Bishop et al. 1998). Finally, Paige and Wolfe (1997) and Fall and Zimpelman (2016) evaluated subsistence harvest of birds (including goldeneyes, mallards, mergansers, geese, and scoters) and bird eggs in communities surrounding Prince William Sound.

Mammals

Twenty-three studies documented presence and ecology of six marine mammal species in PWS: humpback whales (*Megaptera novaeangliae*), Dall's porpoise (*Phocoenoides dalli*), Steller sea lion (*Eumetopias jubatus*), harbor seal (*Phoca vitulina*), sea otter (*Enhydra lutris*), and river otter (*Lontra canadensis*).

There were seven studies documenting sea otter presence, distribution, survival, foraging ecology, and harvest during winter. From 1990-2006, the U.S. Fish and Wildlife Service conducts ship-based sea otter surveys every other year during March concurrent with their marine bird surveys (McKnight et al. 2008; Agler et al. 1997). From 1987-1990 and again from 1992-1994 survival of sea otter pups was estimated by monitoring pups associated with marked adults (Monnett and Rotterman 2000) and by marking and attaching radio-tags directly to sea otter pups (Ballachey et al. 2003). Bodkin et al. (2012) also radio-tagged sea otters, but attached archival time-depth recorders, as well, to evaluate sea otter foraging ecology. Reimer and Lipscomb (1998) noted an instance of cancer and viral infection a free-living sea otter. Finally, Fall and Zimpelman (2016) evaluated subsistence harvest of sea otters by residents of Chenega Bay and Cordova.

Harbor seals were documented in seven studies, four of which focused on diving behavior and movement ecology. Satellite-linked depth recorders were attached to adult and juvenile seals for analysis of diving behavior in PWS (Frost et al. 2001) and to evaluate regional differences in diving behavior of seals across the Gulf of Alaska (Hastings et al. 2004). Adults, juveniles, and pups were also fitted with satellite transmitters for a study of harbor seal movement in PWS (Lowry et al. 2006; Small 2005). Frid et al. (2007) conducted focal follows of seals to understand how individuals perceive the relative danger imposed by predators. Finally, Wolfe et al. (2009) and Fall and Zimpelman (2015) documented subsistence harvest of harbor seals by Alaska Natives.

Three studies focused on humpback whales. Research has included ship-based surveys and focal follows of individual whales to estimate predation rates by whales on Pacific herring (Rice et al. 2011; J. Straley, UAS-Sitka, on-going project). During focal follows, researchers also capture photographs of whale flukes, which are used to identify individual whales, and estimate adult survival rates (Mizroch et al. 2004).

Steller sea lions were the focus of five projects which were primarily centered on movement and foraging ecology. Pups and juvenile Steller sea lions were fitted with satellite tags and satellite-linked time at depth recorders to understand foraging decisions, movement patterns, and distribution (Frid et al. 2009, Raum-Suryan et al. 2004). Thomas and Thorne (2001) used infrared imaging to observe night-time predation of sea lions on Pacific herring. Thorne et al.

(2002) used a combination of aerial and hydroacoustic surveys to examine the interactions between sea lions, walleye pollock, and Pacific Herring. Finally, Wolfe et al. (2009) documented subsistence harvest of sea lions by Alaska Natives.

River otters were documented in three studies. From 1997-1998, Blundell et al. (2002) radio-tracked otters year-round from boats and fixed-wing aircrafts to examine social behaviors, such as cooperative foraging. We also found a paper synthesizing the results of research evaluating the impact of the Exxon Valdez oil spill on river otters (Bowyer et al. 2003). Finally, Fall and Zimpelman (2015) documented subsistence harvest of river otters in communities surrounding PWS.

There was one project documenting Dall's porpoise in PWS during winter months. This project involved ship-based surveys from 2007-2015 during November-January and March (J. Moran, NOAA, on-going project).

Discussion

As the search results demonstrate, PWS provides extensive protected habitat for wildlife during the winter months, which must be considered when planning management activities, such as response to natural or anthropogenic perturbations or damage assessments arising from perturbations. The bibliographic search returned studies including zooplankton, mollusks, echinoderms, crustaceans, fish, birds, and mammals (Table 2; Appendix 1, Appendix 2). We were unable to find any studies documenting sea cucumbers, sea urchins, jellyfish, octopus, and several marine mammal species in PWS during winter. The only documentation of squid presence was as bycatch during a walleye pollock trawl survey (Guttormsen and Jones 2010).

As a result of funding by the Exxon Valdez Oil Spill Trustee Council for long term monitoring, there is relatively consistent spatial and temporal coverage of zooplankton documentation since 2009 (Campbell 2013). There also has been extensive documentation of the marine birds occurring in PWS during winter months since the oil spill. From 1990-2006 surveys were conducted only during March. Since 2007 surveys have occurred during all winter months at least once, and spatial coverage in pelagic waters outside of bays and passages has expanded. Fish have been researched extensively in PWS, as well, particularly Pacific herring. Following the oil spill, the herring population in PWS crashed and has not yet recovered (Wiese 2015;

EVOS 2010). Due to the role of Pacific herring as a keystone species and its economic impact on commercial fisheries and coastal communities, the Exxon Valdez Oil Spill Trustee Council developed the Integrated Herring Restoration Program, aimed at determining the factors contributing to the herring population decline and identifying potential recovery actions. This program has since developed into the Herring Research and Monitoring Program which continues to evaluate causes of the population decline, and monitor recruitment, trend, and disease.

Fish populations are notoriously difficult to quantify over large spatial and temporal scales. However, considerable effort has been devoted to surveying herring and walleye pollock populations in PWS using acoustic, aerial, and trawl surveys. Documentation is much less complete for other fish species during winter, such as capelin, sharks, skates, salmon, flatfish, and other groundfish species such as sablefish and Pacific cod. However, ADFG provides annual finfish and groundfish management reports which documents catch numbers for each fishery (Wiese et al. 2015; Wessel et al. 2014).

We found 23 studies documenting the presence, distribution, relative abundance, foraging ecology, and movement ecology of six marine mammal species. However, work on Dall's porpoise was very limited (one study in progress, J. Moran, NOAA), and we could find no documentation of orca (*Orcinus orca*), harbor porpoise (*Phocoena phocoena*), or whale species other than humpback, although these species are known to occur in PWS throughout the year. For example, orca and harbor porpoise are seen during winter humpback whale (J. Moran, NOAA, pers. comm) and marine bird surveys (M. Bishop, PWSSC, pers. comm), but are not included in subsequent reports or publications.

Documentation was extremely limited for invertebrate species, particularly mollusks and echinoderms. Mollusk research primarily consisted of sampling for hydrocarbon concentrations, with most of the sampling occurring during March. Echinoderms were documented in a single study evaluating the biotic contents of ballast water (Ruiz et al. 2000). Therefore, we lack information regarding relative abundance, distribution, or species richness and how these metrics vary within or among years for each species group. Documentation of crustaceans in PWS during winter was limited, as well. Of the seven studies we found, five shrimp species and two crab species were noted. However, ADFG conducts an annual spot shrimp survey during the

month of October. Echinoderms, crabs, octopus, other shrimp species, and fish are routinely caught as by-catch and identified to the lowest taxonomic unit possible. We do not present the results of those surveys here, as October is outside the scope of this paper.

The species list included with the bibliography is by no means a comprehensive report of all species present in PWS during winter. Additional information regarding invertebrate and fish species that may be present in PWS during winter can be found in the following field guides: invertebrates and fish- Baldwin (2013), Byersdorfer and Watson (2010), Jorgensen (2009), Kramer et al. (2008), Stevenson et al. (2007), Gotshall (2005), Kramer and O'Connell (2003), O'Clair and O'Clair (1998), and Ricketts and Calvin (1939); and marine mammals- Wynne (2012).

It is probable that other research documenting the presence of winter species has been conducted in PWS. Studies may have been excluded because reports and publications were not available online or the scope of our search terms may have been too narrow. However, we tried to reduce the chances of missing available research by using multiple search platforms and databases, and by contacting researchers and agencies directly.

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Table 1: The data categories and definitions for the bibliography of winter species in Prince William Sound, Alaska.

Data Category	Definition
ID	Identification number of each unique citation*
Last Name	Surname of lead author
First Name	Forename of lead author
Agency/Institution	Agency/company affiliation of lead author
Other Collaborators	Fore/surnames of co-author(s)
Taxon	Taxonomic grouping of study specie(s)
Scientific Names	Binomial name of study specie(s)
Common Names	Common name of study specie(s)
Years	Year(s) in which research occurred
Winter Months	Winter month(s) (November-March) in which research occurred
Project Months	All months in which research occurred in Prince William Sound
Location	Prince William Sound (PWS), unless more specific project locations given
Status	Complete or Ongoing
Final Product Type	Final Report NA: Ongoing project Publication: peer-reviewed scientific publication Report
Final Product Citation	Citation for the final product. If final product not available, lists project name.
Notes	Brief note summarizing project

*Note: There are repeated identification numbers for studies with more than one entry.

Table 2: Search results of the number of studies that have occurred in Prince William Sound, Alaska during winter for each taxonomic group/species since 1989. Only focal study species are listed below. See Appendix 2 for list of species observed as bycatch and for list of avian species observed during marine bird surveys.

Taxonomic Grouping	Species Common Name(s)	Number of Studies
Zooplankton	NA	5
Mollusks	Blue Mussels	14
Echinoderms	NA	1
Crustaceans	Spot Shrimp, Coonstripe Shrimp, Pink Shrimp, Sidedstriped Shrimp, Pacific Glass Shrimp	5
	Tanner Crab, King Crab	2
	Pacific Herring	35
Fish	Walleye Pollock	15
	Lingcod	5
	Pacific cod	3
	Salmon Shark	2
	Pacific Sleeper Shark	2
	Pacific Halibut, Chinook Salmon, Rockfish	2
	Other (Big and Longnose Skates, Dolly Varden, Spiny Dogfish, Pink Salmon, Yellowfin Sole, Sablefish)	1 each
	Harlequin Ducks	15
	Marine Birds**	14
Birds	Barrow's Goldeneye	4
	Marbled Murrelet	2
	Kittlitz's Murrelet	2
	Common Murre	2
	Other (Black-legged Kittiwake, Scoters, Bald Eagles, Glaucous-winged Gulls, Mallard, Canada Geese, Cackling Geese, Snow Geese, Mergansers)	1 each
	Sea Otters	7
Mammals	Harbor Seals	7
	Steller Sea Lions	5
	Humpback Whales	3
	River Otters	3
	Dall's Porpoise	1

**See Appendix 2 for list of bird species observed during marine bird surveys.

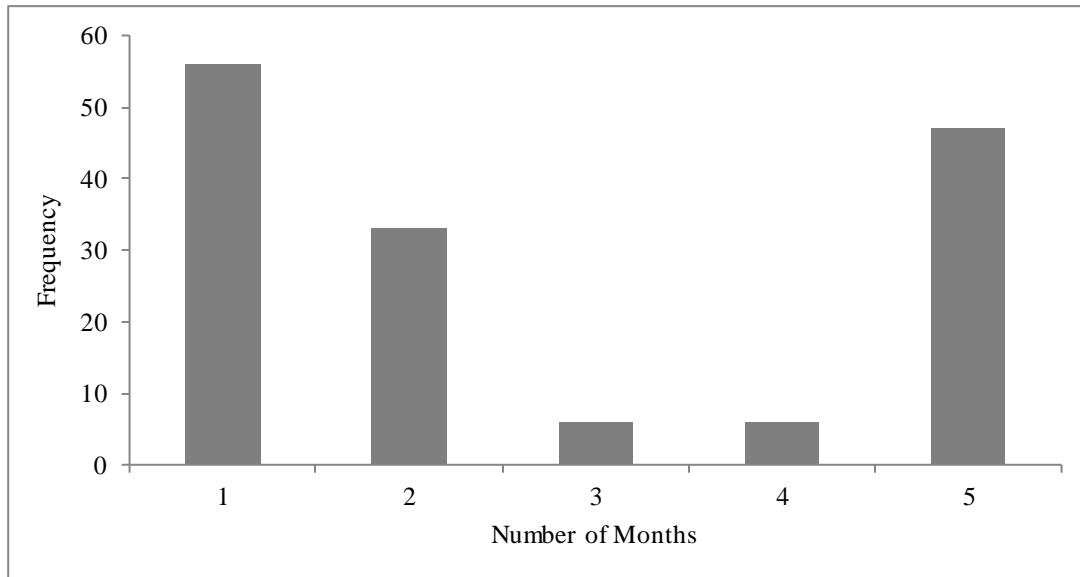


Figure 1. Duration of research activities by month. Most studies occurred either within a single winter month or throughout the entire winter period.

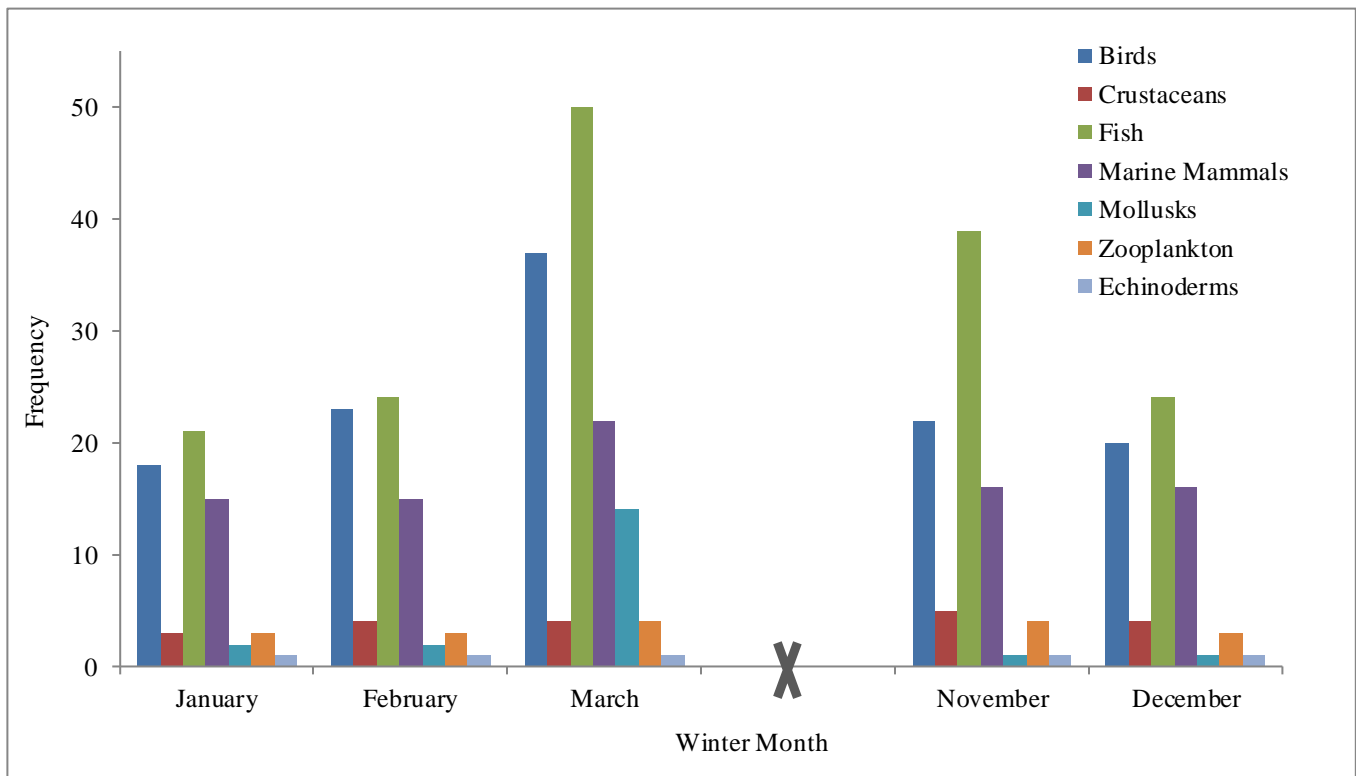


Figure 2. Months in which species groups were studied. March was the month in which the highest number of research activities occurred for all taxa except for crustaceans.