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Fishes and Invertebrates in Gulf of Alaska Bays and Islands: Results From Inshore Ecosystem Surveys in 2011 and 2013

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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Abstract

This report provides a comprehensive summary of the inshore ecosystem surveys conducted during 2011 and 2013 as part of the Gulf of Alaska's (GOA) Integrated Ecosystem Research Program (IERP). The GOAIERP was a large interdisciplinary project with the goal to understand how the GOA environment influences the early survival of juvenile fishes. An essential element of this program was synoptic surveying of inshore and offshore areas in different years and seasons. The work described here addressed the inshore research. Comprehensive fish and invertebrate surveys, as well as oceanographic sampling, were conducted at 11 inshore sites in 2011 and 2013. Two of the sites were islands or island archipelagos and the remainder were embayments of various sizes. Sites were selected based in part on the overall GOAIERP research design that was structured as a comparative study between regions in the eastern and central GOA. Sites were chosen to be representative of the inshore environment of each study region and also to allow comparisons between regions. Surveys were conducted in spring, summer, and fall although fall sampling was limited in both years due to weather and the 2013 shutdown of the federal government. Sampling platforms included a medium-sized chartered vessel in each region equipped for inshore fish sampling and oceanographic work. A 16-ft inflatable skiff was used for nearshore work. Fish sampling was primarily achieved using acoustic surveys and nearshore seine sampling, although small bottom and surface trawls were also conducted. Oceanographic sampling was performed in the nearshore and in the wider inshore waters. Nearshore vegetated habitats included eelgrass and kelps, and most sites had at least some of each habitat type. Seasonal patterns of temperature and salinity were similar among sites, with warming and freshening of waters during summer. Summer temperatures were similar across sites, but protected bays generally had lower salinities. Acoustic backscatter attributed to either fish or zooplankton based on frequency differences varied substantially among sites, years, and seasons. Fish and zooplankton backscatter increased with bottom depth. Fishes were more abundant in 2013, while zooplankton were more abundant in 2011. Sampling of echosign was limited but typically produced catches of Pacific herring *Clupea pallasii*, walleye pollock *Gadus chalcogrammus*, and *Sebastes* species. Nearshore fish communities were also variable but some common trends were evident. Saffron cod *Eleginus gracilis* were found only at the central GOA sites, while shiner perch *Cymatogaster aggregata* occurred only in the east. At most sites there was a strong seasonal pattern in the abundance and composition of nearshore fish species, driven mainly by the appearance of age-0 Pacific cod *Gadus macrocephalus*, saffron cod, walleye pollock, and *Hexagrammos* species during the summer. Length data revealed seasonal patterns in the growth of these juvenile fishes and suggested the possibility of different seasonal cohorts for some species. In general, attributes of individual sites appeared to be more important than broad-scale regional differences. The surveys provided substantial evidence for the importance of inshore areas as refuges for fish, particularly early juveniles.

Contents

Introduction

The surveys described in this document were conducted as part of the Gulf of Alaska (GOA) Integrated Ecosystem Research Program (IERP). The GOAIERP was initiated and largely funded by the North Pacific Research Board to provide a multifaceted, interdisciplinary exploration of the GOA ecosystem and its responses to environmental variation. The program was structured around elucidating factors that influence the early life survival of 5 abundant groundfish species that have commercial value: Pacific cod *Gadus macrocephalus*, walleye pollock *Gadus chalcogrammus*, arrowtooth flounder *Atheresthes stomias*, sablefish *Anoplopoma fimbria*, and Pacific ocean perch *Sebastes alutus*. Spatial variation was a key theme of the GOAIERP, and fieldwork was designed around two study areas in the eastern and central GOA. The GOAIERP research was divided among four components. Three of the components related to trophic level: the Lower Trophic Level (LTL) group studied physical processes as well as primary and secondary producers; the Middle Trophic Level (MTL) focused on forage fishes and inshore processes; and the Upper Trophic Level (UTL) investigated early life stages of the focal fish species, habitat associations, and seabird ecology. A modeling component produced linked physical and biological models that mirrored the processes investigated by the three field components. The research described in this document was conducted as part of the MTL component.

Although it originally focused mainly on the forage base in the GOA, during the process of integrating the program's various research objectives the MTL evolved to include the study of inshore processes (see the end of this section for definitions of the inshore and other areas). The impetus for this decision was the importance of the inshore environment as a potential refuge for juvenile fishes, particularly the GOAIERP focal species. Many inshore areas, including estuaries, small bays, and ocean coastlines, have abundant juvenile fishes and are thought to serve as nursery grounds that have higher juvenile survival than other areas (Blaber et al. 1995, Paterson and Whitfield 2000, Able 2005, Able et al. 2006). This may be due to common features of the inshore including the availability of structured habitat (particularly nearshore vegetation) that reduces predation risk, favorable environmental conditions (e.g., optimal water temperatures), and high productivity and food availability. Inshore areas also provide spawning habitat for adult forage fishes in the GOA such as capelin *Mallotus villosus* (Doyle et al. 2002) and Pacific herring *Clupea pallasii* (Norcross et al. 2001). Because the environment of the inshore often differs from the adjacent open ocean, bays may also serve as a refuge when ocean conditions are suboptimal (Arimitsu et al. 2008).

In the GOA, juvenile fishes use the inshore to a high degree. The Nearshore Fish Atlas (Johnson et al. 2012; https://alaskafisheries.noaa.gov/habitat/fishatlas) contains the records of 14 years of nearshore beach-seining activity throughout Alaska waters. Juveniles of many fish species occurred frequently in nearshore habitats, including members of the Pleuronectidae (flatfishes) and Gadidae (cods) as well as young salmon (*Oncorhynchus* spp.). Inshore trawling studies revealed the ubiquity of juvenile flatfishes in the inshore of the central GOA and demonstrated their preference for inshore habitats (Norcross et al. 1995). Juvenile Pacific cod, particularly young of the year, appear to prefer nearshore habitats (Abookire et al. 2007, Laurel et al. 2007), and juvenile Pacific herring and Pacific sand lance *Ammodytes personatus* are also abundant inshore residents (Robards et al. 1999, Abookire et al. 2000, Johnson et al. 2012). The nearshore areas of the inshore GOA are abundant in eelgrass *Zostera marina*, kelps *Laminaria* spp., and other types of vegetation that provide habitat for small fishes

The goal of this study was to conduct comprehensive surveys of 11 inshore sites in the GOA during different seasons and years. Specifically, our objectives were to

1) Describe large-scale patterns in the abundance and distribution of inshore fishes and zooplankton at representative sites in the GOA.
2) Determine spatial patterns in the abundance and distribution of nearshore marine fish communities.
3) Measure seasonal and interannual changes in the abundance and taxonomic composition of nearshore fish communities.
4) Describe structural and oceanographic habitat features of representative inshore sites.
5) Collect samples to describe diets, growth, and nutritional condition of inshore fishes.

A Note on Terminology: The terms used to describe geographic areas in marine ecosystems, as well as regions of the GOA, can be confusing. Here, we use offshore, inshore, and nearshore to define the areas under study. *Offshore* refers to open ocean waters of the shelf and basin, or in other words, any open waters outside of embayments. *Inshore* means the various embayments. The *nearshore* is the inner zone of the inshore, generally intertidal and upper subtidal waters <10 m depth that have the potential for abundant submerged vegetation. Fishery scientists working in Alaska commonly refer to three main regions of the GOA delineated by relevant statistical areas used by the National Marine Fisheries Service (NMFS): western (NMFS area 610), central (NMFS areas 620 and 630), and eastern (NMFS areas 640 and 650). These NMFS designations differ slightly from those used in the present study. Throughout this document we refer to the *western* GOAIERP study region (WGSR, located in the NMFS central GOA regulatory area) and the *eastern* GOAIERP study region (EGSR, located in the NMFS eastern GOA regulatory area) (Fig. 1). All results throughout the document are presented from the west to east study region

Materials and Methods

Survey Design: Study Area and Timing

Overview

During 2011 and 2013 the GOAIERP nearshore survey sampled 11 diverse sites distributed across the northern GOA. Six sites were in the eastern GOAIERP study region (EGSR; located in the NMFS eastern GOA regulatory area, EGOA) and five in the western GOAIERP study region (WGSR; located in the NMFS central GOA regulatory area, CGOA) region[1] (Fig. 1 and Table 1). Sampling sites and survey timing were chosen based on the overall GOAIERP research objectives and design. When the sites were selected in 2010, little quantitative data existed to describe their physical characteristics, but during the GOAIERP a research team used high-resolution bathymetry and a geographic information system (GIS) to produce descriptive metrics of bay attributes (e.g., surface area, watershed size; Zimmerman et al. 2016). This work provided us with a better means of comparing sites *post hoc* and allowed us to assign each site to one of five groups based solely on physical attributes: EGSR small bays, EGSR large bays, WGSR medium bays, WGSR very large bays (containing only Aialik Bay, which was unique in our surveys), and islands (Table 1).

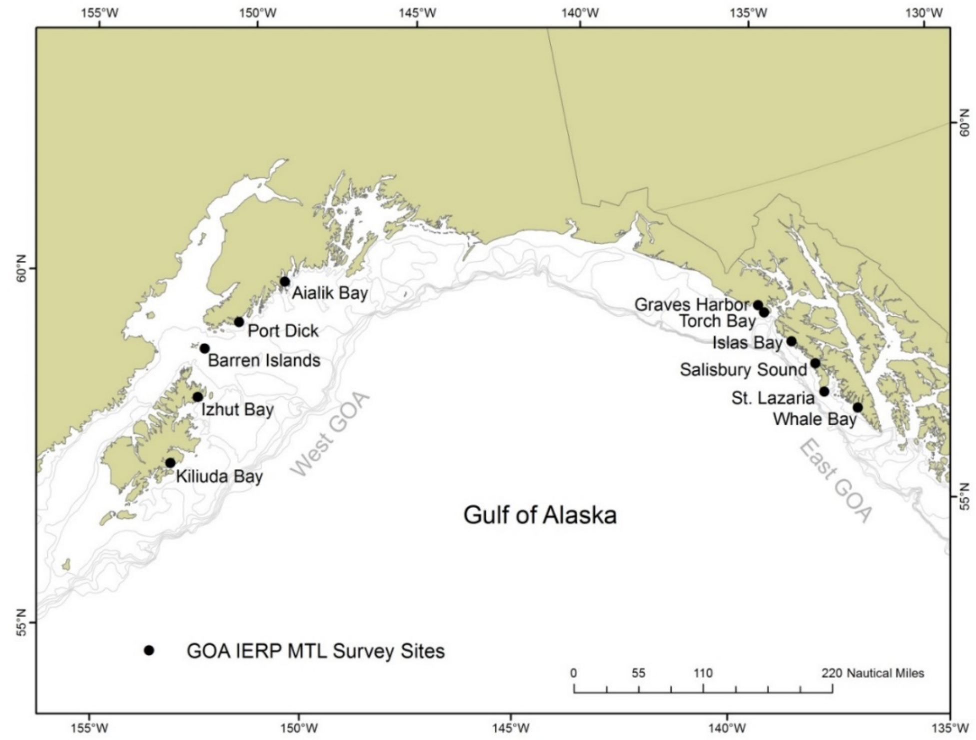

Figure 1. -- Gulf of Alaska (GOA) sites sampled by the 2011 and 2013 GOAIERP inshore surveys.

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[1] The multidisciplinary nature of the GOAIERP caused some confusion over the naming of study areas, mainly regarding the establishment of a “western” study region that is located in the part of the GOA that NMFS regards as the central GOA regulatory area (CGOA), which is located west of Kodiak Island. To conform with the overall GOAIERP project the east/west division and resulting acronyms are used throughout this document rather than EGOA/CGOA.

Table 1. -- Approximate locations, group assignments, and physical attribute data for the 11 sites visited by the 2011 and 2013 GOAIERP nearshore surveys. Attribute data are from Zimmerman et al. (2016).

Group	Site	Approx. latitude (°N)	Approx. longitude (°W)	Water surface area (km^2)	Mean bottom depth (m)	Maximum bottom depth (m)	Water volume (km^3)	Shoreline length (km)	Watershed area (km^2)
East small	Islas Bay	57.808	136.384	7.3	22	95	0.2	43.9	44
	Torch Bay	58.322	136.808	7.5	36	102	0.3	26.5	19
	Graves Harbor	58.284	136.736	12.6	47	144	0.6	39.3	35
East large	Whale Bay	56.655	134.951	71.5	81	364	5.9	163.7	394
	Salisbury Sound	57.332	135.696	70.2	80	273	5.8	136.3	153
West medium	Port Dick	59.279	151.133	64.4	100	291	6.8	104.5	329
	Izhut Bay	58.205	152.266	89.5	69	220	6.5	112.9	244
	Kiliuda Bay	57.308	153.048	93.5	47	106	4.6	95.6	460
Aialik	Aialik Bay	59.775	149.657	239.1	141	303	34.4	226.5	594
Islands	Saint Lazaria	56.98	135.702	-	-	-	-	-	-
	Barren Islands	58.948	152.159	-	-	-	-	-	-

Site Selection Criteria

Site selection was heavily influenced by one of the central GOAIERP hypotheses that focused on a comparison between the eastern and western study regions, but other factors were also important:

1) Sites representative of the main study regions: The most important criterion that guided site selection was that they represent each study region, both in terms of covering the spatial extent of each region's coastline as well as representing the types of nearshore sites that exist in each region. Because the WGSR was bigger, the nearshore sites in that region were farther apart. Sites were as representative of each region as was possible given the additional considerations listed below.
2) One island/bird rookery site in each region: To foster integration with the UTL component of the GOAIERP, one nearshore site in each region was devoted to surveys near seabird rookeries being studied by the UTL GOAIERP research team for bird diets and reproductive success.
3) Match bay and habitat types between the east/west areas: Because the east/west comparison was a core part of the GOAIERP, we matched types of bays between the regions to the extent that was possible. This effort was limited by the lack of similarity among bays on each side (e.g., there was no complement to Aialik Bay in the EGSR). A further restriction was that some complementary sites were not suitable for

sampling. For example, Chugach Bay in the WGSR had been selected as a complement to Islas Bay in the east until the 2010 pilot work indicated that Chugach Bay was so exposed that sampling there would be likely disrupted by weather (see below).

4) Accessibility and sampling effort: Two logistical considerations also shaped the selection of sites. We surveyed during spring, summer, and fall, so the ability to reliably access sites and conduct sampling in those seasons was important. While no site was accessible in all weather, there were some (e.g., Shelikof Bay in the EGSR) that were considered too exposed to be included. An additional logistical constraint was the amount of surveying time available in each season (approximately 15 days per region per season).
5) Although the selected sites were not exhaustive in their representation of each region, 5 or 6 sites was the maximum we felt could be visited during a survey while still achieving an appropriate level of sampling effort at each site.
6) Availability of historical data: An original objective of the MTL group was to compare results of the current nearshore surveys to historical work in the same areas. As that effort progressed it became clear that the historical data were insufficient to make such comparisons, but during site selection those bays which had historical data were preferred. For example, one factor in choosing Kiliuda Bay and Izhut Bay is that they were both the site of ecological research in the 1970s (OCSEAP 1976).

Survey Timing

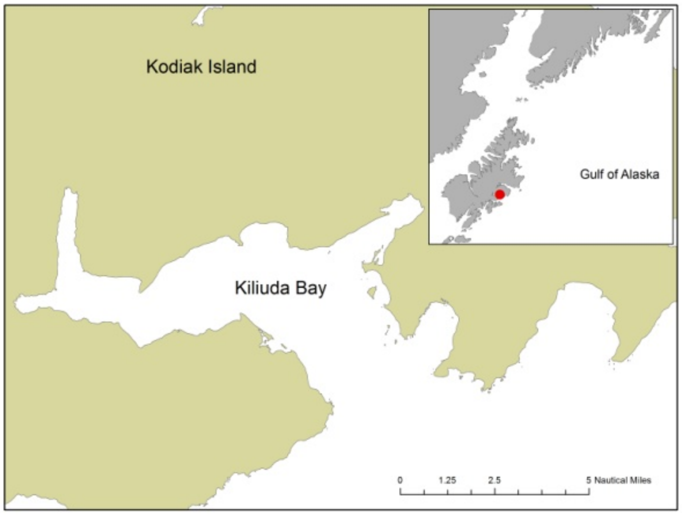
As was the case with site selection, survey timing balanced project objectives and logistical concerns. The surveys were conducted in three seasons to match the fieldwork conducted by the UTL and LTL groups: spring (March/April), summer (July/August), and fall (September/October; Table 2). The EGSR and WGSR were sampled sequentially, beginning in the east. Approximately one week separated the regional surveys in each season to allow for shipping of gear between regions.

Table 2. -- The dates of the surveys by area, season, and year. Survey legs with an asterisk denotes a shortened survey due to the government shutdown in 2013.

East Gulf of Alaska (staged from Juneau) (EGSR)	**West Gulf of Alaska (staged from Kodiak) (WGSR)**
April 13 – April 30, 2011 (Spring)	May 5 – May 19, 2011 (Spring)
July 6 – July 20, 2011 (Summer)	August 2 – August 17, 2011 (Summer)
September 19 – October 4, 2011 (Fall)	October 13 – October 28, 2011 (Fall)
April 16 – April 30, 2013 (Spring)	May 9 – May 23, 2013 (Spring)
July 23 – August 6, 2013 (Summer)	August 13 – August 27, 2013 (Summer)
*September 23 – September 28, 2013 (Fall)	*November 2 – November 11, 2013 (Fall)

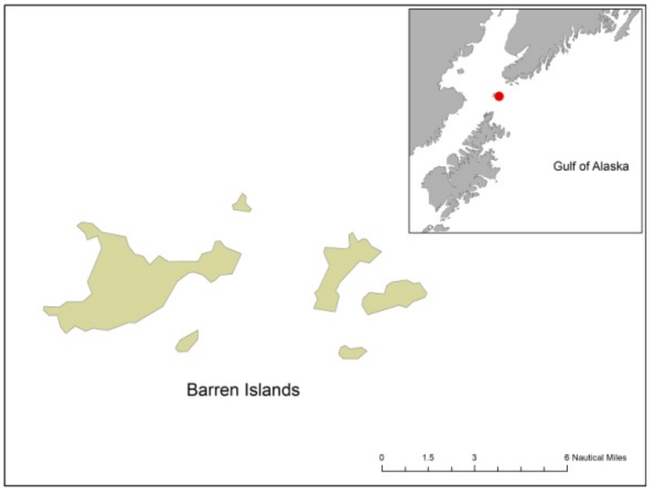
Sampling Bay Maps and Site Descriptions

The sampling sites possessed some similarities but also many unique features, which are described below and in Table 1. The sites are presented in order from west to east (see Fig. 1 for overview). Sites varied in size so scale bars are different in each map; the inset maps show the location of the site in the study region.

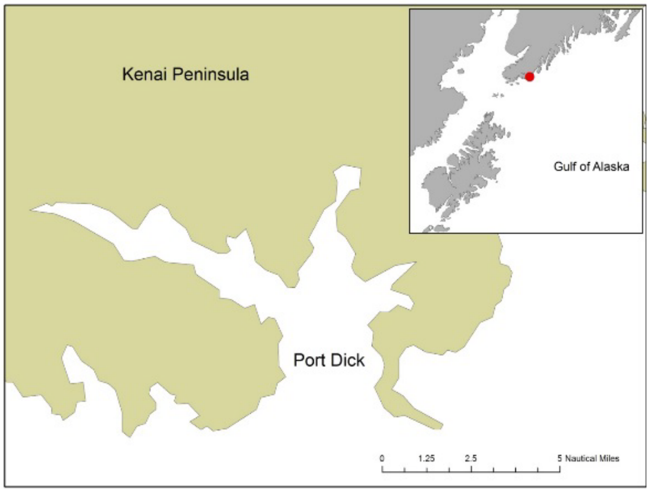


Kiliuda Bay: The southernmost site in the WGSR, Kiliuda Bay is characterized by relatively shallow water depths and substantial physical and biological heterogeneity within the bay. A sill separates the inner part of the bay from the outer sections and appears to limit the exchange of water in the bay. Kiliuda Bay has substantial nearshore vegetated habitat; the inner bay is dominated by eelgrass while the outer sections are mainly bottom and canopy kelps. There are also numerous gravel and sand beaches.

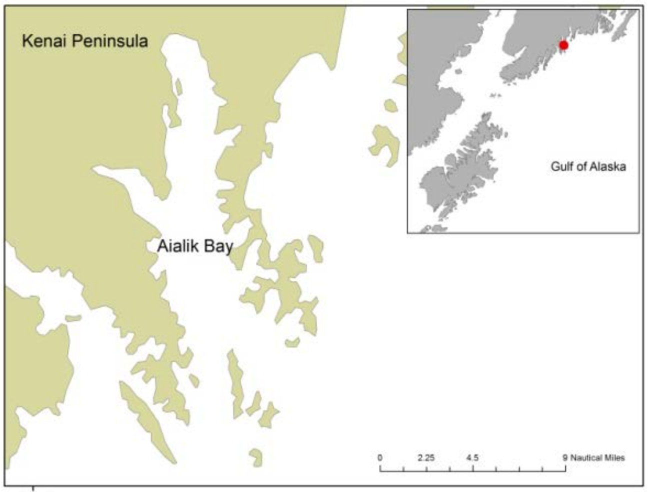
Izhut Bay: Located on Afognak Island (immediately north of Kodiak Island), this is a relatively open site with a deep central section and multiple smaller embayments along its shoreline. Two of these embayments, Kitoi and Saposa Bays, are particularly sheltered and a salmon hatchery is located in Kitoi Bay. The nearshore habitat includes eelgrass, kelps, and gravel beaches.



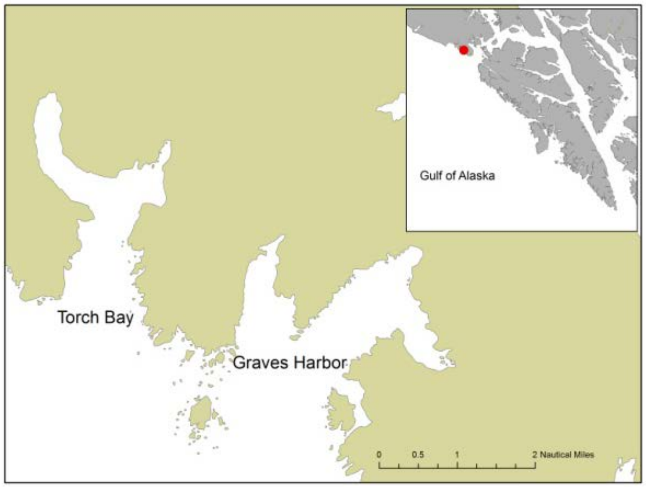
Barren Islands: These islands are located between the Kodiak Archipelago and the Kenai Peninsula mainland. The waters surrounding the Barren Islands are highly productive and support large concentrations of predators. One of the islands, East Amatuli, is a major seabird breeding ground that is monitored by the U.S. Fish and Wildlife Service (USFWS). The most abundant species are fork-tailed storm-petrels *Oceanodroma furcata*, black-legged kittiwakes *Rissa tridactyla*, glaucous-winged gulls *Larus glaucescens*, and tufted puffins *Fratercula cirrhata*. There is also a Steller sea lion *Eumetopias jubatus* rookery on Sugarloaf Island.



Port Dick: This site is located on the southern tip of the Kenai Peninsula. It has three main areas: the West Arm, with extensive eelgrass beds along its northern shoreline; Taylor Bay, which has a tidal flat at its head and areas of eelgrass and kelps; and Sunday Harbor/Takoma Cove, rocky inlets with patches of eelgrass at their heads. The Port Dick watershed drains a small part of the Grewingk-Yalik Glacier Complex, a large ancient icefield on the southern Kenai Peninsula, suggesting that Port Dick has some glacial influence.



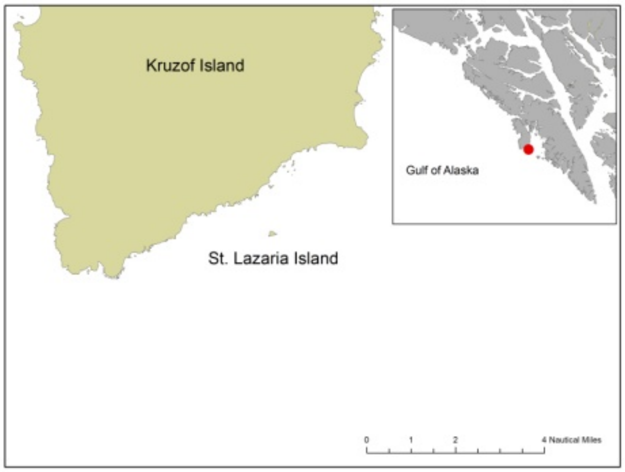
Aialik Bay: This site is a huge, deep, glaciated fjord with three tidewater glaciers. The shoreline is generally very steep with only occasional patches of nearshore kelps. Shallow areas with vegetated habitats occur mainly in the northern end of the bay, especially north of the sill (near the words "Aialik Bay"). Aialik Bay is one of several similar fjords occurring on the southern coast of the Kenai Peninsula.



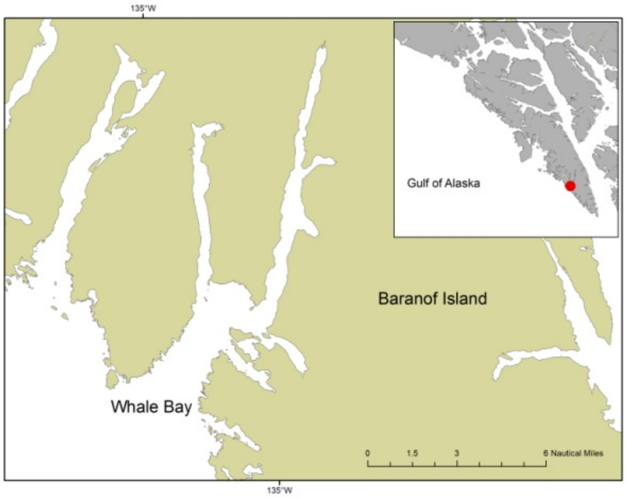
Torch Bay/Graves Harbor: These two sites are very close to each other and for some aspects of the project were considered as a single site. The bays are located immediately north of Cross Sound, a highly productive area and a research focus of the GOAIERP. Nearshore areas in Torch Bay consist mainly of gravel beaches, with small areas of kelps and eelgrass. Graves Harbor was much more diverse with large areas of kelp, sand and gravel beaches, and small patches of eelgrass.

Islas Bay: This site is located south of Cross Sound on the outer coast of Chichagof Island. The bay is relatively shallow and most of the site is open and exposed with some canopy kelps. The inner areas of the site (Porcupine and Ilin Bays) are more sheltered and contain eelgrass beds in addition to areas of kelp.

Salisbury Sound: Of the nine embayments included in the nearshore survey, this was the only site that was not a closed system: the sound connects to inside waters of Southeast Alaska through Peril Strait and to Sitka Sound via Neva Strait. Otherwise Salisbury Sound possesses many of the same features as the other sites including small coves with nearshore kelp patches, some eelgrass, and sand and gravel beaches. There is a strong gradient of diminishing ocean influence towards the inner parts of the sound (St. John Baptist Bay).



St. Lazaria Island: This is the other seabird-associated sampling site and consists of one small island with a high density of breeding seabirds including fork-tailed storm petrels, rhinoceros auklets *Cerorhinca monocerata*, murres (*Uria* spp.), and cormorants *Phalacrocorax pelagicus*. St. Lazaria is located in highly productive Sitka Sound.



Whale Bay: The southernmost site in the eastern region, Whale Bay consists of two main areas: the Great and Small Arms, which are narrow inlets withsteep, rocky shores and shallow, vegetated (eelgrass and kelps) areas at their heads; and the Kritoi Basin area which is characterized by flatter shorelines, protected coves, and a variety of kelp and sand/gravel habitats.

Sampling Subarea Maps and Descriptions

For the purposes of the nearshore sampling (purse seine and beach seine), subareas were identified within each of the bay sampling sites (with the exception of the island sites, St. Lazaria and the Barren Islands). Similar to the sites themselves the subareas were delineated according to several criteria.

Subareas were chosen to represent the major vegetated habitat types available in each bay. Not every habitat type occurred in each bay in suffficent abundance to be considered a major habitat type; for example in many places small patches of eelgrass occurred along shorelines but did not constitute extensive habitat areas. Subareas were also chosen to represent the full spatial extent of each bay, regardless of habitat type.

The nature of the subarea divisions varied among sites, particularly regarding spatial scale. Seine hauls within subareas were consistently close to each other (within ~ 1 km), but the distance between subareas was variable. In the larger bays such as Kiliuda Bay and Port Dick, subareas were typically located ~ 10 km apart. In small bays such as Islas Bay and Graves Harbor, subareas were separated by only 1-2 km. How this might affect interpretation of subarea-based fish and oceanography data is unclear, but it is likely that variation among subareas is lower in smaller bays. However this is also affected by the physical structure of each bay. For example, in Islas Bay distances are small but the Fjordselheim site is much more exposed than the other subareas. This is reflected in the lower salinities in the inner subareas.

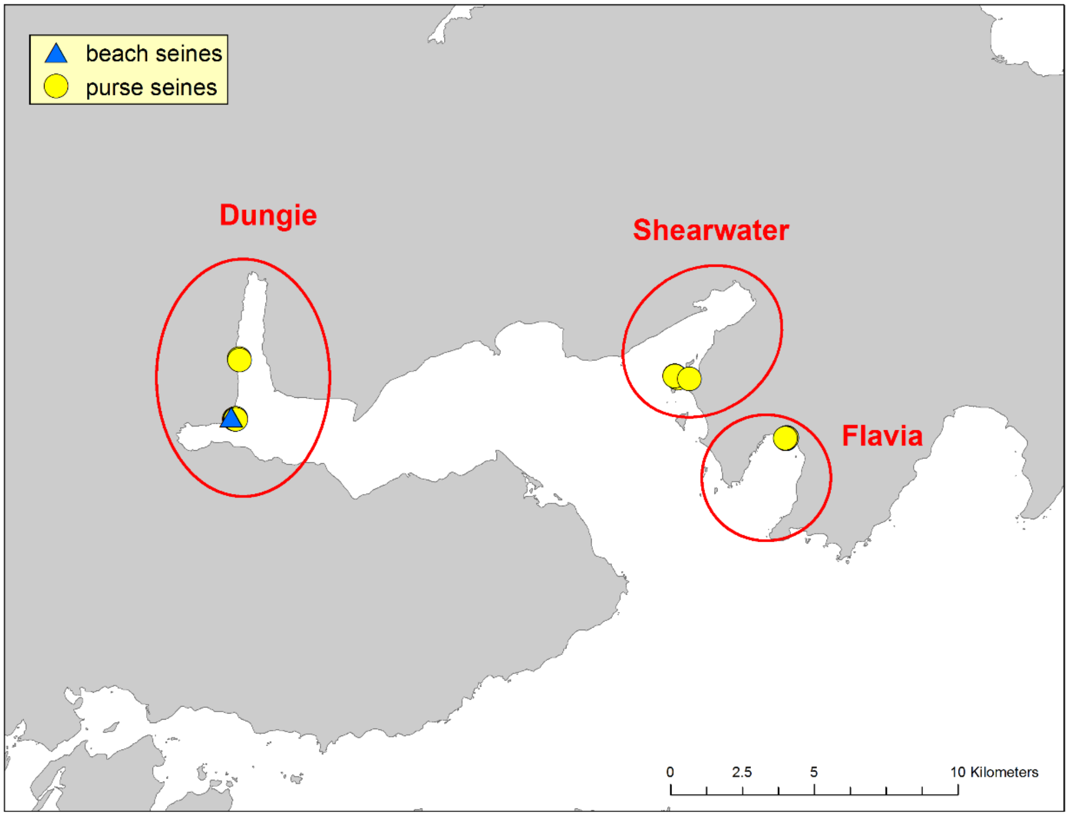
The subarea information on the following pages follows an identical format for each bay and includes basic habitat summaries such as temperature, salinity, and percent habitat cover. We present results in this section to aid in characterinzing the subareas. Each subarea is described in the following way:

- A map showing the names and boundaries of the subareas in each bay. The map also indicates the locations of seine sets. Only the seining locations that were repeatedly sampled are shown; therefore the maps do not reflect all of the seine sets.

- A habitat table with the relative distribution of habitat types that were sampled within each subarea. The proportions are based on the number of hauls conducted in each habitat type. As a result the data are not reflective of all habitat types in each subarea and do not necessarily indicate the true spatial extent of each habitat. In general the proportions are relative indicators of the vegetated habitats available to fishes in each subarea. For example the nearshore habitat in the Dungie subarea of Kiliuda Bay was almost completely dominated by eelgrass whereas the Flavia subarea consisted exclusively of kelp habitats. In each of those subareas there were extensive areas of gravel beach, bedrock, and other non-vegetated habitsts that were not sampled.

- A table of average temperature and salinity values for each subarea by season and year of sampling. These are values measured at approximately 5 m depth at each purse seine site; blank cells indicate no sampling due to weather, time constraints, etc.

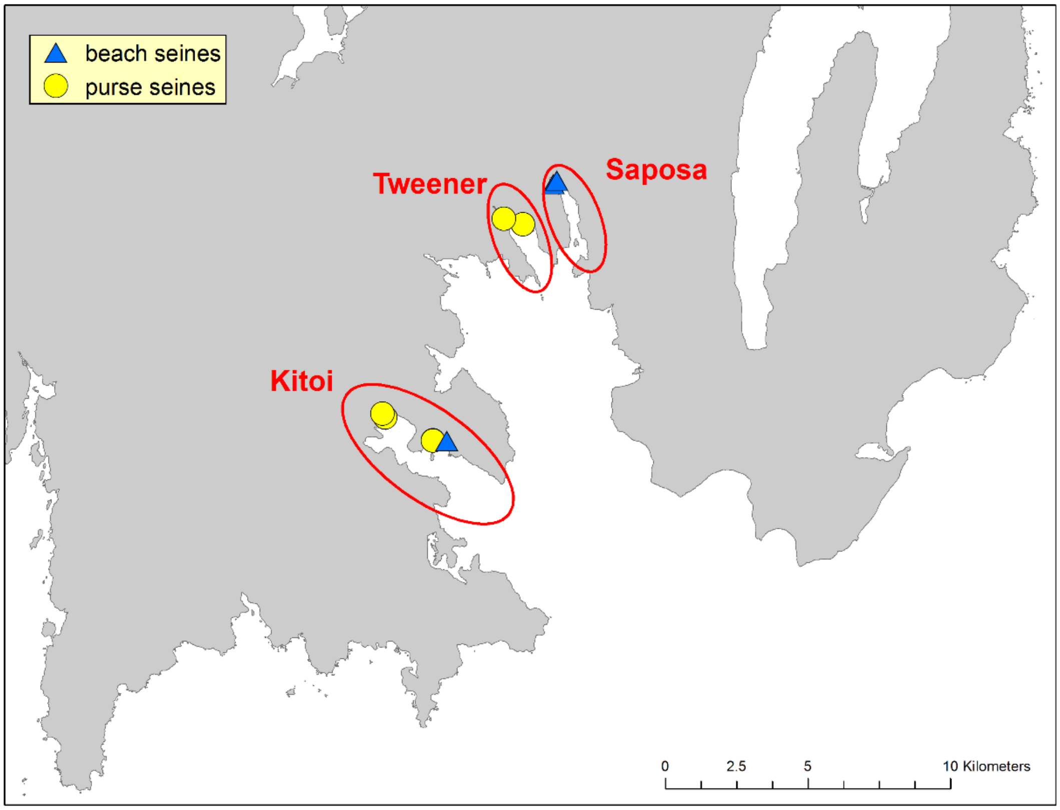
Kiliuda Bay



Seine site habitat types	Dungie	Shearwater	Flavia
eelgrass	100%		
kelp		58%	100%
eelgrass/kelp		33%	
sand		9%	

	Year	Season	Dungie	Shearwater	Flavia
average nearshore temperature (°C)	2011	spring	6.8	7.6	7.2
		summer	11.4	11.3	11.2
		fall	8.9	8.1	8.2
	2013	spring	6.6	6.5	5.1
		summer	12.3	10.2	10.5
		fall	8.1	7.7	7.9
average nearshore salinity (psu)	2011	spring	25.5	29.1	29.3
		summer	29.9	30.9	30.7
		fall	31.4	32.0	32.0
	2013	spring	29.0	31.2	31.9
		summer	29.7	31.4	31.0
		fall	30.3	30.3	31.2

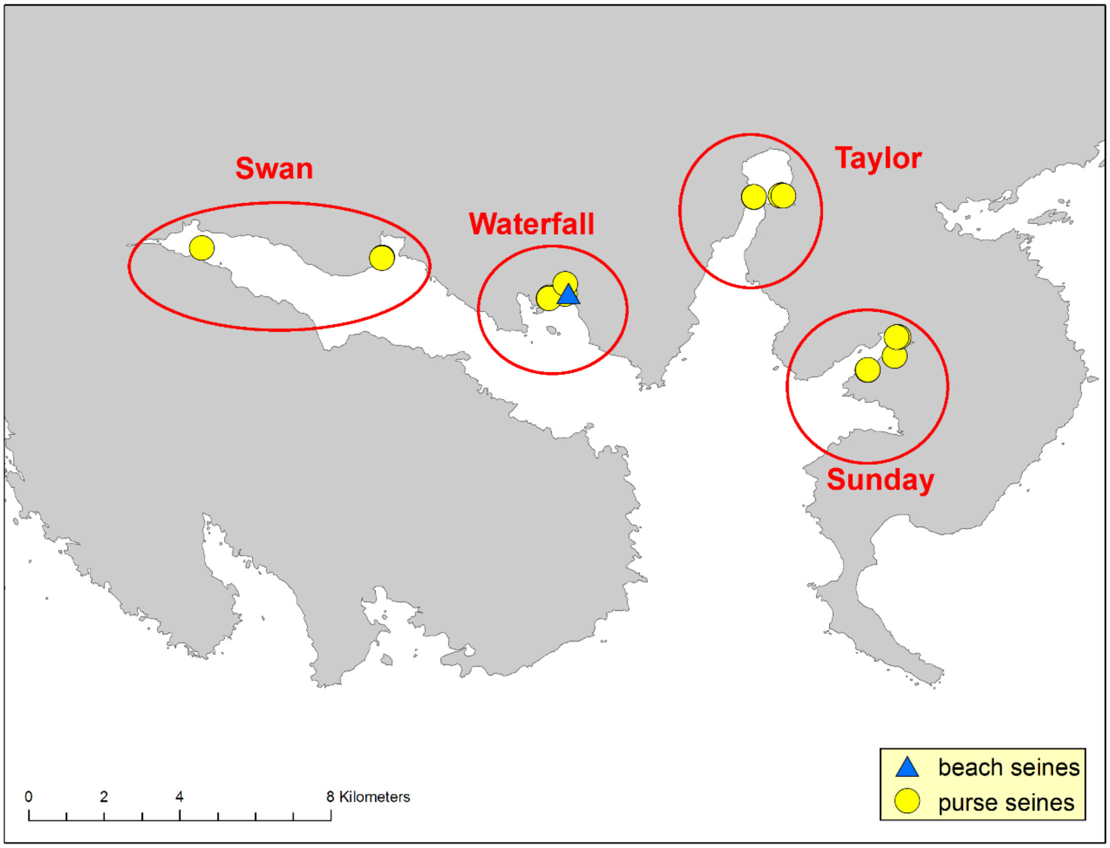
Izhut Bay



Seine site habitat types	Kitoi	Tweener	Saposa
eelgrass			25%
kelp	80%	100%	75%
eelgrass/kelp	20%		
sand			

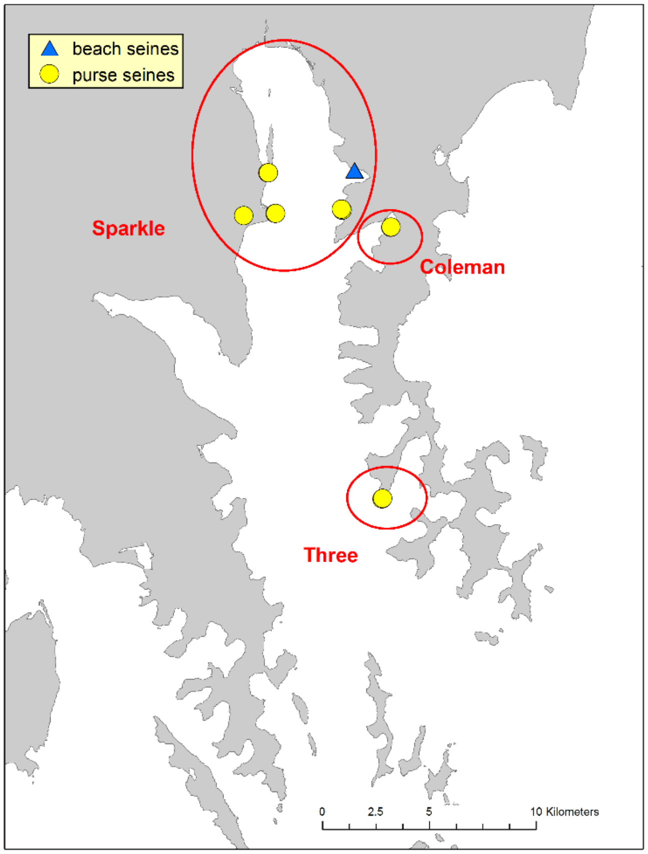
	Year	Season	Kitoi	Saposa	Tweener
average nearshore temperature (°C)	2011	spring		5.7	5.6
		summer	12.6		
		fall			
	2013	spring	6.7		6.8
		summer	12.0		11.0
		fall			
average nearshore salinity (psu)	2011	spring		32.0	28.7
		summer	30.5		
		fall			
	2013	spring	31.3		31.4
		summer	30.7		31.1
		fall			

Port Dick



Seine site habitat types	Swan	Waterfall	Taylor	Sunday
eelgrass	100%	50%		35%
kelp		50%	8%	65%
eelgrasss/kelp			92%	
sand				

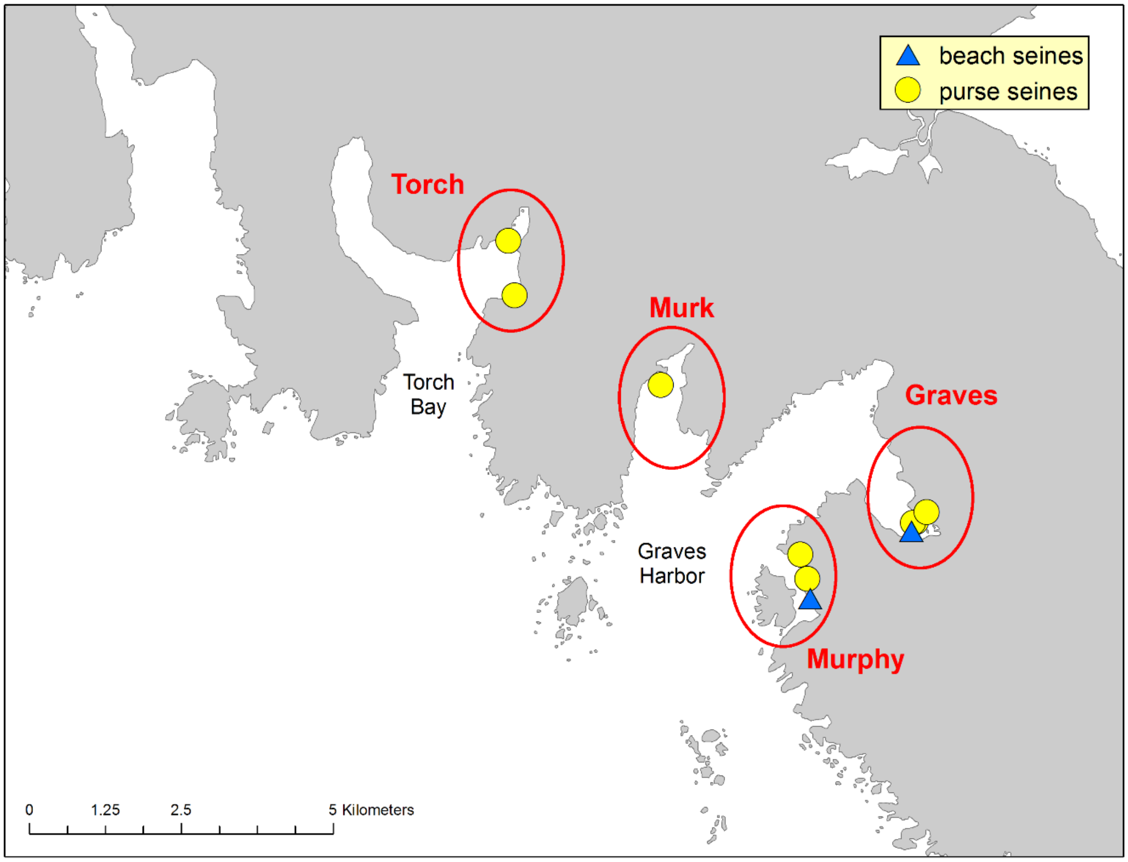
	Year	Season	Swan	Waterfall	Taylor	Sunday
average nearshore temperature (°C)	2011	spring	5.6	5.3		5.8
		summer	12.7	12.0	12.0	12.9
		fall		9.1	9.0	8.3
	2013	spring				
		summer	12.4	12.8	11.4	13.2
		fall	8.5	8.8	8.0	8.5
average nearshore salinity (psu)	2011	spring	30.7	28.2		30.9
		summer	27.7	29.0	25.1	28.7
		fall		28.8	28.0	27.3
	2013	spring				
		summer	27.8	27.5	22.8	24.6
		fall	28.7	28.8	26.6	28.3


Aialik Bay

Seine site habitat types	Sparkle	Coleman	Three
eelgrass			
kelp	70%	100%	100%
eelgrasss/kelp	20%		
sand	10%		

	Year	Season	Coleman	Sparkle	Three
average nearshore temperature (°C)	2011	spring	5.7		
		summer	13.7	12.5	13.9
		fall			
	2013	spring	5.1	4.7	5.7
		summer	14.6	12.8	13.9
		fall			
average nearshore salinity (psu)	2011	spring	29.0		
		summer	26.1	24.3	25.9
		fall			
	2013	spring	31.2	30.7	30.5
		summer	26.0	25.0	25.8
		fall			

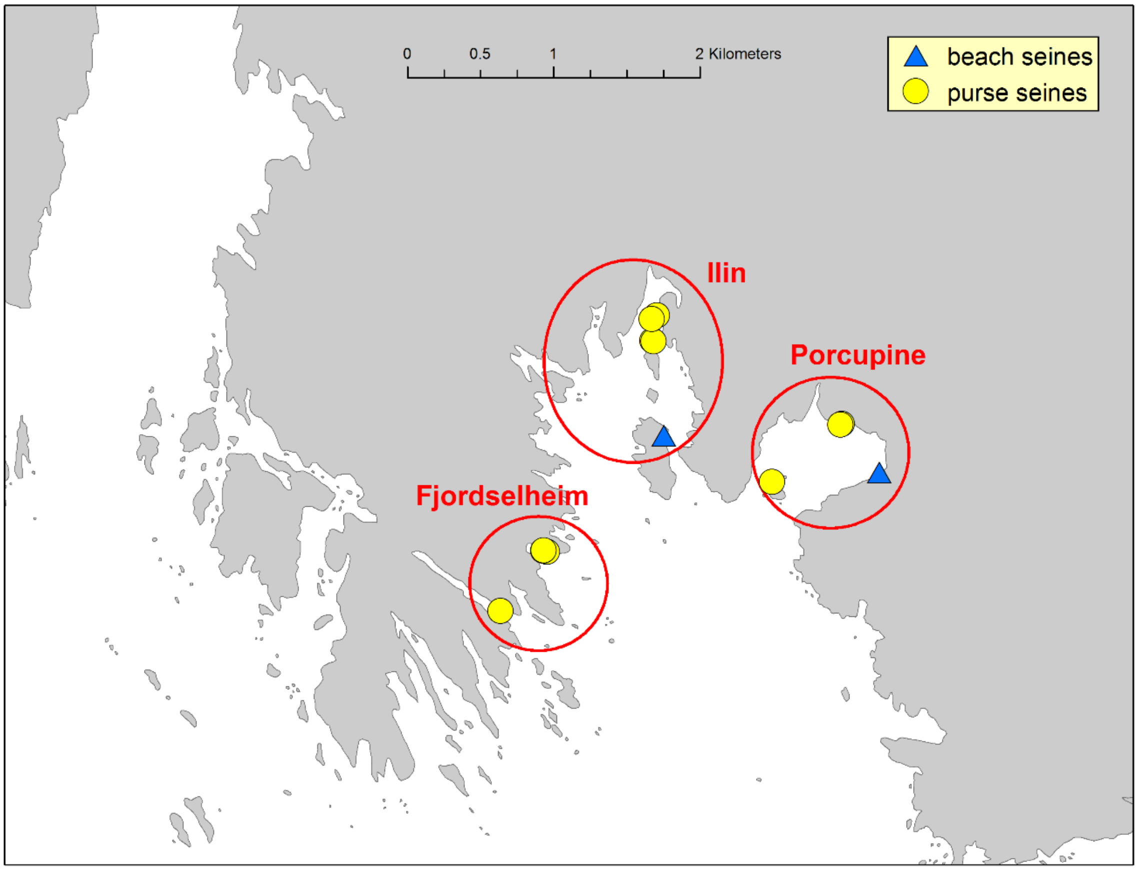
Torch Bay and Graves Harbor



Seine site habitat types	Torch	Murk	Murphy	Graves
eelgrass				
kelp	100%	100%	100%	100%
eelgrass/kelp				
sand				

	Years	Season	Torch	Murk	Murphy	Graves
average nearshore temperature (°C)	2011	spring	6.7			
		summer	12.6	11.5	10.4	12.6
		fall				
	2013	spring			6.0	5.0
		summer	11.9	9.8	9.8	
		fall				
average nearshore salinity (psu)	2011	spring				
		summer	31.0	30.8	31.2	30.6
		fall				
	2013	spring				
		summer	31.3	31.6	31.3	
		fall				

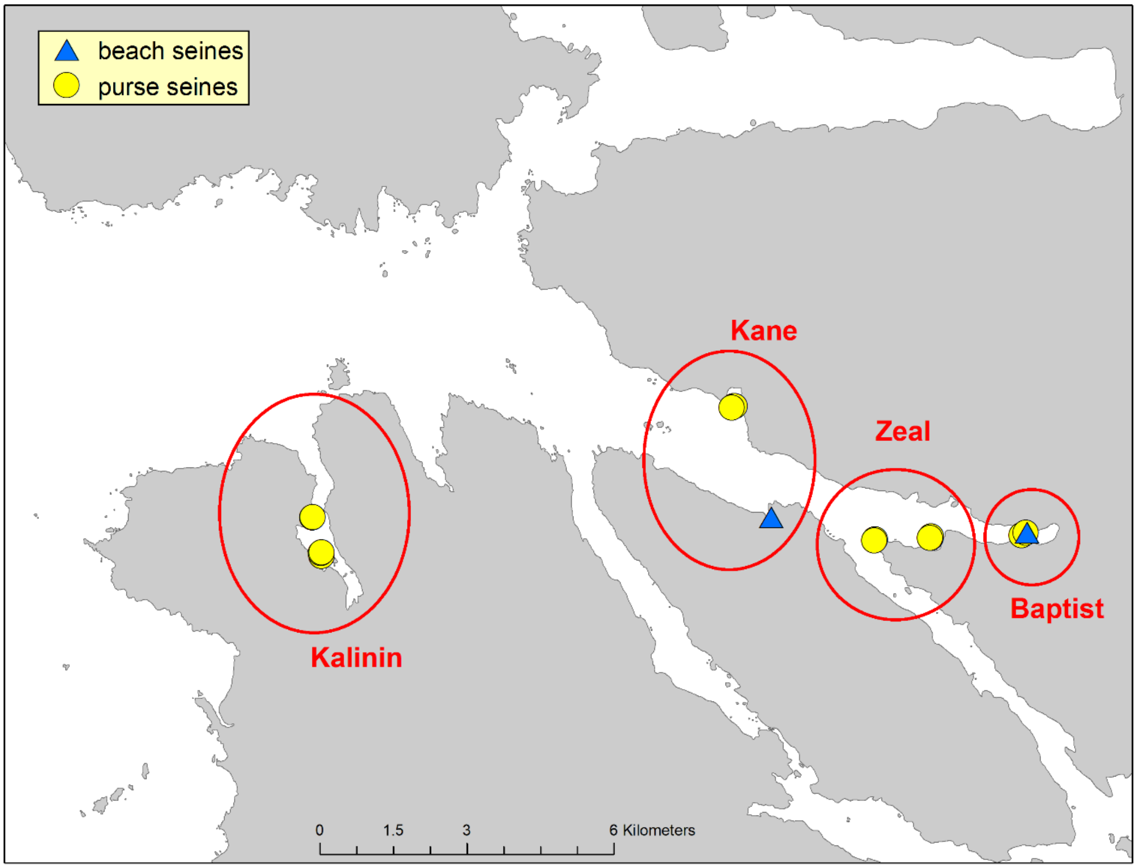
Islas Bay



Seine site habitat types	Fjordselheim	Ilin	Porcupine
eelgrass		33%	
kelp		67%	
eelgrass/kelp	100%		100%
sand			

	Year	Season	Fjordselheim	Ilin	Porcupine
average nearshore temperature (°C)	2011	spring	6.2	6.6	6.6
		summer	12.7	11.5	11.4
		fall	11.6	11.6	11.6
	2013	spring	6.3	6.0	6.4
		summer	9.5	10.9	9.9
		fall			
average nearshore salinity (psu)	2011	spring			
		summer	30.9	30.8	31.1
		fall	30.2	29.7	29.6
	2013	spring	28.4	25.8	25.8
		summer	32.0	32.0	31.8
		fall			

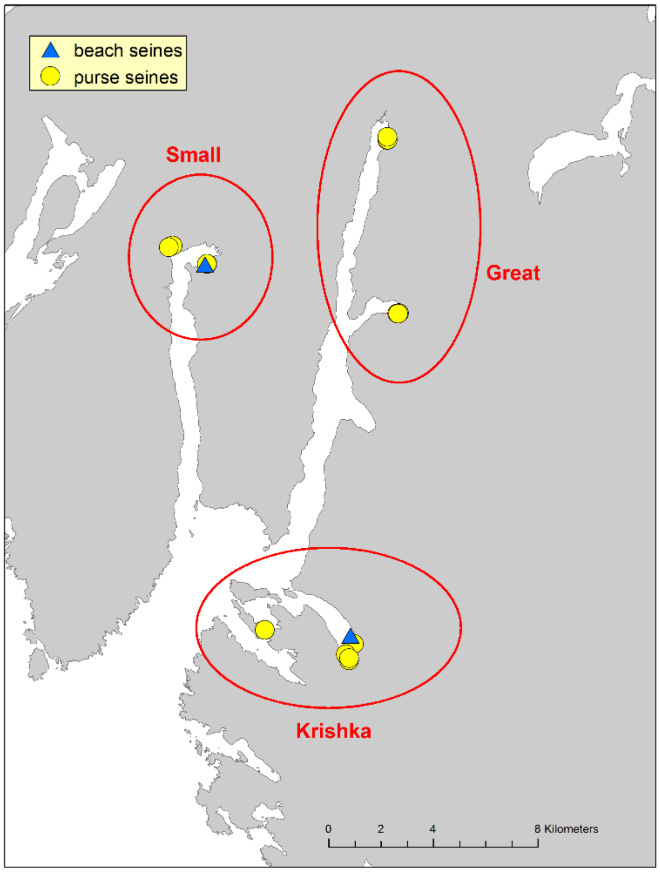
Salisbury Sound



Seine site habitat types	Kalinin	Kane	Zeal	Baptist
eelgrass				100%
kelp			100%	
eelgrass/kelp	33%	100%		
sand	67%			

	Year	**Season**	**Kalinin**	**Kane**	**Zeal**	**Baptist**
average nearshore temperature (°C)	2011	spring				
		summer	13.8	11.9	11.8	13.4
		fall				
	2013	spring	7.7	7.4		6.8
		summer	13.6	12.0	13.4	
		fall	12.0	11.5	11.4	11.4
average nearshore salinity (psu)	2011	spring				
		summer	30.8	30.8	30.2	30.0
		fall				
	2013	spring	31.2	30.5		31.0
		summer	31.3	31.4	31.2	
		fall	31.1	30.2	30.2	30.3

Whale Bay



Seine site habitat types	Small	Krishka	Great
eelgrass	38%	17%	
kelp		42%	
eelgrass/kelp	62%		100%
sand		41%	

	Year	Season	Small	Krishka	Great
average nearshore temperature (°C)	2011	spring			
		summer	11.6	12.3	
		fall	11.5	11.1	10.8
	2013	spring	7.8	7.9	7.3
		summer	16.3		13.9
		fall	11.9	11.6	11.1
average nearshore salinity (psu)	2011	spring			
		summer	30.4	28.6	
		fall	29.0	28.8	28.9
	2013	spring	30.4	28.1	25.0
		summer	24.2		21.3
		fall	29.2	26.9	16.9

Sampling Methods

Platforms

All field efforts in both 2011 and 2013 took place aboard two chartered vessels (referred to hereafter as the “main vessel”). In the EGOA, the vessel was the FV *Seaview*, a 54 ft steel crabber/longliner. The vessel in the WGOA was the RV *Island C*, a 77 ft steel research/general charter vessel. At all sites except the Barren Islands and St. Lazaria Island, a 16-ft Achilles inflatable boat powered by a 20 HP outboard (referred to hereafter as the “skiff”) was used for acoustic sampling in water less than 20 m depth and for all nearshore sampling. A summary of the total number of hauls by gear type and cruise can be found in Appendix C (Table C-1).

Acoustics

Acoustic backscattering was surveyed using a calibrated Simrad EK60 echo sounder with 38-12- and 120-kHz transducers in a ‘Polywog’ towed body (YSI Integrated Systems & Services), which was deployed from the side of the main vessels. The 38-kHz transducer had a 12º conical beam, and the 120-kHz transducer had a 7º conical beam. Sampling from the main vessel generally occurred in areas of 20-250 meters bottom depth. Parallel tracklines were used except where narrow bays made navigation too difficult (e.g. the Whale Bay area). In these areas a zigzag transect pattern was used. Transect spacing ranged from 0.125 nm in smaller bays such as Torch Bay and Graves Harbor to 2.0 nm in the Barren Islands, and surveys were completed in 1-3 days. A total of 61 site-surveys covering 4100 km of acoustics transects were completed during the project (this includes 4 sites sampled during a 2010 pilot study in the EGSR, which used the same methods as the other surveys). All surveys were conducted during daylight hours.

Acoustic backscatter was post-processed using Echoview 5.4 (Myriax Pty Ltd, Hobart, Tasmania, Australia). The observed backscatter was partitioned into signals consistent with either fish or zooplankton (Fig. 2) based on their relative frequency response, using a two-frequency variant of the method described in De Robertis et al. (2010). The water column data from the acoustic records (i.e., samples > 1 m from the transducer and 1 m above the first bottom echo) were smoothed by a 5 ping by 5 range sample sliding window (using a ‘top hat’ convolution algorithm with equal weights of 1), and the frequency response ($S_{V,120kHz} - S_{V,38kHz}$) in each cell was computed. Analysis cells with a frequency response in the range of -16 to 8 dB were assigned to the “fish” category and those in the range of 8 to 30 dB were assigned to the “zooplankton” category (cf. fig. 2 of De Robertis et al. 2010). In some cases, a continuous near-surface scattering layer with a frequency response largely consistent with the fish category was evident. Although the scatterers constituting this layer are unknown, they are not primarily forage fishes or large zooplankton (e.g., Wolliez et al. 2012), and this backscatter was manually excluded prior to applying the frequency difference criteria.

The spring and summer 2011 38 kHz data from the tow body were compromised due to undiscovered damage caused by flexing of the conductors in the transducer cable, which intermittently impacted the backscatter strength at 38 kHz. These data were corrected for this bias by using the transmit pulse and the bottom echo as a reference (see Appendix D for details), which has proved useful in investigations of instrument performance. After correction, residual uncertainty for 38 kHz backscatter is estimated at ~ 0.5 dB or ~12 % in linear terms. The fish/zooplankton classification used in this study is robust to errors of < ± 3dB (i.e. a factor of 2. Consequently, the unaffected 120 kHz data are used as an index of abundance, and the 38 kHz data classification are used only for classification of backscatter, which is relatively robust to residual errors. Data from the 2010 pilot study and after summer 2011 were not subject to biases introduced by damaged cable. After the damage was discovered, more robust armored data cables were used on the tow body and the instrumentation was carefully monitored during surveys for any signs of cable damage by 1) continuously monitoring the strength of the transmit pulse, 2) monitoring the resistance across transducer quadrants, and 3) conducting more frequent sphere calibrations.

The 120 kHz backscatter data from 6 m below the surface to 0.5 m above the sounder-detected bottom were echo-integrated into the nautical area scattering coefficient (s_A, m^2 nmi^{-2}; a measure of backscatter per unit area - see MacLennan et al. 2002) in 100 m along-track units and 5 m depth bins. A –67 dB re 1 m^{-1} minimum integration threshold was used for the fish category, and -75 dB re 1 $m^{-1}$for the zooplankton category. Data were summarized by transect by first removing data occurring between transects and then computing the mean backscatter for each transect by averaging all 100 m along-track samples on that transect and site visit. The mean backscatter per unit area for each site *s* sampled on cruise *i* ($s_{A,s,i}$) was computed by first weighting the average backscatter observed on a given transect *t* ($s_{A,s,i,t}$) by number of 100 m along track samples on that transect ($n_{,s,i,t}$) and then dividing by the total number of samples during that visit; that is,

$$s_{A,s,i} = \sum_t s_{A,s,i,t} \cdot n_{s,i,t} / \sum_t n_{s,i,t} \ . \qquad (1)$$

The area between 5- and 20-m depth contours was surveyed from the skiff using an ES60 echo sounder and a 38/200 ‘combi’ single-beam transducer mounted on a pole attached to the transom, with the transducer below and off to the side of the propeller . The 38-kHz transducer had a 13° by 21° beam, and the 200-kHz transducer had a 7° conical beam. A total of 20 skiff surveys covering 381 km of trackline were conducted at 7 different sites over the course of this study. The results of the nearshore skiff surveys are not presented here, and will be presented in a future publication.

Verification of Acoustic Backscatter on Main Vessel and Skiff

Verification of acoustic sign was attempted using several gear types: midwater trawl, jigging, gillnet, and underwater camera. Jigging proved to be the most effective method attempted to capture fish in the inshore bays, but a large fraction of the backscatter could not be identified with confidence (i.e., in many instances no fish were captured, particularly in midwater, and the probability of capture as a function of species and size remains unknown). Additionally, jigging, which was likely to be highly selective in terms of which species and size/age classes are captured (Millar and Fryer, 1999). For example, demersal rockfishes were readily captured with jigging gear. Thus, for the purposes of this study, we employed acoustic methods to classify the observed backscatter as consistent with broad categories corresponding to either ‘fish’ or ‘zooplankton’ based on the relative frequency response at 38 and120 kHz (described above). This acoustic classification was supplemented with summaries of the jig-captured species that provide some qualitative information on the presence of the most abundant species at each study site.

Midwater trawl: Aboard the main vessels, verification trawls were conducted using a small fine-mesh otter trawl towed by a 3/8-in Spectra single warp (Appendix A-1). The net was originally a shrimp bottom trawl that was modified by the Alaska Fisheries Science Center (AFSC) Research Fishing Gear Program staff and Research Nets, Inc. (Bothell, Washington) to increase the net opening height and allow the option of towing on the surface. The final net opening was 25 ft wide × 12 ft high and the codend was equipped with a 4 mm knotless mesh liner. The warp was attached via a 90 ft V-bridle to 2 × 4 ft plywood and steel doors (approximate weight 40 lb each) that were connected to the net with 24 ft dandylines. Fifty pounds of lead weight were attached to each end of the footrope at the point where the dandylines attached. The net was deployed off the stern of the vessel using either a gillnet reel or an anchor winch (the anchor winch was far superior; it allowed greater reliability and quicker retrieval and enabled the towline to be easily dogged off during towing). In 2011 the depth of the tow was monitored using a Furuno netsounder or scope ratio; in 2013 only the scope ratio was used. Neither method provided reliable estimation of tow depth while the net was deployed, but a temperature-depth recorder (TDR) was placed on the net for each tow so that actual tow depth was known. Tow duration depended on the intensity and distribution of the acoustic backscatter.

Jigging: Jigging was performed using line-counter trolling reels and a variety of tackle depending on which species were anticipated in the catch. Pacific herring and other small fishes were sampled with herring jigs that typically consisted of multiple size-10 hooks and fluorescent beads or fabric attached to a 0.4 mm monofilament line. Larger fishes (e.g., rockfishes and walleye pollock) were sampled mainly with Point Wilson Dart jigging spoons of various sizes and colors. Lead weights were used to sink lines quickly and reduce the effects of current and depth. Typically both jig types were used in a location until it could be determined which species were present. Once the boat had relocated acoustic sign and gear was deployed, jigging was conducted for a minimum of 15 minutes with a catch target of 5 individuals of each species encountered. The duration of jigging events varied but was usually 0.5 hour or less, and there were typically 2-5 jigging rigs in the water at any one time. Similar jigging was performed during skiff acoustics operations except that usually only one of the two skiff crew members fished.

Gillnet: During pilot fieldwork in 2010 and the spring surveys of 2011 we attempted to use a variable-mesh set gillnet to verify echosign. The net was 70 ft long and 10 ft wide, and mesh size varied from 0.5-1.5 in stretched mesh. We attempted both vertical and horizontal deployments at various depths. The net twisted excessively in strong currents and its fragile meshes easily suffered damage from large fish, so use of the net was discontinued after spring 2011.

Underwater video: Two underwater camera rigs were used during the surveys, one for the main vessel and one for the skiff. Main vessel camera deployments were unsuccessful for identifying midwater fishes due to multiple equipment failures and the limited range of the camera view (most fish aggregations were not sufficiently dense for the camera to reliably discern and identify individuals. The skiff camera was partially successful in identifying fishes and was also used for habitat assessment during exploration of potential seining locations.

Other Sampling Approaches

Surface trawl: Surface trawls were conducted opportunistically with the same net described in “Acoustics” to verify backscatter, except that the wing weights were reduced from 50 to 15 lb and large inflatable buoys were attached to the headrope. Surface trawls were not intended to be quantitative so tow duration was not consistent. The preferred duration was 45-60 min but was reduced if weather conditions or bay size interfered with the deployment. Surface trawl catches are reported in Appendix C (Table C-2).

Beam trawl: The beam trawl was a 3.1 m bottom trawl based on the original design of Gunderson and Ellis (1986) and modified by Abookire and Rose (2005). The roller gear employed by Abookire and Rose (2005) was only used for two hauls; otherwise the original tickler chains were used. The beam trawl was deployed off the gillnet reel using 3/8-in Spectra line and a scope ratio that varied from 5:1 to 10:1. The trawl was considered to be set once the reel had stopped letting out line; trawls were then conducted for 5 min at a speed between 2 and 3 knots. Due to time constraints the beam trawl was not consistently deployed across space and time; beam trawl catches are summarized in Appendix C (Table C-2).

Nearshore Sampling

Overview

Two gear types, beach seine and purse seine, were used to sample fishes in nearshore areas (max. depth 20 ft). Beach seines were used to sample up to the shoreline, although this gear type was limited to areas where the net could be hauled out on land (e.g., gravel beaches). The size of the beach seine differed between 2011 and 2013. In 2011, we deployed a small beach seine identical to nets typically used for nearshore sampling in Puget Sound. The small size of the beach seine limited its sampling range, so for the 2013 field season a new beach seine was developed with dimensions twice as large as was used in 2011 (see below and appendix A). The larger beach seine was used to sample areas with depth < 10 ft. and the purse seine was used to sample depths from 10-20 ft. The purse seine was a more effective gear than the beach seine for several reasons: its deployment did not depend on access to the shore, so areas far from the shoreline or with steep topography could be sampled; ideal tide conditions were not required (i.e., low tide was not needed for access to eelgrass beds, as is often the case with beach seines); and the depth range of the purse seine was most appropriate for the habitats to be sampled (e.g., kelp beds). As a result, the purse seine was used much more often than the beach seine, particularly in 2013.

Purse Seine Specifications and Deployment

The purse seine was 20 ft deep and 150 ft long with a weep mesh size of 1 ¼ in and a bunt mesh of 1/8 in knotless netting (i.e., the portion of the net where fish were concentrated was 1/8 in mesh; Appendix A). The diameter of the net when fully deployed was 48 ft, resulting in a sampling footprint of 1,800 ft^2. Because the size and shape of the footprint was consistent among hauls, catches among purse seine hauls were directly comparable and treated as catch per unit effort (CPUE). To our knowledge this is the first publication describing the use of such a net, so detailed instructions for its deployment are included in Appendix B. A brief overview of a purse seine haul is included below:

1) A chartplotter and echosounder were used to identify exact haul locations. Deployments were limited to 20 ft maximum depth to ensure that the leadline reached the bottom.
2) The seine was deployed out of the 16-ft skiff by two scientists, one at the bow and the other manning the 20 HP outboard. The net took up most of the space in the boat, but otherwise the small size and maneuverability of the skiff was an advantage in setting the net in diverse habitats.
3) The skiff was backed in a circle while the bow scientist dropped the net into the water.
4) When the net was fully deployed and the circle closed, the two ends of the net were clipped together and the purse line was pulled in by hand to close the bottom of the net.
5) After the net was fully pursed, the net was retrieved in the reverse manner it was deployed, leaving at the end a small bag where the captured fish were concentrated. Unless catches were very large, the bag was lifted on board for catch sorting.

Beach Seine Specifications and Deployment

Beach seine size differed between years: in 2011 a 29 ft × 5.5 ft net was used, whereas in 2013 the net was 57 ft × 10 ft (Appendix A). Relative dimensions were identical between years and both seines had a center bag with a setback; this created a pouch that enhanced retention of captured fishes. Deployment was similar between years and followed the approach used in other nearshore studies in Alaska (e.g., Johnson et al. 2003) except that only two scientists were required.

The net was stacked in the bow of the skiff. Lines were attached to each end of the net, and one line was fastened to the shore using a small anchor. The skiff backed in a semicircle while one scientist let the net out into the water from the bow. Once the skiff returned to the shore, one scientist got out and held the unanchored end of the net while the other scientist quickly anchored the skiff. The second scientist then retrieved the anchored line and the net was slowly pulled into shore. Catch processing occurred on shore.

Haul Locations

The locations of beach and purse seine hauls were established *a priori* through exploration of each bay, identification of available nearshore vegetated habitats, and determination of sampling feasibility. Exploration occurred during pilot surveys conducted in 2010 and continued into the spring and summer cruises of 2011. Although we did not explore the entire coastline of every bay, we investigated sufficiently to identify the major habitat types in every part of each bay and develop a general map of habitat distributions. As part of this process we identified subareas in each bay with distinct characteristics, either due to spatial separation or differences in topography or aquatic vegetation. The section on subareas below contains more information regarding the identification and selection of subareas. Within each subarea we determined the number of haul locations needed to adequately assess the nearshore habitats it contained. A final step involved assessing the potential for the ability to sample consistently at the chosen positions. Locations were discarded if they were difficult to access at certain tide states or in severe weather. For example, lagoons in Kiliuda and Aialik Bays were accessible only during high flood tides, and one portion of Graves Harbor was too rocky and exposed for consistently safe sampling. Because we generally had only 2-3 days to survey each bay, time limitation was also a factor, especially in large bays with long transit times. In Aialik Bay, for example, it would have been ideal to sample several sites in the outer part of the bay, but because the bay is so large we were forced to limit outer-bay sampling to one representative location and focus our efforts on the more variable habitats in the inner bay. After summer 2011 no new seine locations were established and sampling focused on revisiting areas sampled in previous surveys.

Nearshore Habitat Descriptions

Nearshore fish sampling was a central focus of the nearshore surveys, and nearshore sampling sites were classified according to the type of habitat. Nearshore habitats were complex and included sand and gravel, rocks of varying sizes, seagrasses, and multiple kelp species of diverse shapes and sizes. We observed a high degree of spatial variation in the density and species composition of the vegetation. There was also a strong seasonal cycle in vegetation coverage, with the highest density observed during the summer and much of the vegetation disappearing by November. It was beyond the scope of these surveys to fully characterize each type of nearshore habitat; instead, sampling sites were assigned to one of five general habitat types, described below. The density of the cover was not explicitly measured and was not included in the classification. Similarly, seasonal changes in cover were not measured although season was an important separate factor in most analyses. Exposure to wave action influenced the vegetation found at a site but was not included as a separate factor in habitat classification. Habitat types were as follows:

Eelgrass: Many sites consisted of dense beds of eelgrass (*Zostera marina*). These were generally found in protected areas with soft sediment and relatively low salinity. Eelgrass distribution is depth-dependent, so in areas with steeper topography eelgrass often occurred in a narrow fringe along the shoreline. Eelgrass was often mixed with kelps; a site was considered an eelgrass site if a visual inspection revealed the site was 75% or more eelgrass.

Kelp: The attributes of sites classified as kelp varied considerably. The predominant feature of kelp sites was a layer of bottom-associated, large-bladed brown kelps (*Laminaria* spp. and *Saccharina* spp.). These kelps were often mixed with green kelps (e.g., sea lettuce *Ulva lactuca*) and red kelps (e.g., red eyelet silk *Sparlingia pertusa*). Although it was impossible to sample thick canopy-kelp forests, at many sites canopy kelps occurred in low densities (i.e., there might be 2-3 canopy kelps within the seining area). The predominant canopy kelp encountered was bull kelp *Nereocystis luetkeana*, although in Aialik Bay and Graves Harbor dragon kelp *Eualaria fistulosa* was more common. The density of dragon kelp at the sampling sites was higher than at sites where bull kelp was encountered. Some kelp sites contained patches of eelgrass. Kelp sites tended to be more exposed than eelgrass sites although this was not universally true.

Eelgrass/Kelp: At some sampling sites eelgrass and kelps were mingled, or occurred in small patches that were sufficiently close to each other that sampling could not be limited to one habitat type. The proportion of eelgrass and kelp varied, but most combined sites had either equal proportions of each or contained more eelgrass than kelp.

Gravel/Cobble: Gravel beaches occurred throughout the study regions. While some of these were bare of vegetation, most gravel sites contained small kelps at low to medium densities. The most common kelp encountered at these sites was rockweed *Fucus distichus*. Cobble of various sizes was also commonly encountered at these sites. Sites with boulders larger than approximately 30 cm diameter were actively avoided to limit damage to the fishing gear. Gravel sites varied in their exposure.

Sand: Sites classified as sand were generally vegetation-free although sparse eelgrass and kelps were found at some sites. Sand sites were generally in protected areas, and some sand sites contained detritus.

Catch Processing and Sample Collection

Sorting and Species Identification

The following description pertains directly to processing of seine catches; catch processing for other gear types was similar. The entire catch was sorted and, with some notable exceptions, individuals were identified to species. Some small fishes (juvenile greenlings, juvenile rockfish, juvenile salmon, and small sculpins) were difficult to identify to species level in the field (i.e., species identification relied on analysis of meristics or close inspection of traits such as lateral line length and shape). During pilot studies conducted in 2010 a qualitative analysis was performed of the tradeoff between the value of identifying each individual to species level (and the time and effort required to do so) and the need to provide a comprehensive and representative survey of each nearshore site. Because the geographic breadth of the nearshore surveys and the comprehensive analysis of each bay were the most important objectives of the study, we decided to identify the taxonomic groups of fish listed above only to genus level in order to maximize the number of seine hauls conducted in each bay. Voucher specimens were collected and later identified to species, which allowed us to determine species presence although we were unable to quantify the species composition within those taxonomic groups.

Subsampling

For most taxonomic groups all individuals were counted directly, but we regularly encountered very large catches that required sub-sampling of the main catch constituents. Species occurring in small numbers were removed from the catch and counted separately. The remaining catch, which often included several species (e.g., age-0 Pacific cod and walleye pollock), was subsampled using a plastic bowl. The number of subsamples differed according to the size and complexity of the catch, and the catch was mixed continuously by hand to ensure representative subsamples. Subsamples were set aside and the bowl was used to measure the volume of the remaining catch. Total catch was calculated as average count per bowl × total number of bowls.

Length Measurement

For groups with less than 20 individuals in a catch, length was measured for all individuals. For larger catches at least 20 length measurements were taken from a random sample. The number of length measurements was increased for very large catches and for catches where it appeared that multiple size modes existed and a larger number of measurements was required to ensure an adequate size composition (e.g., juvenile Pacific herring often displayed substantial variability in size within a set so 50-60 measurements were taken). Due to the small sizes of most of the fishes encountered, and the difficulty of accurately recording their weight onboard, count and length were the only metrics collected for most catches.

Sample Collection for Laboratory Analysis

Whole fishes were collected for laboratory analysis of fatty acid and stable isotope composition, energy density, and species identification. Samples were placed in sealed plastic bags and stored on ice until the evening of the day they were collected (i.e., 12 hours max.). Specimens that were collected for body composition and energetics analysis were removed from the ice at the end of the day and wrapped tightly in two layers of plastic wrap to eliminate contact with air. Wrapped individuals were placed together in doubled plastic bags and frozen at -40°C. Specimens vouchered for species identification were preserved in plastic jars containing 10% formalin.

Oceanographic Sampling

Nearshore Hydrography

During each purse and beach seine haul, temperature and salinity were measured at the middle of the water column (i.e., at 10 ft depth for a typical purse seine). In 2011 measurements were taken using a CTD-Diver conductivity, temperature, and depth (CTD) datalogging sensor (Schlumberger Water Services, Denver, CO, USA). The CTD-Diver recorded continuously and yielded values for specific conductance, so post-processing of the data was required to identify the relevant sections of the data record and convert conductance to salinity. In 2013 a CastAway CTD datalogging sensor (SonTek, San Diego, CA, USA) was used. The CastAway recorded only each cast or point measurement and displayed the data (including salinity values in psu) directly on the device. Mean subarea temperature and salinity values are included in the subarea descriptions above.

Comprehensive Site Oceanography

At every site we performed comprehensive oceanography at multiple stations (results will be presented elsewhere). At each station three main activities were performed (Fig. 2):

1) Water column sampling using a Seabird 19-Plus CTD recorder. In 2011 and 2013 the CTD carried a dissolved oxygen (DO) sensor and a turbidity sensor; in 2013 the CTD was also equipped with a sensor for photosynthetically available radiation and a fluorometer to estimate chlorophyll.
2) Vertical net tows for zooplankton samples were conducted using a Sea-Gear 9761 ring net with 60 cm diameter mouth and 150 micron mesh; samples were preserved in buffered 5% formalin.
3) Water samples were collected at the surface and at 20 m depth and filtered for subsequent chlorophyll and nutrient analysis, as well as to calibrate the oxygen and salinity data recorded by the CTD.

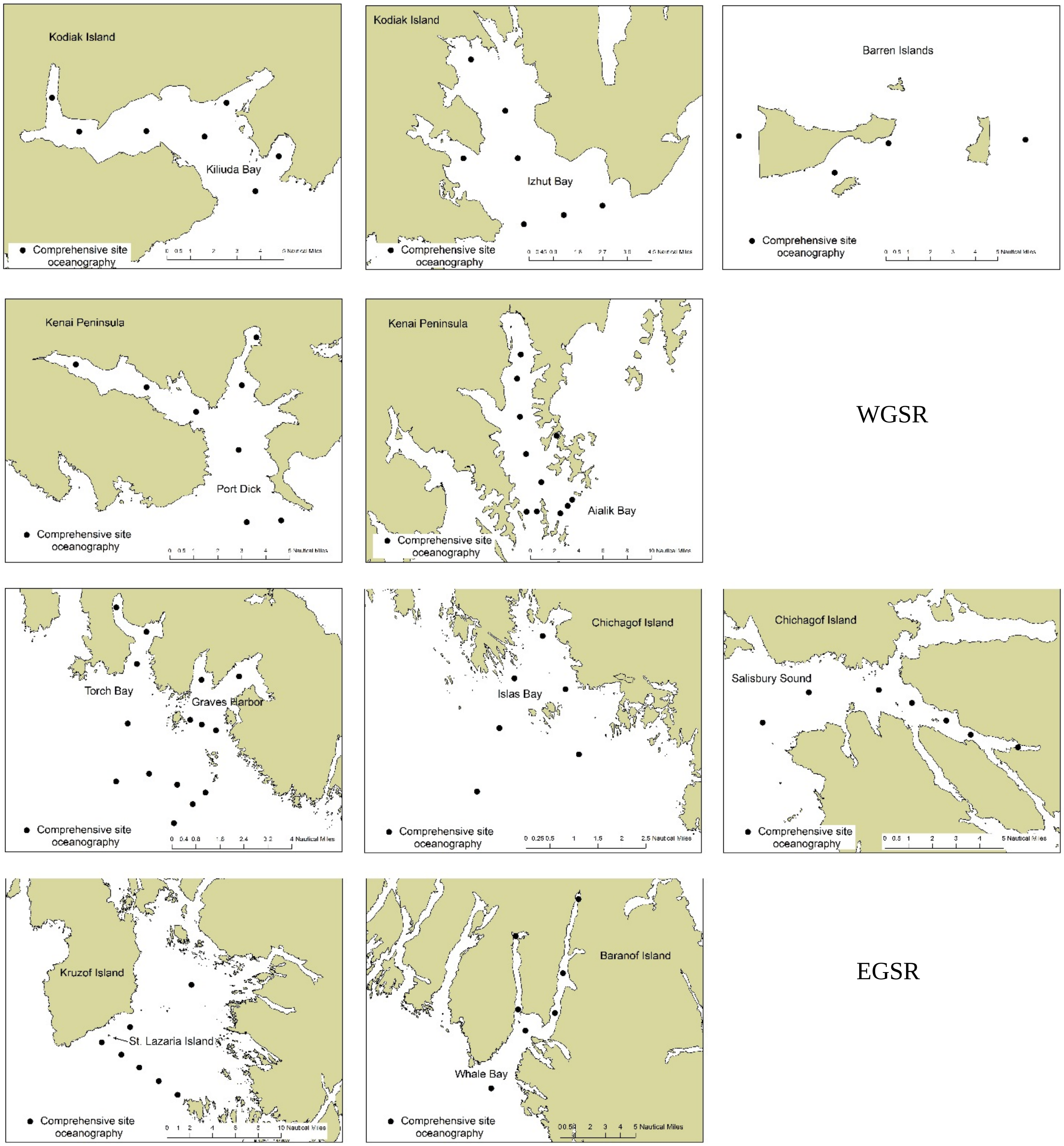


Figure 2. -- Locations of the comprehensive site oceanography for both the WGSR and EGSR, 2011, and 2013.

Results

Nearshore Acoustic Surveys

Fish and Zooplankton Backscatter by Site and Year

Mean acoustic fish backscatter at 120 kHz varied substantially between years and among sites (Fig. 3, upper panel). In addition, annual patterns were not consistent among sites. The two island sites, Barren Islands and St. Lazaria, exhibited relatively low backscatter in both years as did Islas Bay. Among the remaining 8 sites, 6 showed similar fish backscatter levels (> 500 s_A) in 2013. Backscatter in 2011 was generally lower and more variable among sites. Large bays exhibited the highest mean backscatter, and for three of these (Kiliuda Bay, Aialik Bay, and Port Dick) 2013 values were much higher than in 2011. Two large bays in the EGSR, Salisbury Sound and Whale Bay, exhibited higher mean fish backscatter in 2011 but the difference between years was less. In contrast to the patterns for fish, backscatter attributed to zooplankton was lower in 2013 than 2011 at most sites (Fig. 3, lower panel). This was particularly true for the western sites. Similar to fish, the two island sites and Islas Bay consistently had the lowest zooplankton backscatter. Salisbury Sound and Whale Bay had relatively high backscatter in both years. Zooplankton backscatter tended to be higher in 2011 compared to 2013 (Fig. 3). Although our ability to sample zooplankton backscatter was limited, one successful midwater trawl in Salisbury Sound in 2011 revealed abundant large euphausiids.

Fish and Zooplankton Backscatter by Site and Season

Backscatter attributed to fish displayed seasonal patterns that differed among regions (Fig. 4, left panels). In the WGSR, fish backscatter was higher in the spring than in summer in both years. Fish backscatter in the EGSR was more variable. Values in 2013 were consistently higher in summer than in spring; in 2011 most eastern sites had higher fish backscatter in summer than in spring but Salisbury Sound exhibited an opposite pattern (Fig. 4). Zooplankton backscatter also showed seasonal trends (Fig. 4, right panels). In both regions, zooplankton backscatter was generally higher in spring than in summer. Izhut Bay had an extremely high level of backscatter in spring of 2011 (Fig. 4).

Spatial Patterns in Fish Backscatter

The intent of the following section (including Figs. 5-26) is to provide information regarding the spatial patterns in 120 kHz fish acoustic backscatter at each site during each season of 2011 and 2013. Fish backscatter could not be consistently attributed to species but relevant fish catch data are discussed where they are available. Quantitative analysis of these data in subsequent manuscripts demonstrated that 1) the effects of site were larger than the temporal variables, 2) there were no consistent differences in backscatter between regions, and 3) water depth likely explains some of the differences in fish and zooplankton abundance across sites.

Kiliuda Bay: Spatial patterns and amounts of fish backscatter in Kiliuda Bay varied with year and season (Figs. 5 and 6). Backscatter patterns generally varied in relation to a shallow sill that approximately bisects the bay (marked on the spring 2011 map in Fig. 5). West of the sill, backscatter was often typified by moderate backscatter over a relatively large area. Echosign in the outer bay was often highly localized and indicated dense aggregations of fish. Jigging in 2011 and 2013, as well as trawling conducted during pilot studies in 2010, suggested that the inner-bay backscatter was composed mainly of Pacific cod and walleye pollock, including adults. The outer-bay echosign usually yielded catches of Pacific herring. Seasonal patterns were inconsistent: backscatter values in the inner bay were highest in spring 2013, while outer-bay values were highest in fall 2011.

Izhut Bay: Due to time constraints, the acoustic transects in Izhut Bays occurred mainly along the edges of the bay, with a small number of transects extending fully across the bay (Figs. 7 and 8). Seasonal variability appeared to be lower in Izhut Bay than some other sites, but fish backscatter was higher in 2013. The highest fish backscatter was observed in the deeper areas in the middle of the bay. Sampling of echosign in Izhut Bay was limited and usually captured adult *Sebastes* spp., especially in the upper bay (e.g., spring 2013).

Barren Islands: Fish backscatter was generally low in the Barren Islands (Figs, 9 and 10). When fish backscatter was observed it was normally limited to only one part of the site (e.g., spring 2011 and summer 2013). During pilot studies in 2010 we observed an extremely dense, highly localized aggregation of juvenile capelin that may have been created in part due to tidal herding. Tidal currents are extremely high at this site and strong fronts are common, so the patterns observed in 2011 and 2013 may also have been influenced by tides.

Port Dick: Fish backscatter in Port Dick was generally highest in the deep waters located in the middle of the West Arm and the outer part of the bay (Figs. 11 and 12). Backscatter amounts in these areas seemed to follow similar annual and seasonal patterns. Jigging in the deeper aggregations usually captured pollock and *Sebastes*.

Aialik Bay: Similar to Izhut Bay, the extensive size of Aialik Bay meant that acoustic transects were mainly limited to the shallower bay edges (Figs. 13 and 14). Backscatter was highest in spring in both years; we were unable to visit this site in fall of either year. Fish backscatter was highest in the outer reaches of the bay, and limited sampling resulted in catches of herring, walleye pollock, Pacific cod, and *Sebastes* spp. Dedicated acoustic surveys conducted in other Kenai Peninsula fjords have identified that aggregations of pre-spawning walleye pollock dominate the backscatter in deeper parts of these bays in spring (Guttormsen and Jones 2010).

Torch Bay: Backscatter in this small bay was limited except in summer of 2013 (Figs. 15 and 16). Jigging produced Pacific herring that usually occurred in small, dense “herring balls”. On several occasions these schools were being actively pursued by groups of Steller sea lions that interfered with sampling activities due to the need to avoid marine mammal disturbance.

Graves Harbor: Another small bay, Graves Harbor exhibited limited fish backscatter that occurred mainly along the bay edges (Figs. 17 and 18). *Sebastes* spp. were captured by jigging in these areas.

Islas Bay: Islas Bay was unusual among the all of the sites in that it consistently contained very little fish echosign (Figs. 19 and 20). The reason for this is unknown, but Islas Bay is shallow very exposed to the ocean and the interaction between waves and the complex topography results in turbulent waters throughout the site.

Salisbury Sound: Fish backscatter was high in Salisbury Sound in most years and seasons (Figs. 21 and 22). Echosign was highest in the outer Sound where depths were greater. Inner portions of the Sound had lower backscatter that was also more variable. Exposed conditions in the outer region made fish sampling there impossible; echosign in the inner Sound was characteristic of Pacific herring but jigging was unsuccessful due to the small size of schools as well as their mobility.

St. Lazaria Island: Similar to the Barren Islands, fish backscatter was generally low at this site (Figs. 23 and 24). Echosign tended to be associated with the bottom and jigging produced abundant *Sebastes* spp.; little midwater backscatter was observed.

Whale Bay: Fish backscatter was relatively high in Whale Bay in most years and seasons (Figs. 25 and 26). High backscatter levels were observed in all parts of the bay, including the two deep arms and the shallower protected areas in the southeastern section of the site. Midwater trawling and jigging captured abundant Pacific herring and juvenile pollock. *Sebastes* spp. were captured mainly along the steep edges of the two arms.

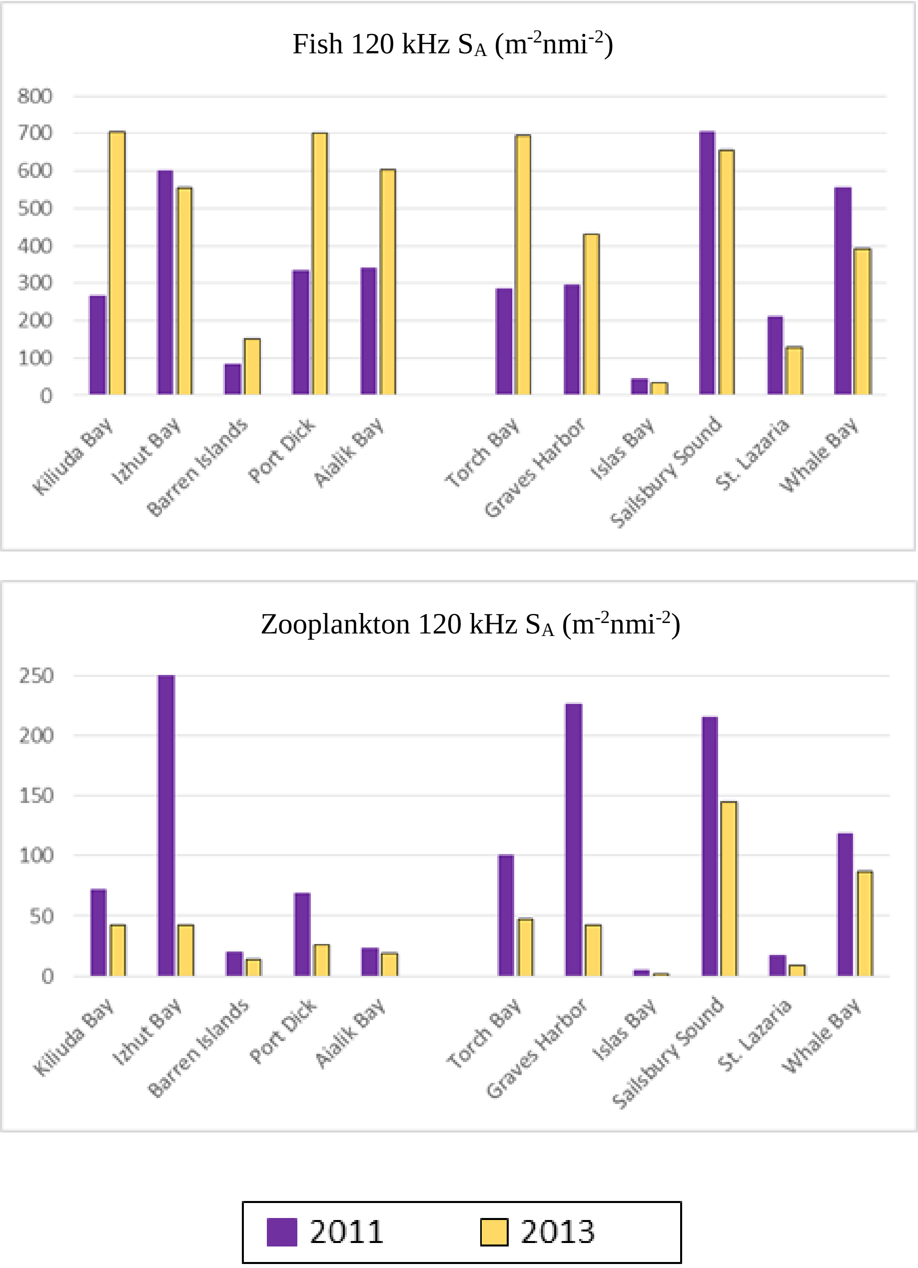


Figure 3. -- Mean acoustic backscatter measured during GOAIERP inshore surveys for fish and zooplankton by site and year.

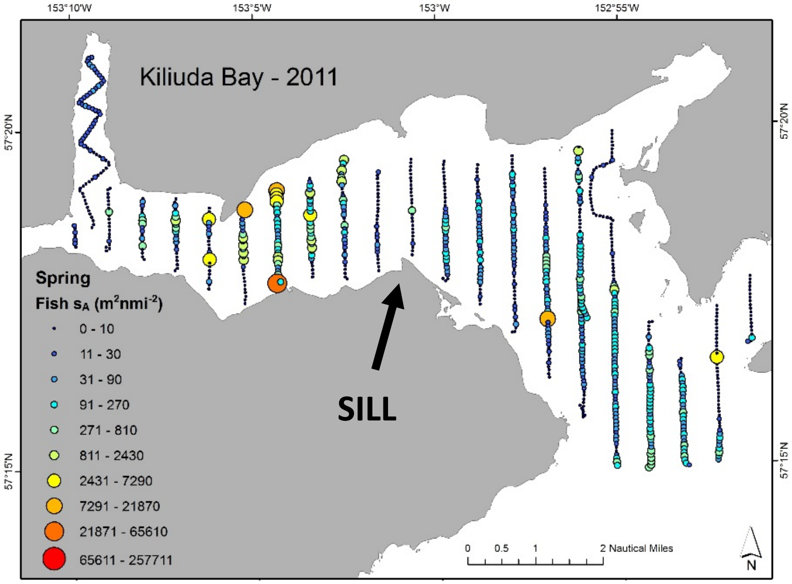

Fish 120 kHz S_A (m^2nmi^{-2}) - spring

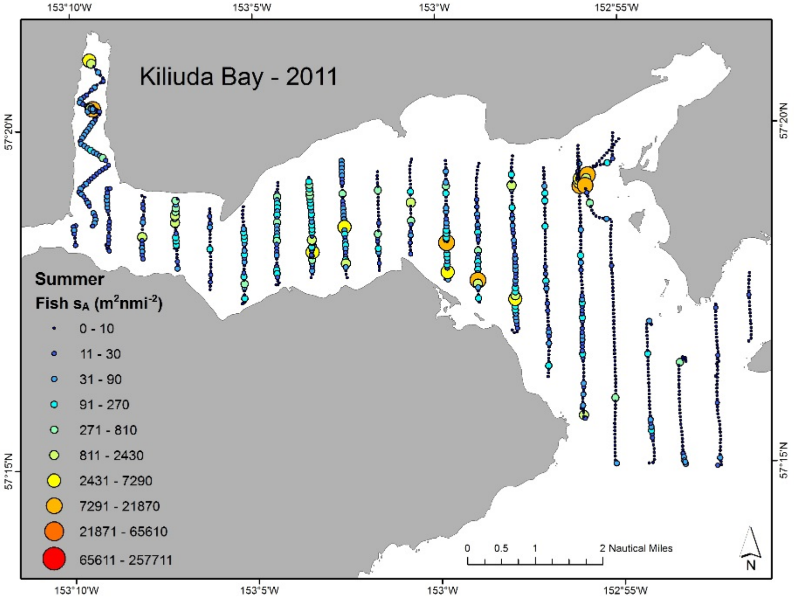
Zooplankton 120 kHz S_A (m^2nmi^{-2}) - spring

Fish 120 kHz S_A (m^2nmi^{-2}) - summer

Zooplankton 120 kHz S_A (m^2nmi^{-2}) - summer

Figure 4. -- Mean acoustic backscatter measured during GOAIERP nearshore surveys for fish and zooplankton by site, season (spring and summer), and year. Missing values indicate year/season combinations where sampling did not occur. An * indicates an extremely high value (i.e., Zooplankton, Izhut Bay, spring, 2011) that was truncated to allow better resolution of the remaining values.





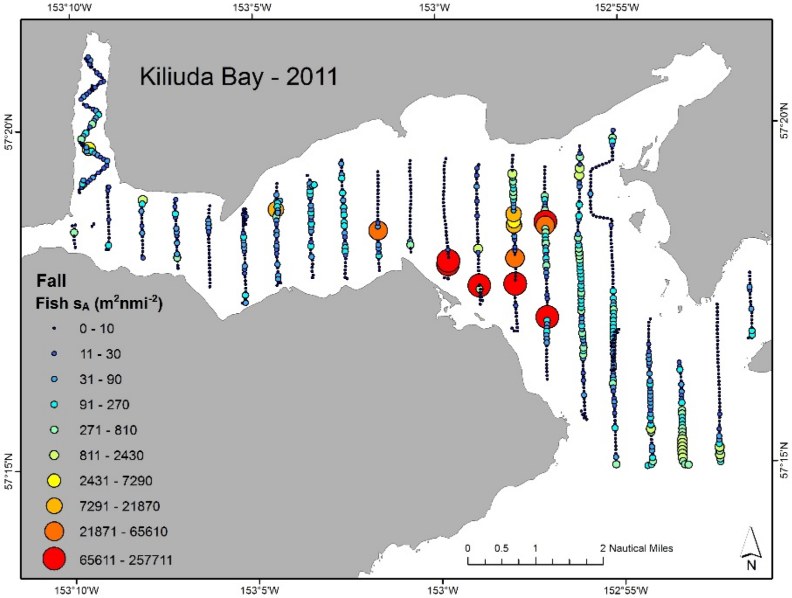


Figure 5. – WGSR Kiliuda Bay acoustic transect results for fish at s_A ($m^2\ nmi^{-2}$) for 2011 in the spring, summer, and fall.

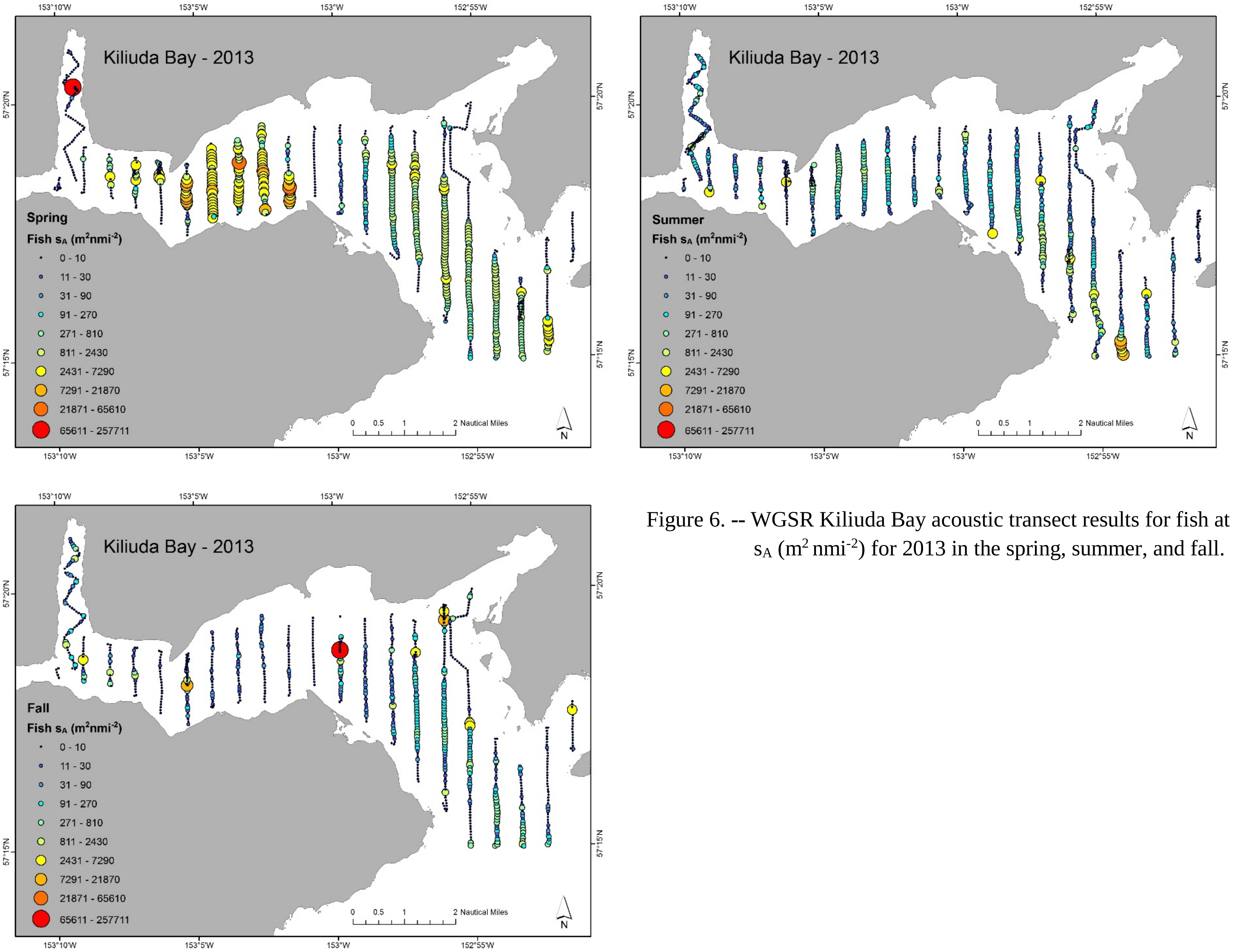


Figure 6. -- WGSR Kiliuda Bay acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2013 in the spring, summer, and fall.

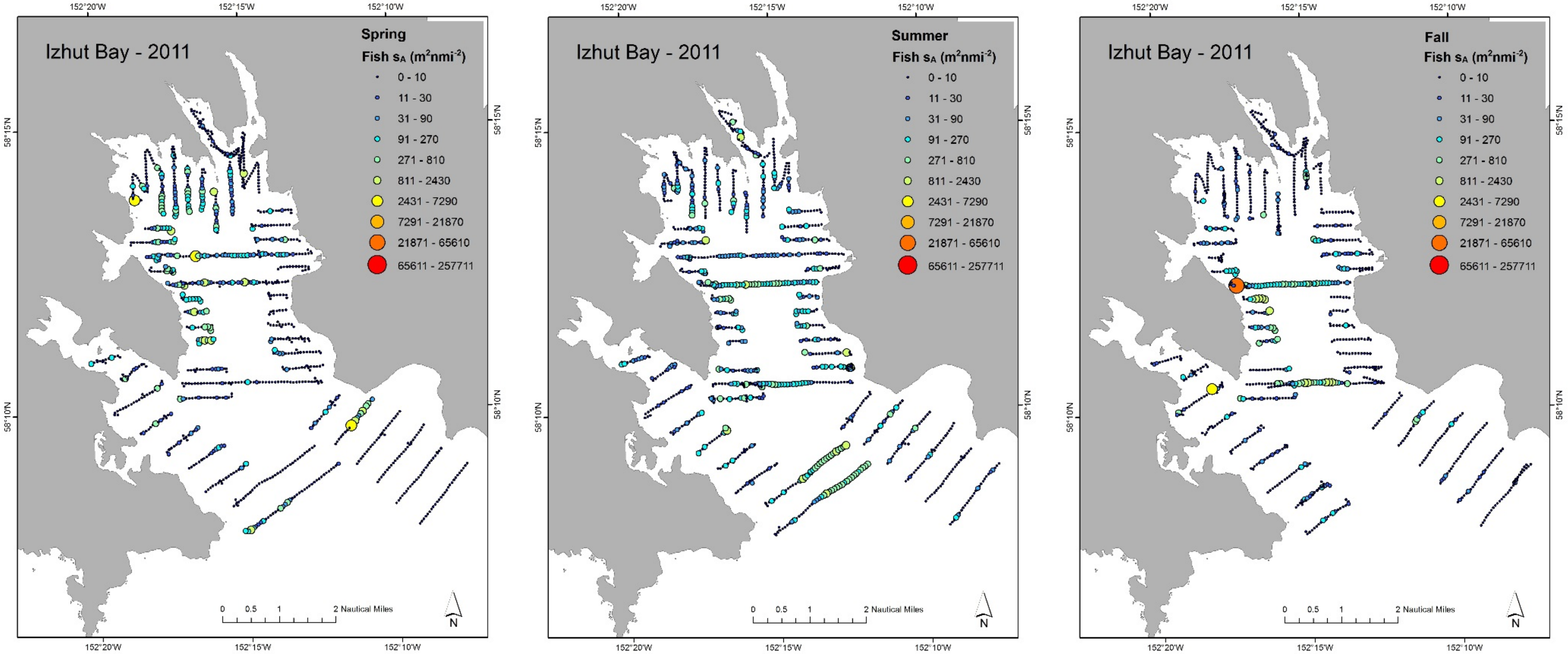


Figure 7. -- WGSR Izhut Bay acoustic transect results for fish at s_A ($m^2\,nmi^{-2}$) for 2011 in the spring, summer, and fall.

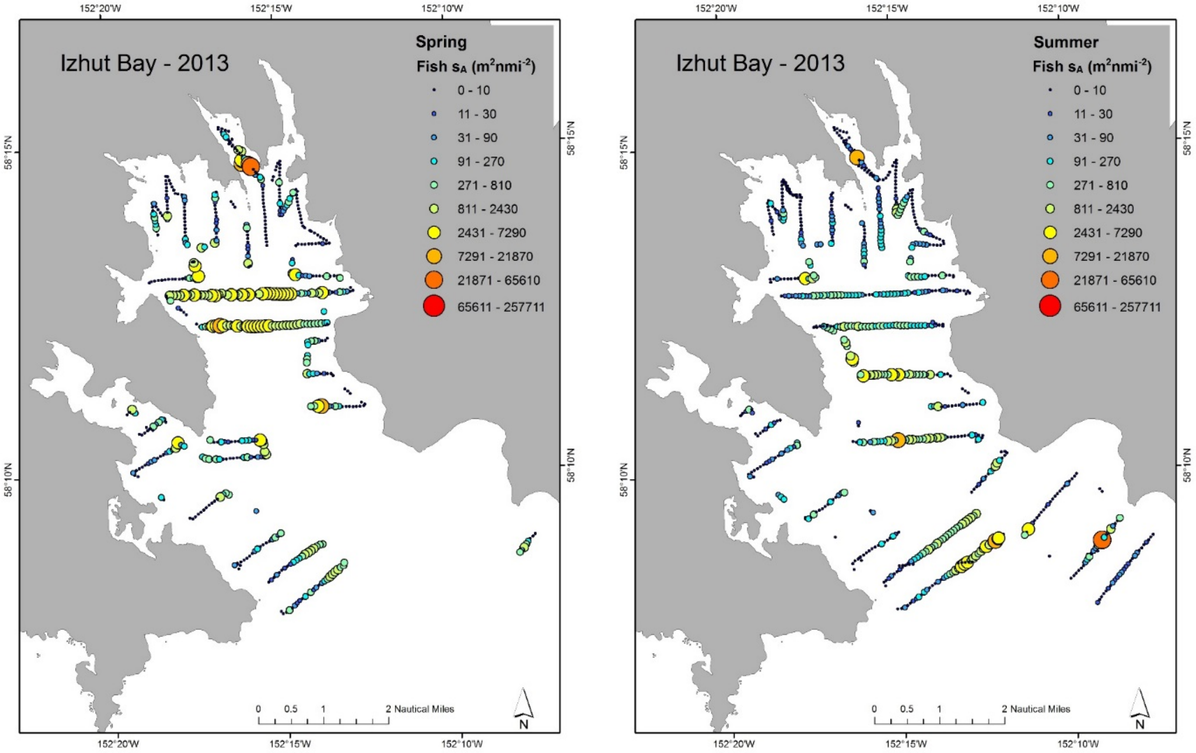
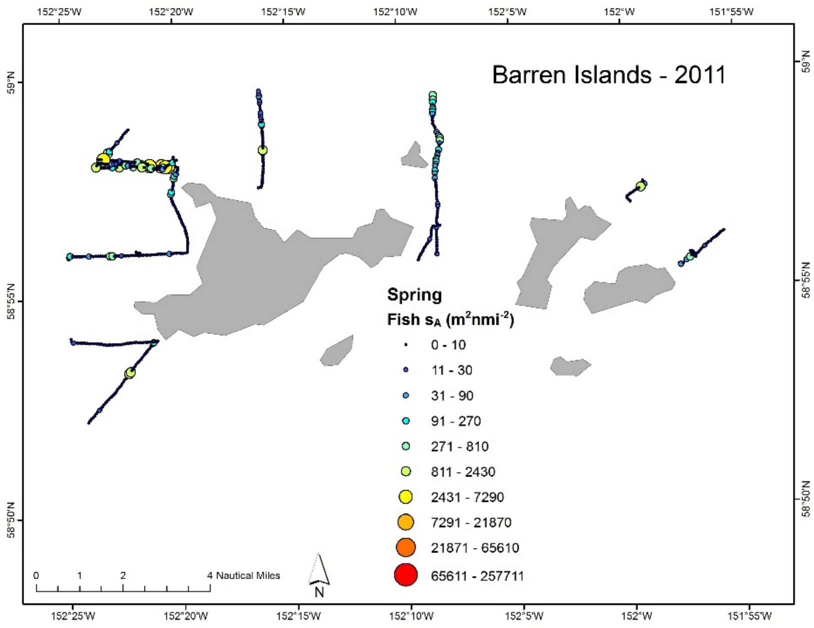
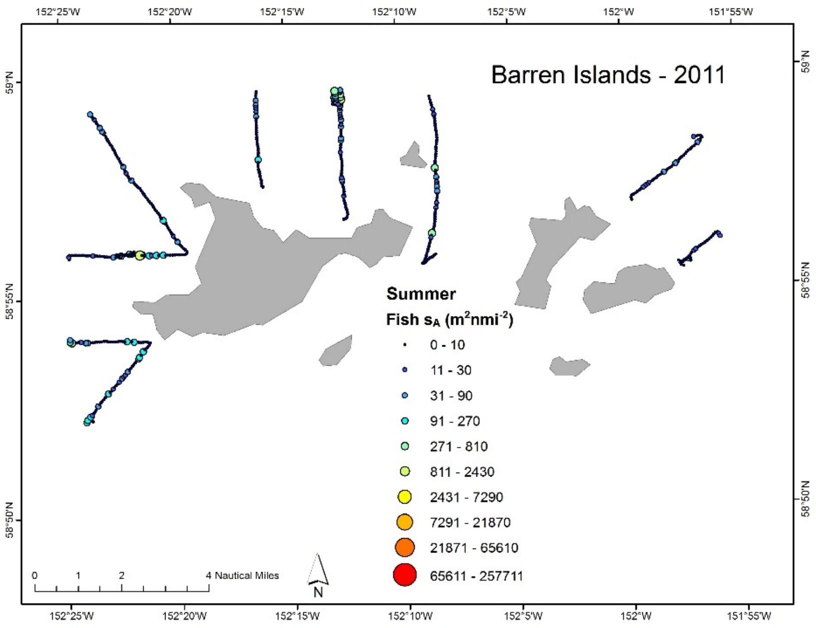


Figure 8. -- WGSR Izhut Bay acoustic transect results for fish at s_A ($m^2\,nmi^{-2}$) for 2013 in the spring and summer. No acoustic sampling occurred in fall 2013.





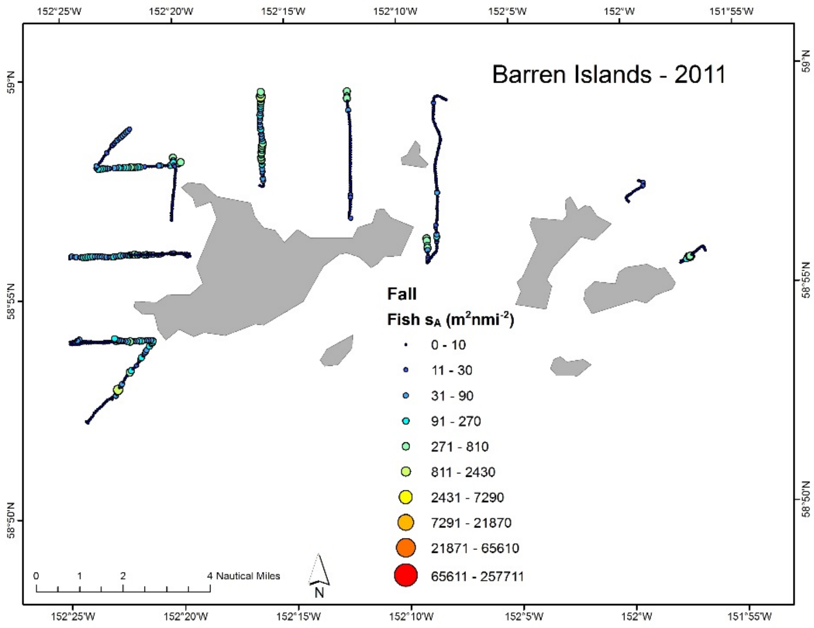


Figure 9. -- WGSR Barren Islands acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2011 in the spring, summer, and fall.

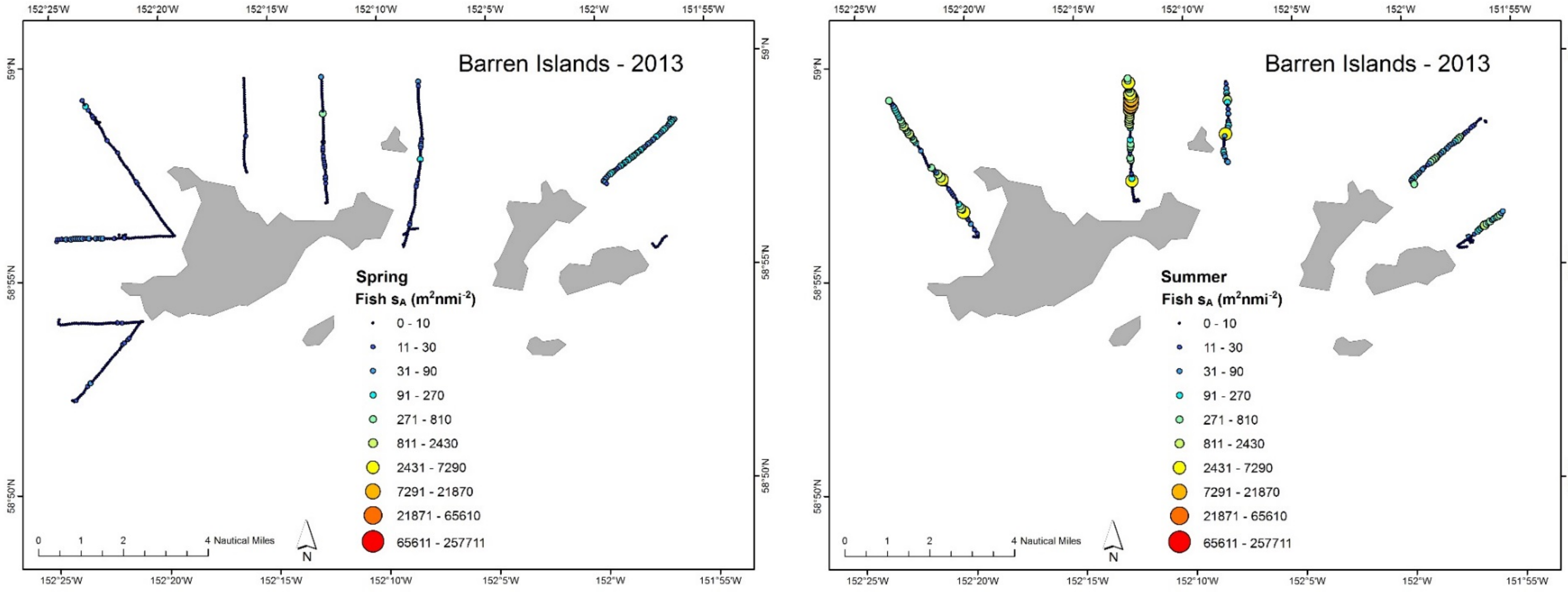
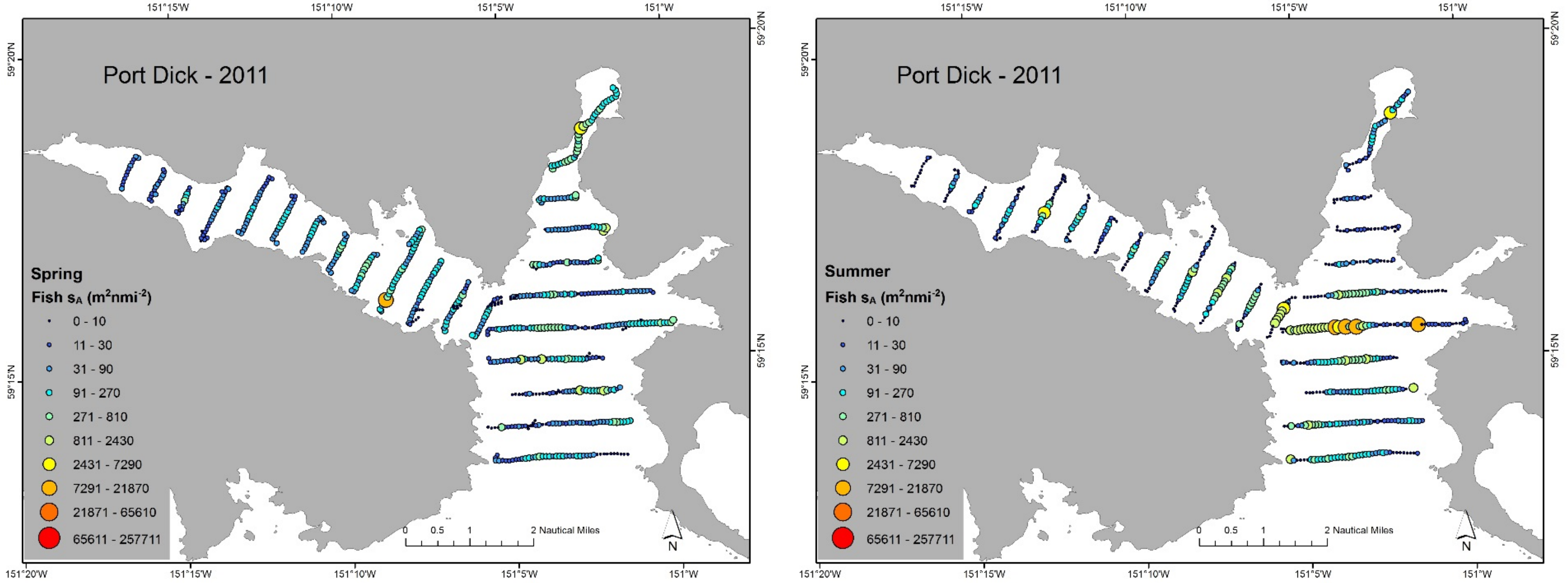


Figure 10. -- WGSR Barren Islands acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2013 in the spring and summer. No acoustic sampling occurred in fall 2013.



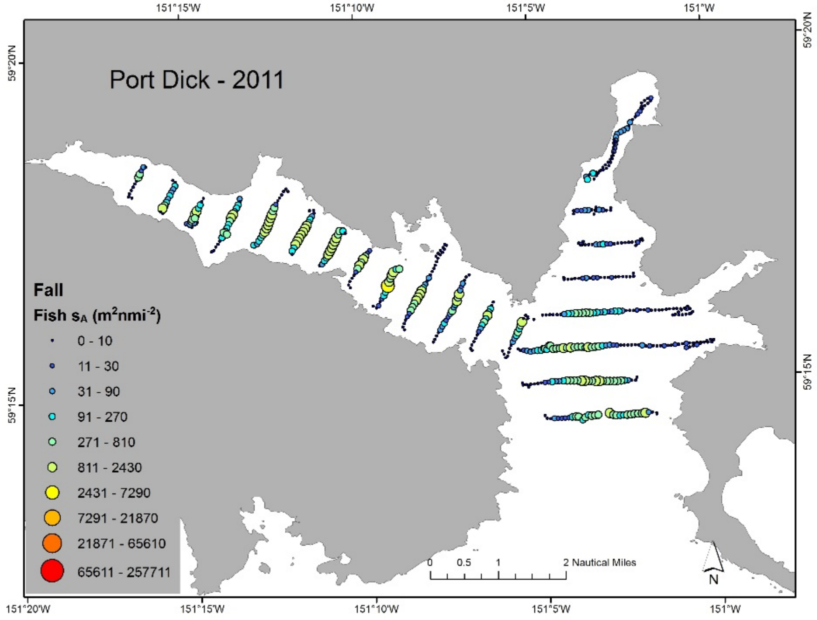
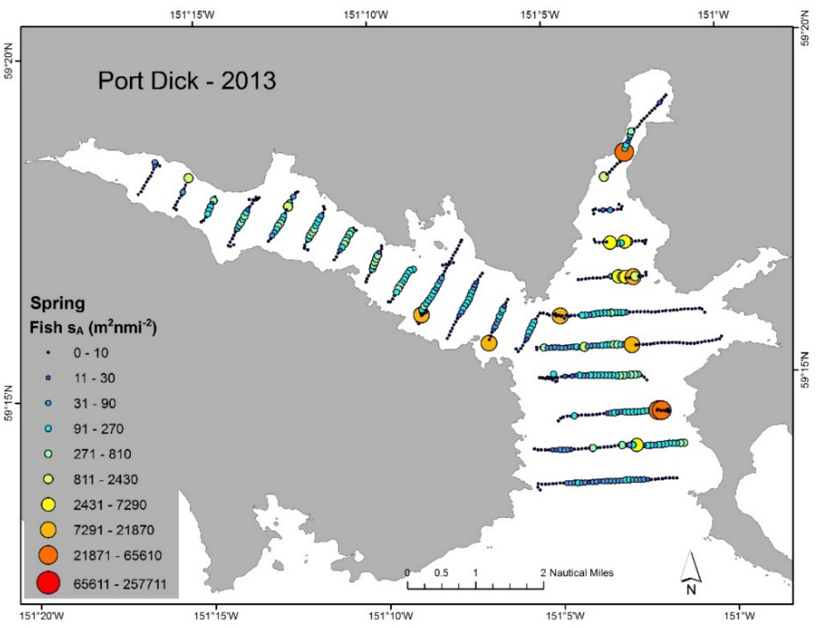
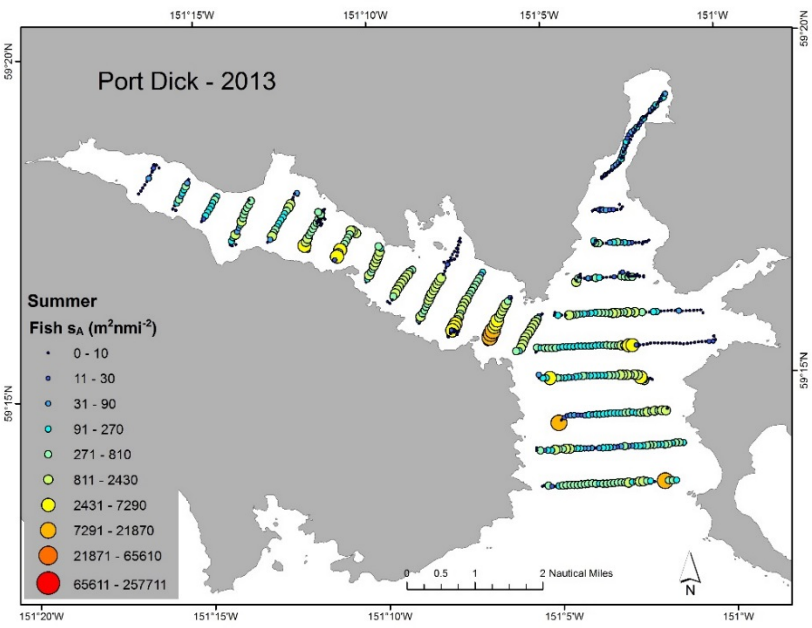


Figure 11. -- WGSR Port Dick acoustic transect results for fish at s_A ($m^2 nmi^{-2}$) for 2011 in the spring, summer, and fall.





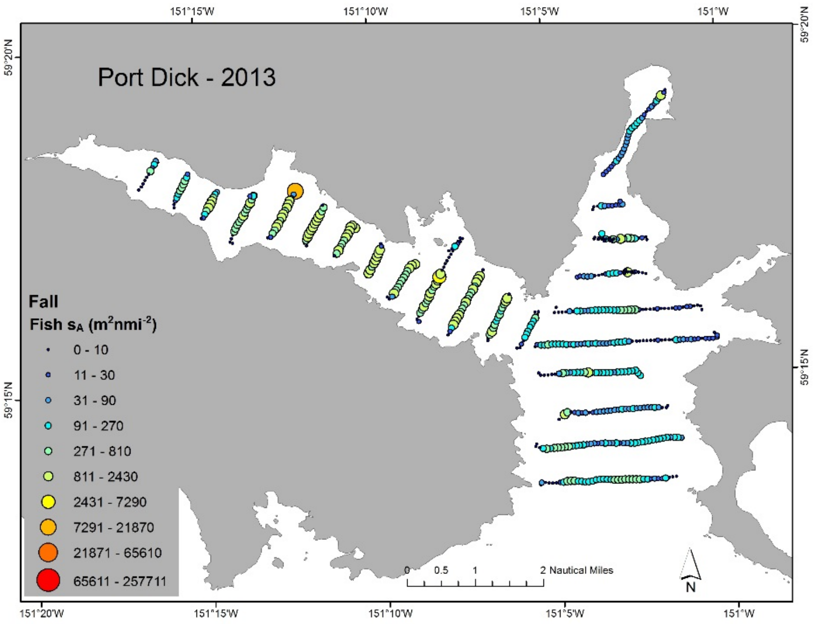


Figure 12. -- WGSR Port Dick acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2013 in the spring, summer, and fall.

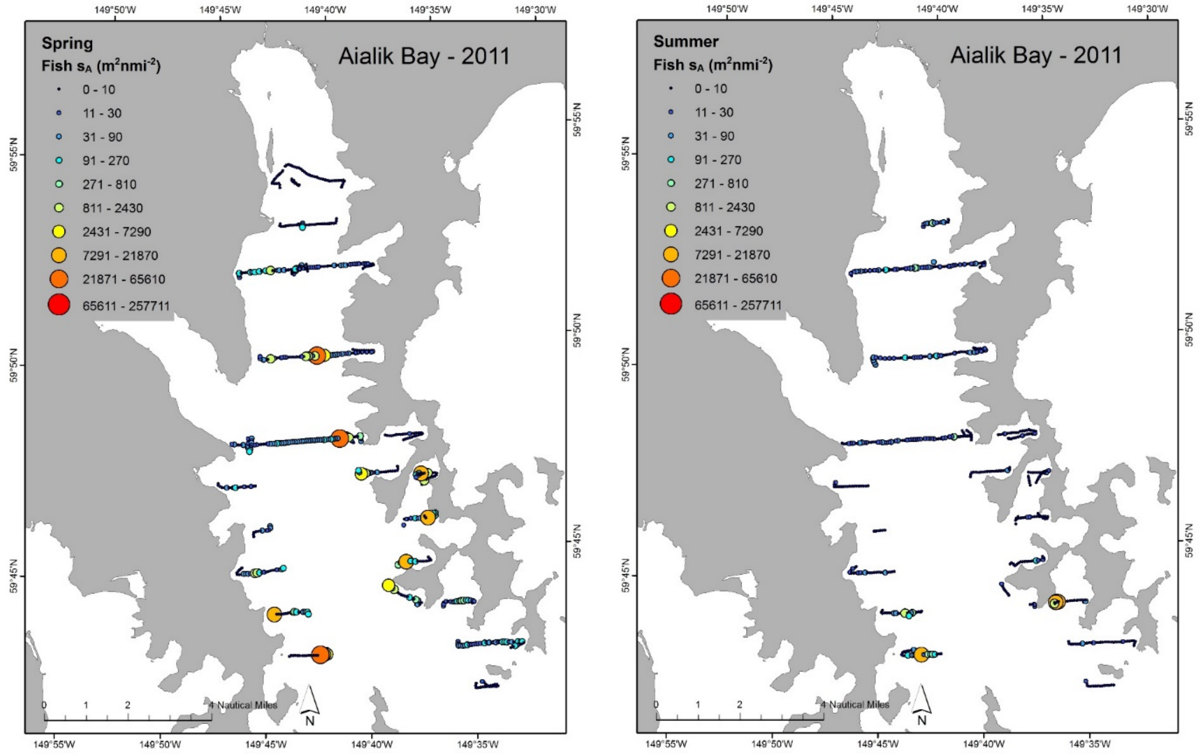


Figure 13. -- WGSR Aialik Bay acoustic transect results for fish at s_A ($m^2 nmi^{-2}$) for 2011 in the spring and summer. No acoustic sampling occurred in fall 2011.

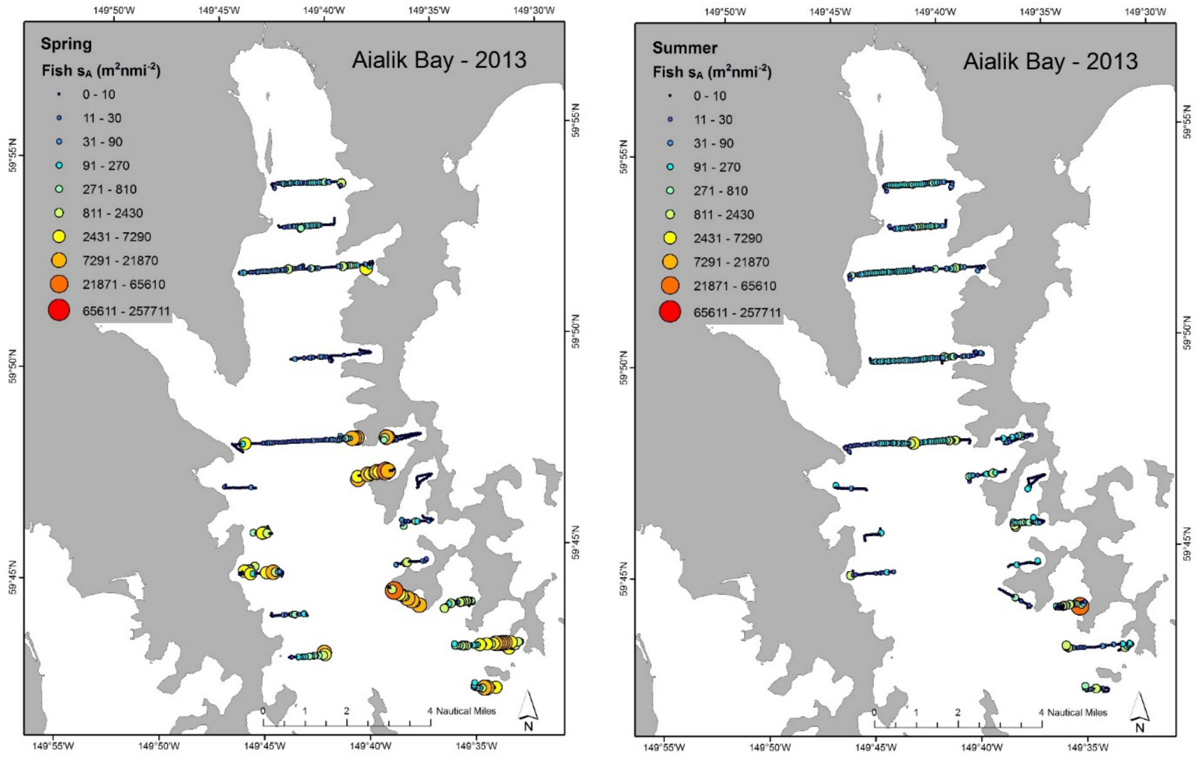


Figure 14. -- WGSR Aialik Bay acoustic transect results for fish at s_A ($m^2\ nmi^{-2}$) for 2013 in the spring and summer. No acoustic sampling occurred in fall 2013.

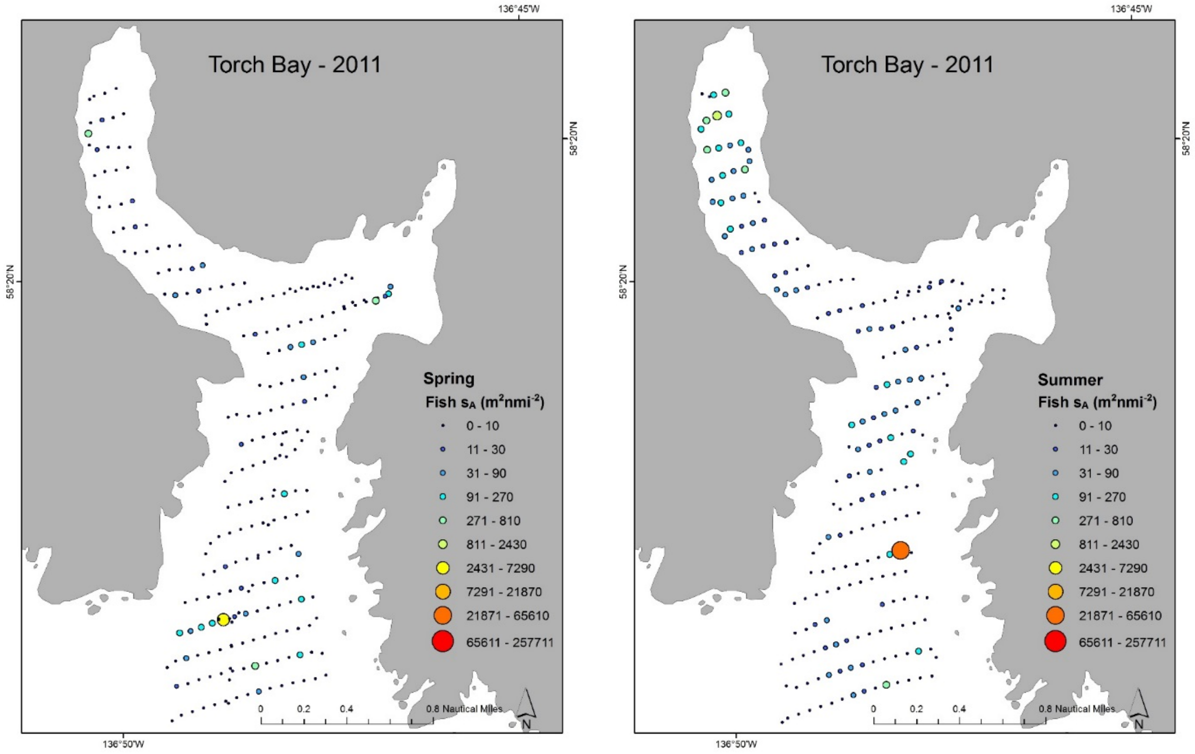


Figure 15. -- EGSR Torch Bay acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2011 in the spring and summer. No acoustic sampling occurred in fall 2011.

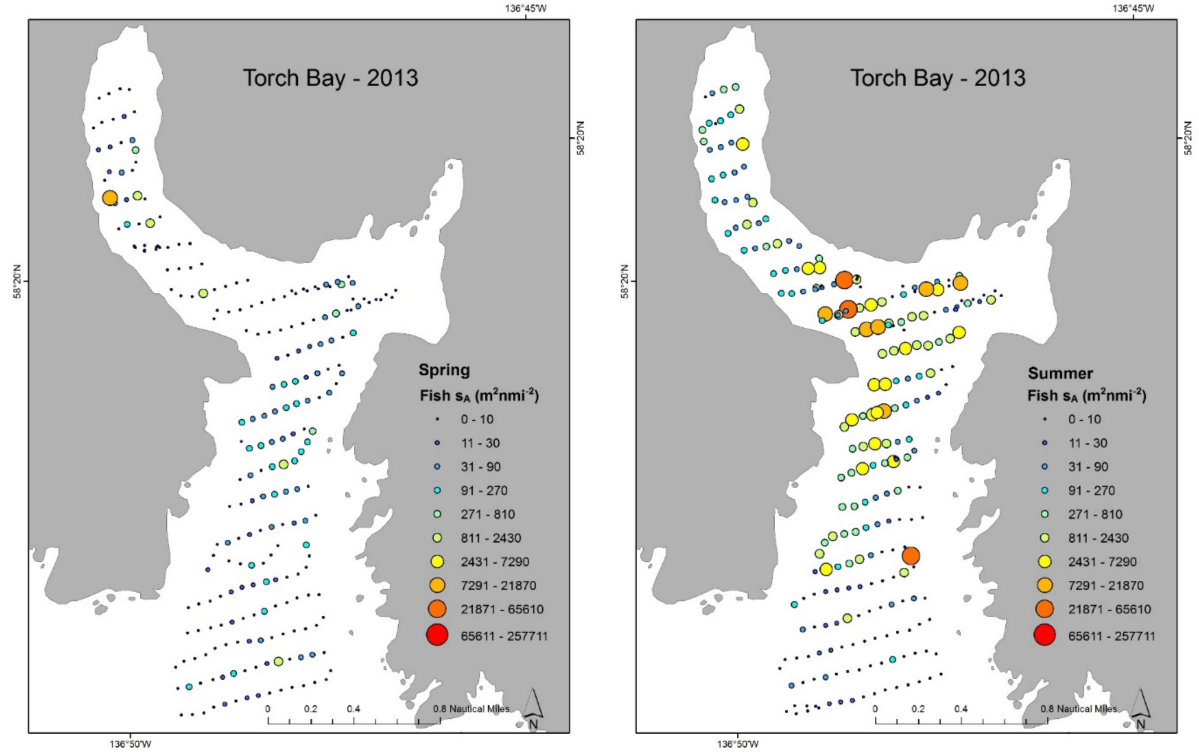


Figure 16. -- EGSR Torch Bay acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2013 in the spring and summer. No acoustic sampling occurred in the fall 2013.

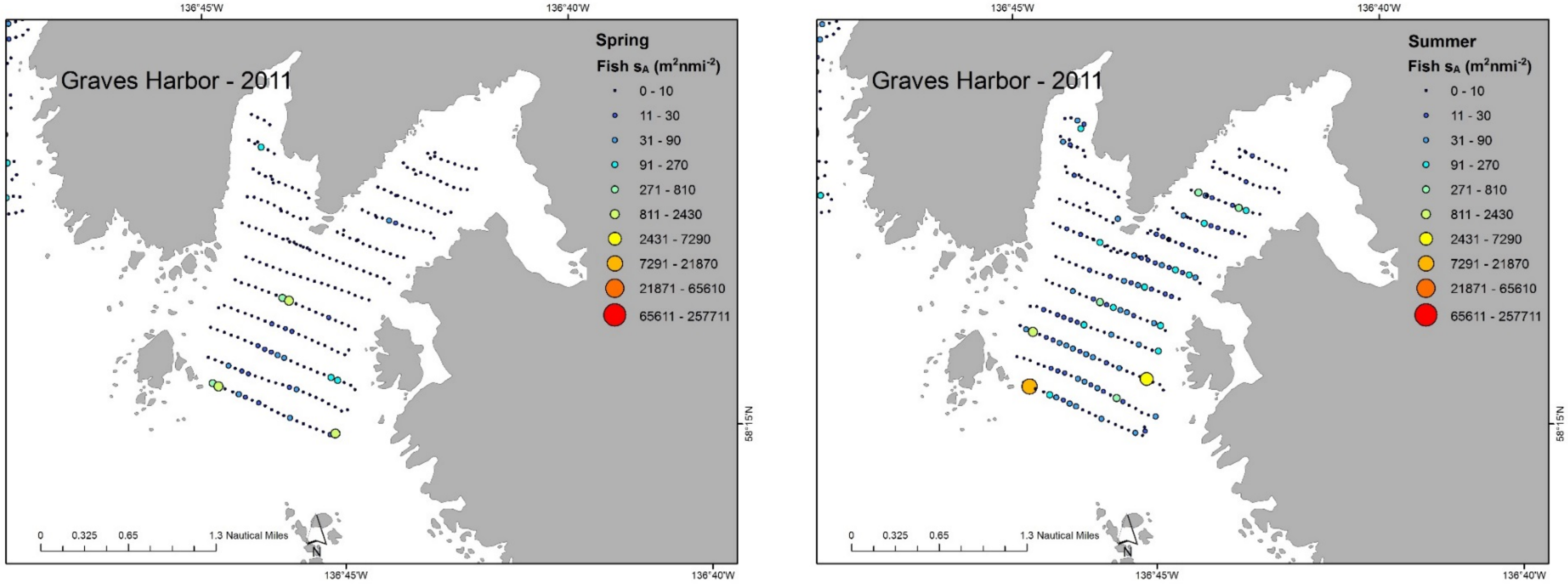


Figure 17. -- EGSR Graves Harbor acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2011 in the spring and summer. No acoustic sampling occurred in fall 2011.

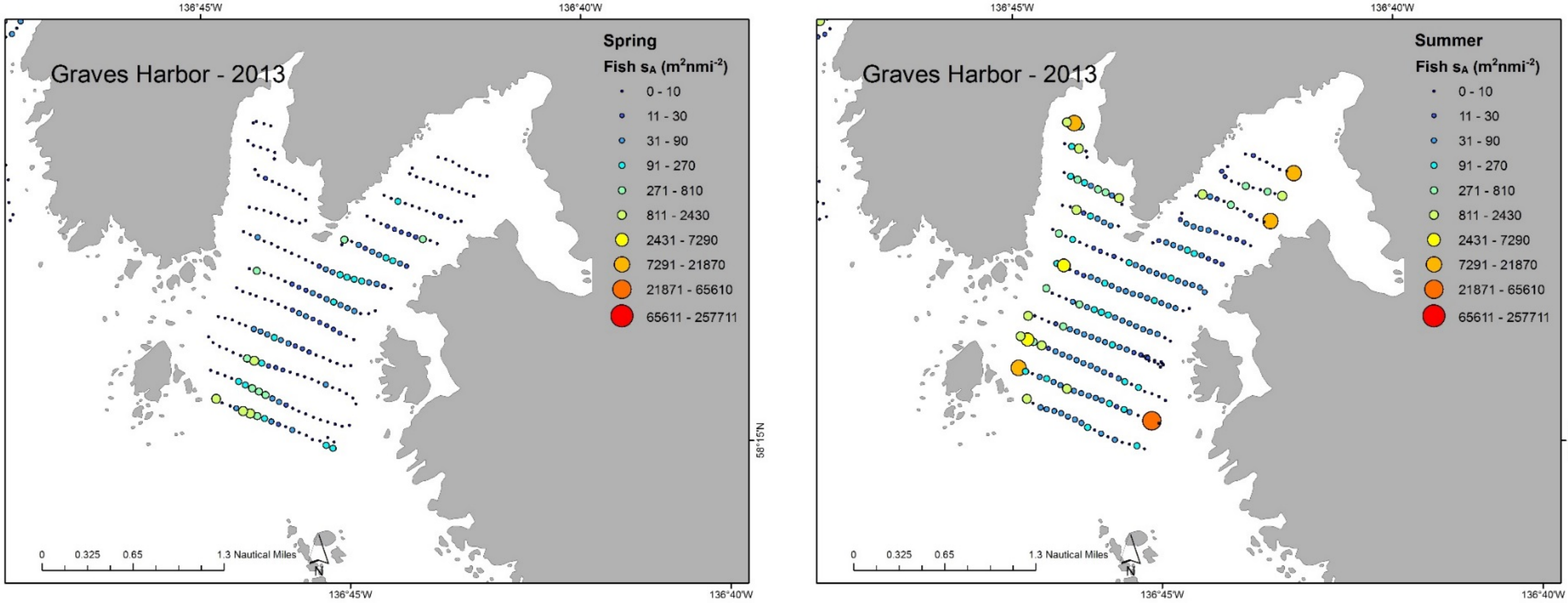


Figure 18. -- EGSR Graves Harbor acoustic transect results for fish at s_A ($m^2 nmi^{-2}$) for 2013 in the spring and summer. No acoustic sampling occurred in fall 2013.

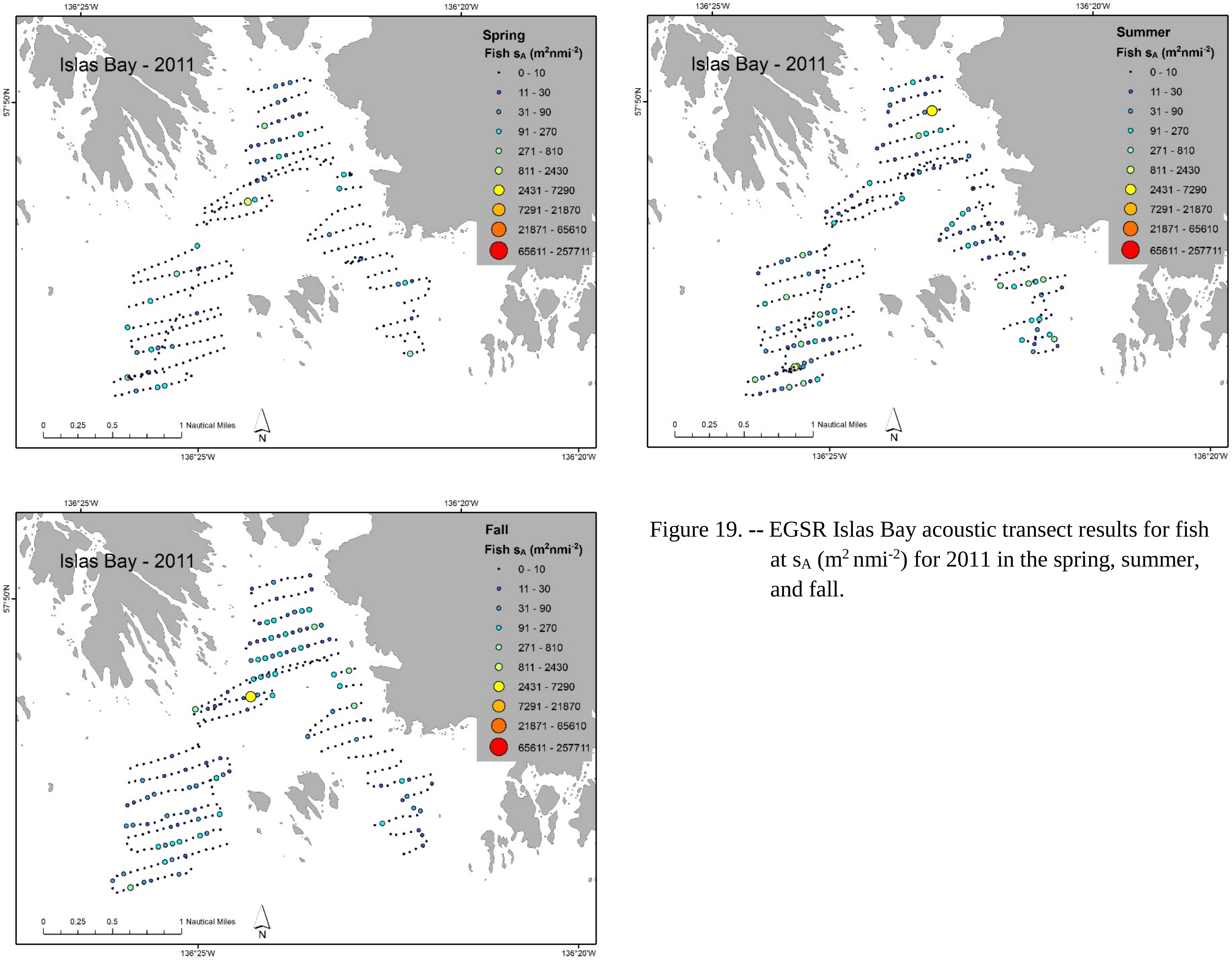


Figure 19. -- EGSR Islas Bay acoustic transect results for fish at s_A ($m^2\,nmi^{-2}$) for 2011 in the spring, summer, and fall.

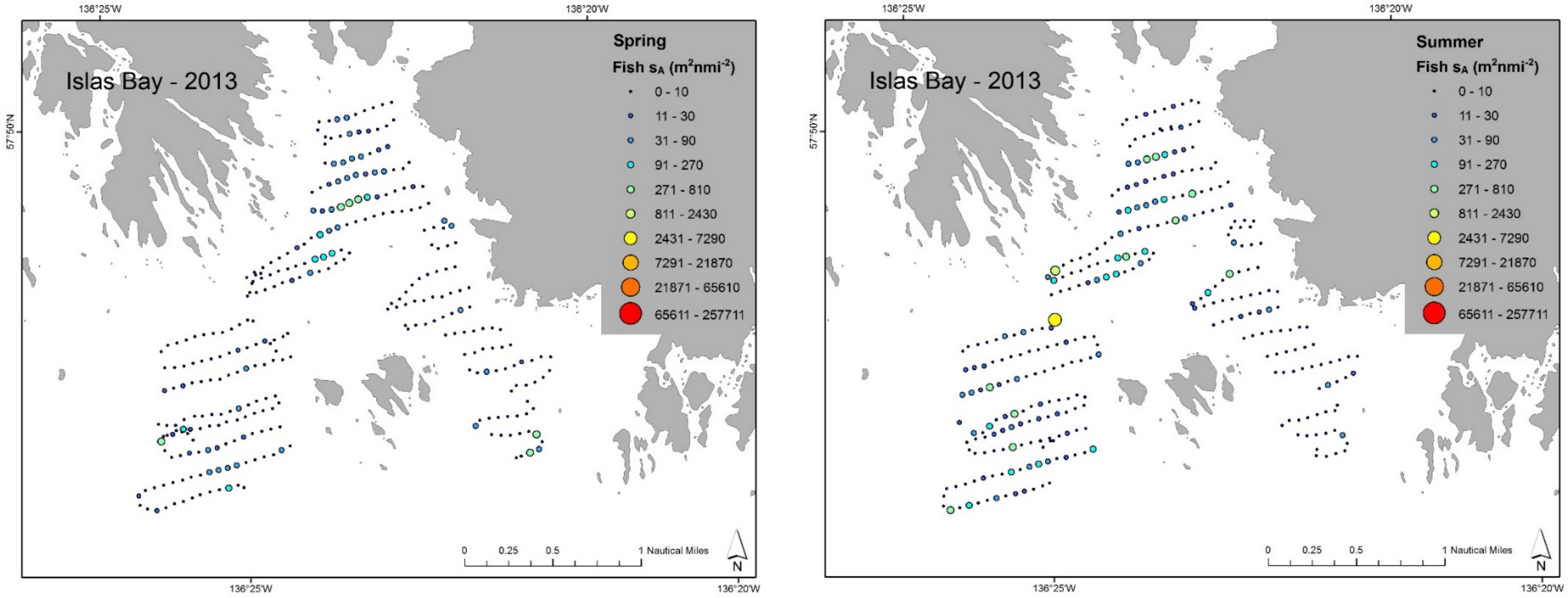
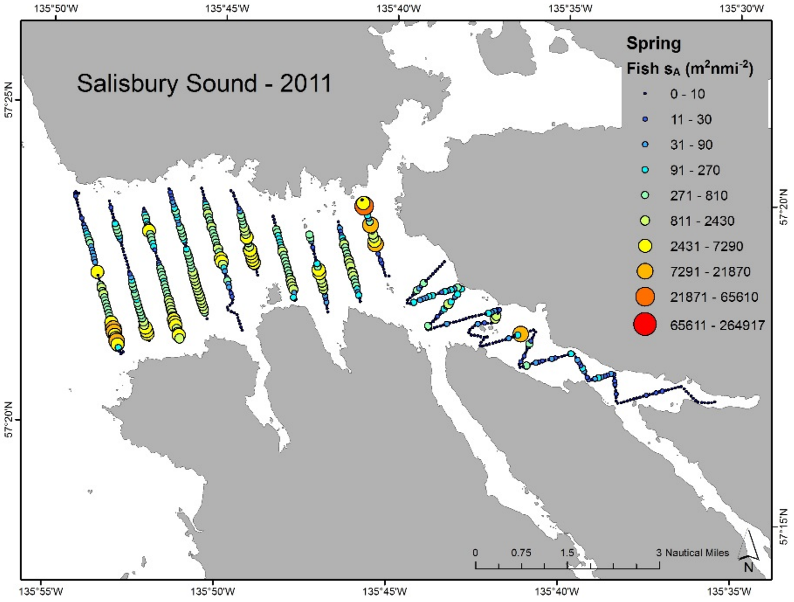
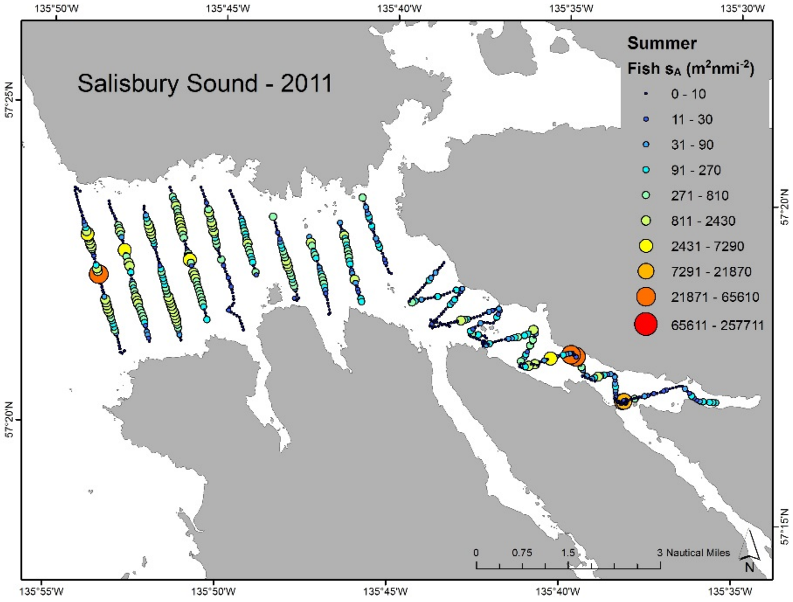


Figure 20. -- EGSR Islas Bay acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2013 in the spring and summer. No acoustic sampling occurred in fall 2013.





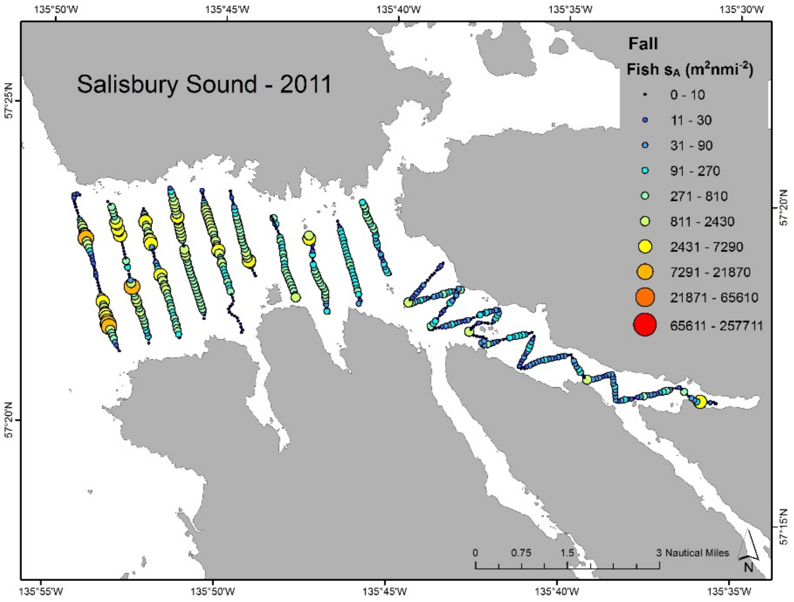
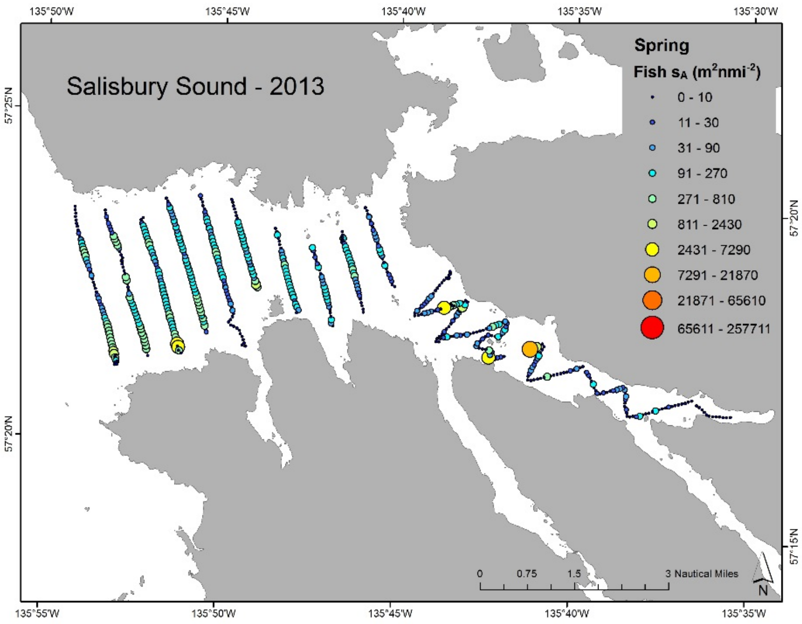
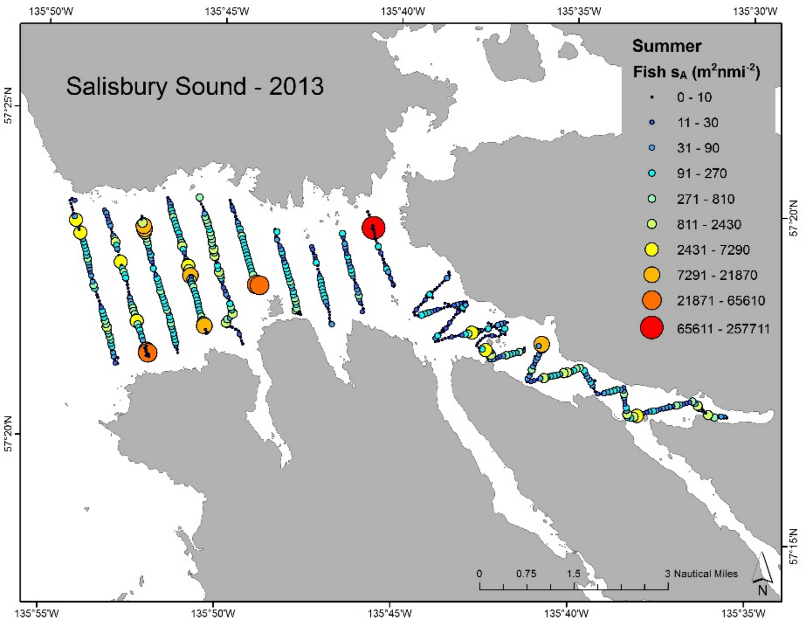


Figure 21. -- EGSR Salisbury Sound acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2011 in the spring, summer, and fall.





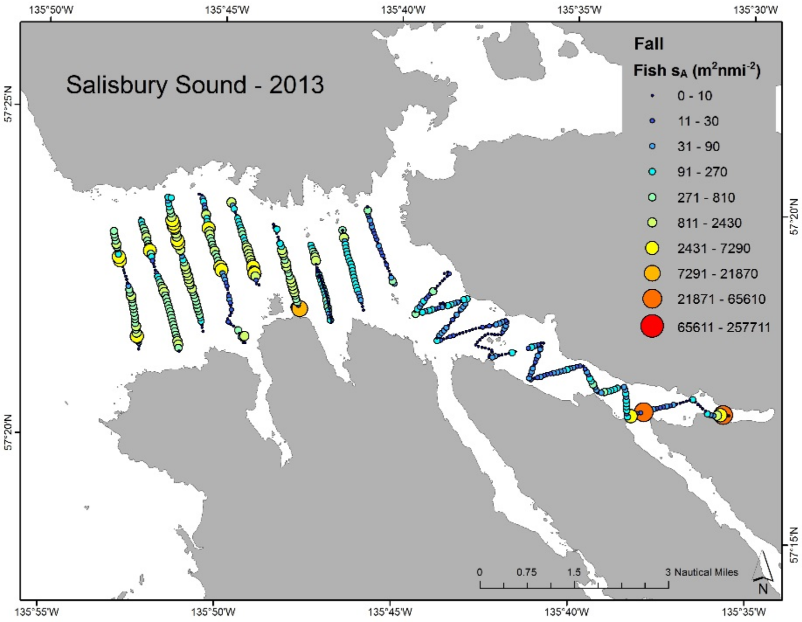
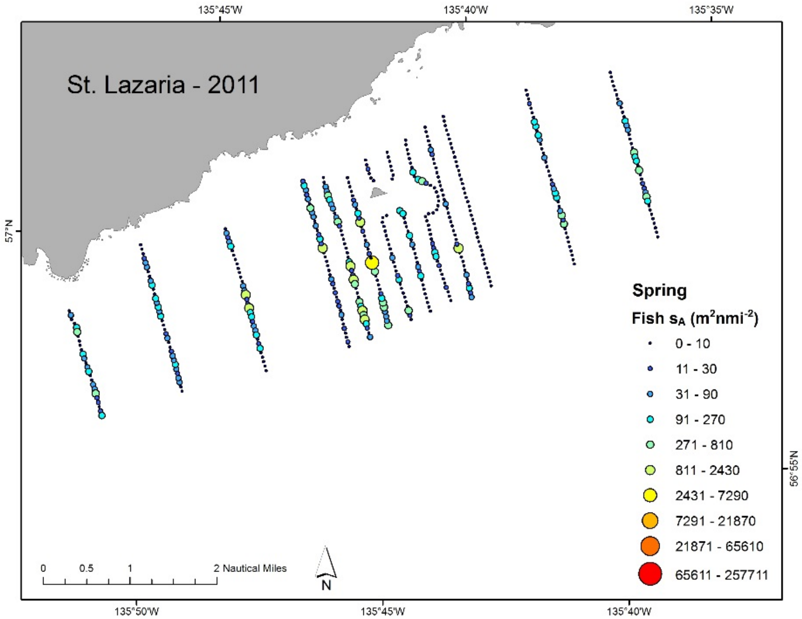
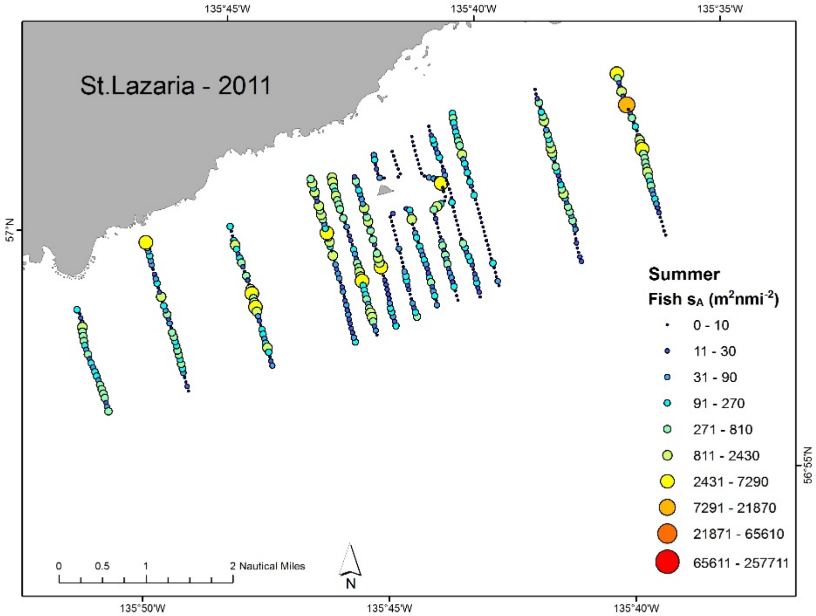


Figure 2. -- EGSR Salisbury Sound acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2013 in the spring, summer, and fall.





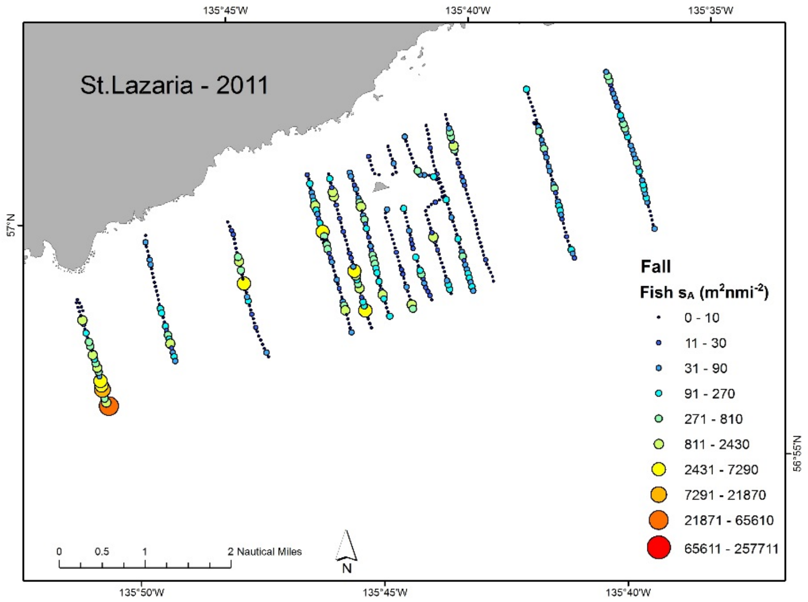
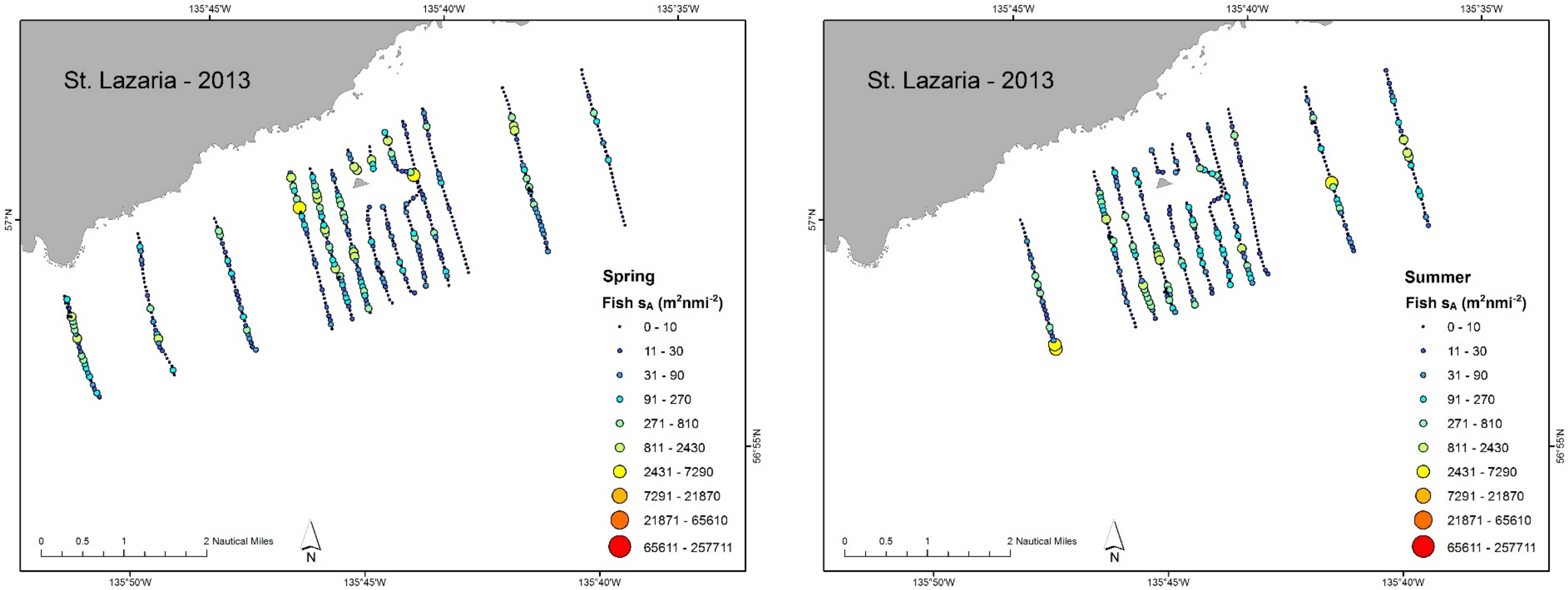


Figure 23. -- EGSR St. Lazaria Island acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2011 in the spring, summer, and fall.



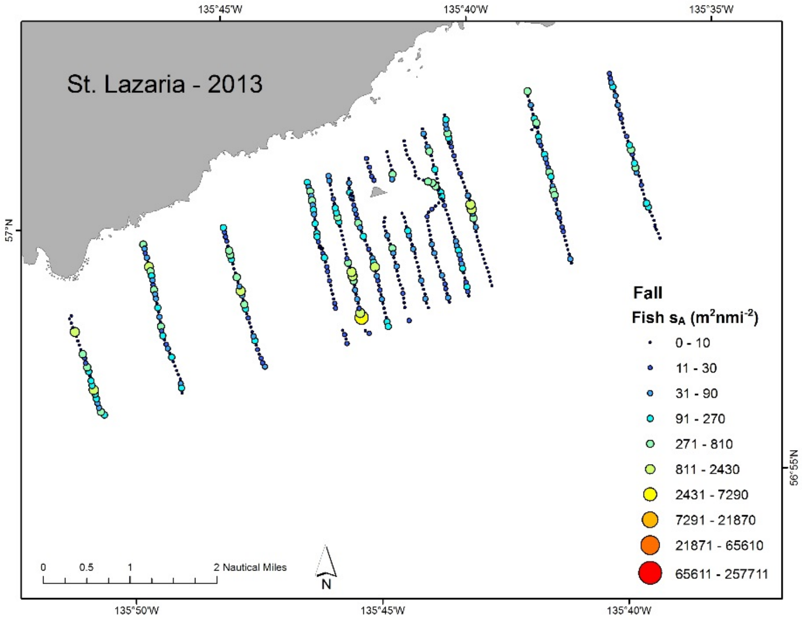


Figure 24. - EGSR St. Lazaria Island acoustic transect results for fish at s_A ($m^2\ nmi^{-2}$) for 2013 in the spring, summer, and fall.

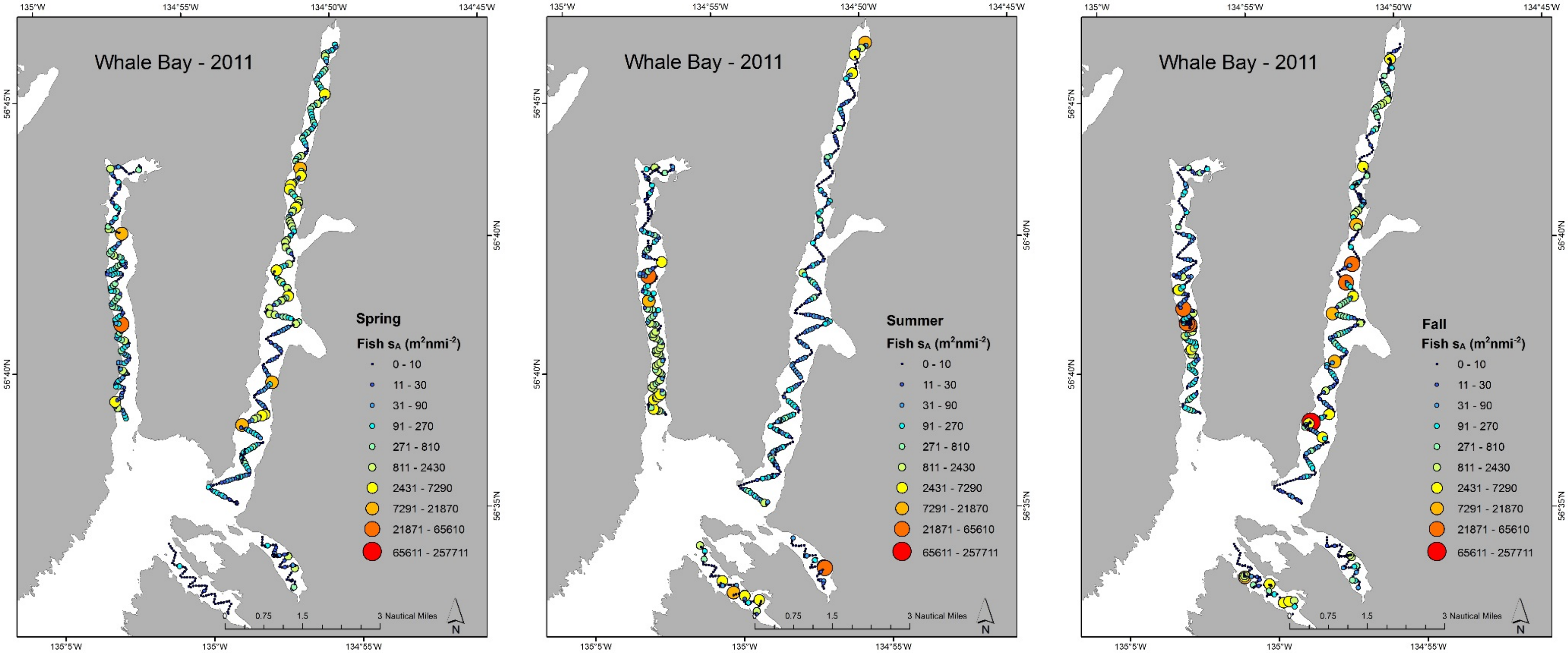


Figure 25. -- EGSR Whale Bay acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2011 in the spring, summer, and fall.

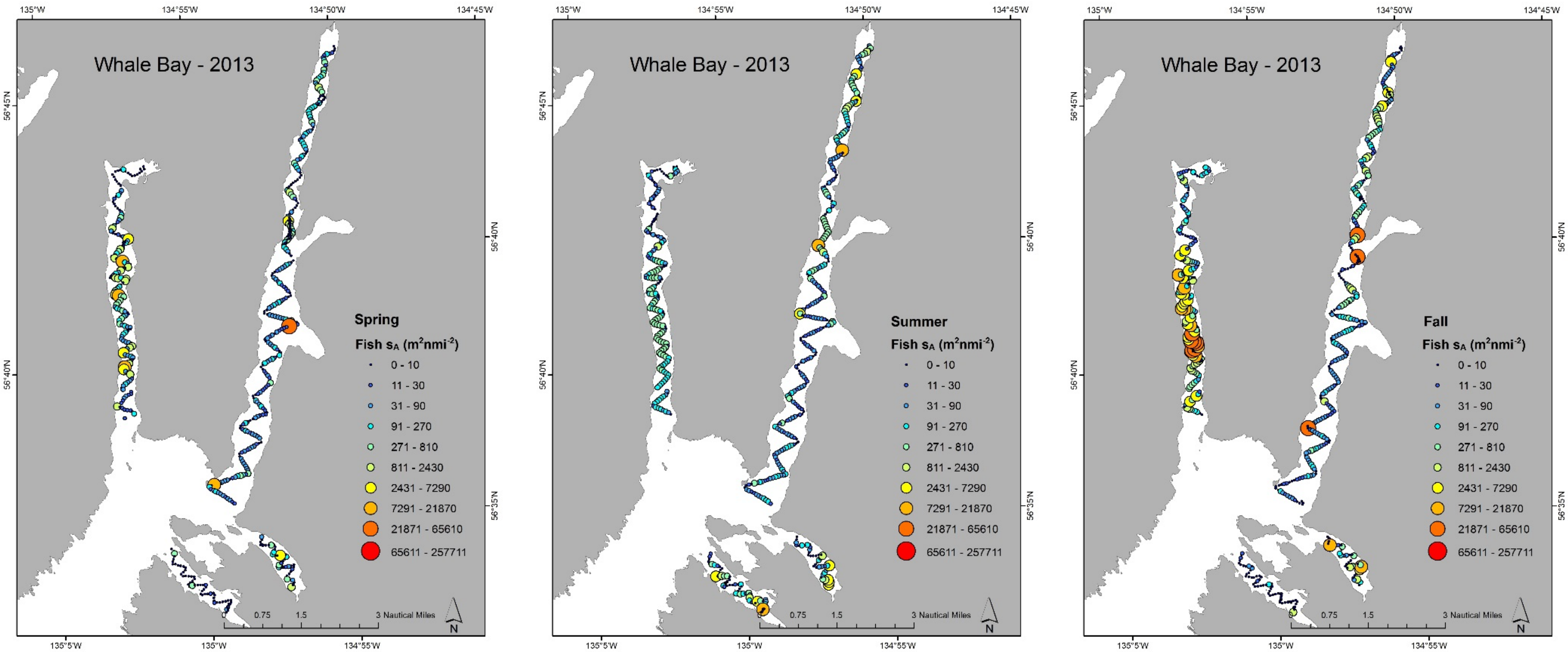


Figure 26. -- EGSR Whale Bay acoustic transect results for fish at s_A (m^2 nmi^{-2}) for 2013 in the spring, summer, and fall.

Nearshore Fish Sampling

Nearshore Community Composition

Kiliuda Bay*:* Species composition of purse seine catches in Kiliuda Bay (Figs. 27 and 28) displayed some of the most dramatic seasonal and within-bay variation observed in the surveys. The inner subarea (Dungie) had catches that were markedly different from sites in the outer part of the bay (Shearwater and Flavia). Dungie catches were dominated by saffron cod, whereas outer-bay catches were more diverse and contained more juvenile Pacific cod and greenlings. The outer bay also had abundant unidentified fish larvae in some seasons that were never observed in the inner-bay sites. This spatial separation is likely due to differences in vegetated habitat: Dungie sites contained only abundant eelgrass, whereas the outer subareas were mainly kelp. The only seines in the outer bay that contained saffron cod were those in areas that had a mix of kelp and eelgrass. The seasonal changes in species composition were mainly due to the influx of juvenile fishes, particularly age-0 Pacific cod, saffron cod, and greenlings. In spring, these species were either not present or the individuals were older juveniles (age-1+) or (in the case of saffron cod) adults. In summer, age-0 Pacific cod dominated many hauls, and catches of saffron cod contained a mix of age classes. Fall catches contained larger age-0 fish except for 2013, when it appeared that age-0 Pacific cod were no longer present in the outer bay.

Izhut Bay: Catches in Izhut Bay (Figs. 29 and 30) did not have a consistent spatial trend, which may have resulted from the lack of differences among subareas in habitat types (i.e., kelp was the dominant habitat type). Similar to Kiliuda Bay, seasonal patterns appeared to be due to the appearance of age-0 fishes, primarily Pacific cod and lingcod, in summer and continuing into fall. In Izhut Bay, catches also varied considerably among years. In 2013, large numbers of juvenile (likely age-1) Pacific cod and walleye pollock were observed in spring. In summer 2013, juvenile Pacific herring were in high abundance and dominated all catches; in contrast only a few Pacific herring were encountered in 2011.

Port Dick: The species composition of catches in Port Dick (Figs. 31 and 32) varied with season and subarea and between years. The species observed in the western part of the bay (Swan and Waterfall) were substantially different from those in the other subareas, although the basis for this variation differed between years and seasons. In summer 2011, the western catches were dominated by large numbers of age-0 walleye pollock that were not captured in other subareas. In 2013, catches in Swan (where eelgrass was the only habitat type) were mostly saffron cod. The mixed catches in other subareas likely reflected a mix of habitat types. Juvenile rockfishes occurred almost exclusively in the Taylor and Sunday subareas where the habitat consisted mainly of kelps and an eelgrass/kelp mix. Juvenile greenlings occurred in all subareas. A notable observation in Port Dick was the occurrence of large numbers of age-0 Pacific herring in summer of both years, which was limited to the eastern part of the bay.

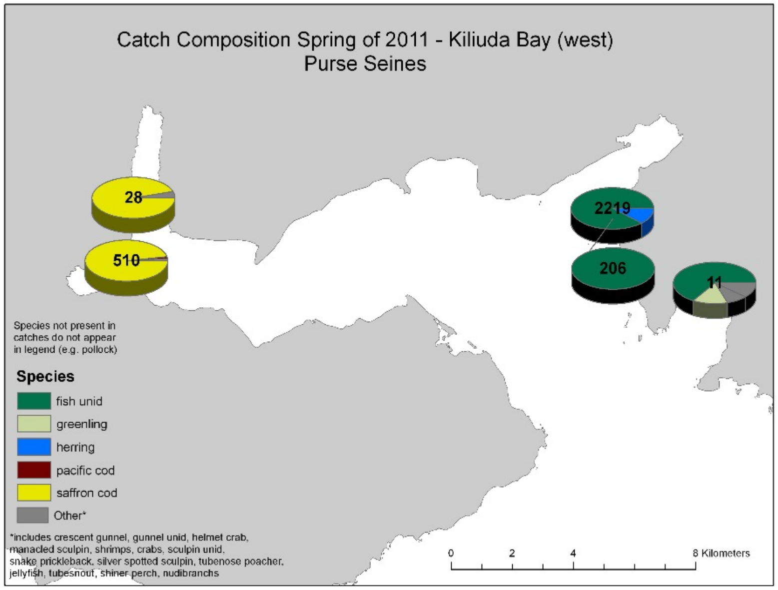
Aialik Bay: Variability in the nearshore fish community in Aialik Bay appeared to be driven mostly by the concentration of suitable nearshore habitat at the head of the bay (Sparkle subarea; Figs. 33 and 34). The outer subareas, Coleman and Three, were kelp habitats. The Three subarea was also typical of the outer bay where the shoreline topography was very steep and there were limited areas where shallow-water vegetated habitats occurred in appreciable densities. In contrast, Sparkle contained a mix of habitat types including some eelgrass. This may explain why age-0 Pacific cod, saffron cod, and walleye pollock were found in only in Sparkle. Catches in Coleman and Three consisted of juvenile rockfishes, greenlings, and Pacific herring. Catches also varied between years, particularly in the abundance of age-0 Pacific cod that were not encountered anywhere in Aialik Bay in 2011. In neither year was the survey able to visit Aialik Bay in fall.

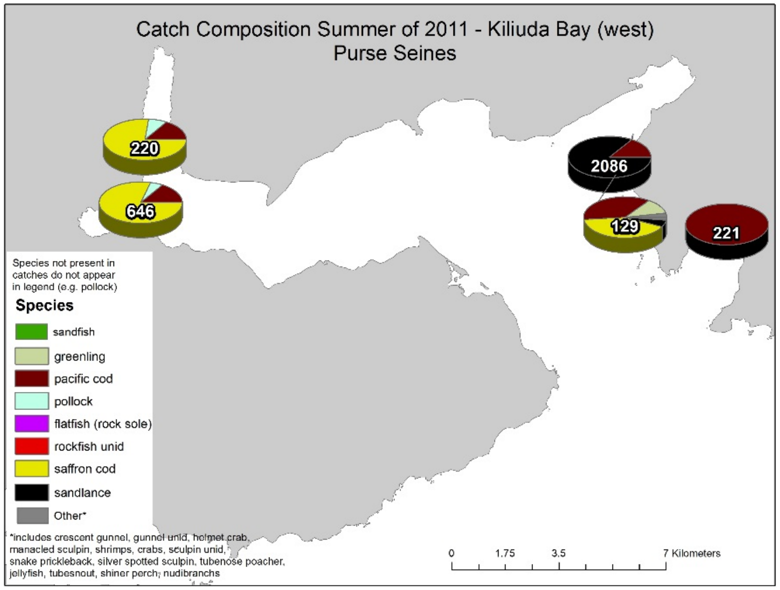
Torch Bay and Graves Harbor: The Torch Bay seine sites (Figs. 35 and 36) were limited to one section of the bay, so within-bay variation was not examined. In addition, we were unable to sample the nearshore in spring or fall of either year. Catches were substantially different between years, with age-0 Pacific cod occurring only in 2013. In summer 2013 we also observed a high abundance of age-0 Pacific herring. In the adjacent but larger Graves Harbor, spatial differences were evident. Age-0 Pacific cod and walleye pollock were observed mainly in the outer subareas (Murk and Murphy). The inner bay (Graves) had a mix of species. The appearance of age-0 Pacific cod and walleye pollock shifted the species composition between spring and summer of 2013, and pollock occurred only in 2013.

Islas Bay: Seine sites in Islas Bay (Figs. 37 and 38) were close together but were divided into 3 subareas due to fine-scale differences in exposure and habitat type. As in other bays, species composition changed with season as age-0 Pacific cod and Pacific herring emerged in summer and fall. Pacific cod occurred consistently in the outer subarea (Fjordselheim), whereas the more protected Ilin and Porcupine subareas had a mix of species that varied between years. In summer 2011, large numbers of age-0 Pacific cod occurred in all 3 subareas; in 2013 they were present in Islas Bay but in low numbers and only in Fjordselheim. Juvenile rockfishes occurred in the majority of catches, as did juvenile greenlings. Age-0 Pacific herring were present in both years but in different seasons (fall 2011 vs. summer 2013). To provide a consistent means of comparison the data presented here do not include beach seine catches, but it should be noted that an eelgrass beach-seine site in the Ilin subarea had very high numbers of juvenile Pacific sand lance in summer 2013.

Salisbury Sound: Catches in Salisbury Sound (Figs. 39 and 40) varied considerably among subareas. In 2011, juvenile rockfishes dominated catches in the two innermost subareas (Baptist and Zeal) although fewer rockfishes were present in 2013. Juvenile greenlings occurred in all four subareas. Age-0 Pacific cod were mainly limited to the middle subarea (Kane) and were present in both years. The outermost subarea (Kalinin) differed the most in its fish community and in the amount of variability in species composition among seasons and years. In 2011, Kalinin catches were dominated by snake pricklebacks *Lumpenus sagitta* and unidentified larval fishes. Shiner perch were also observed only in this subarea. Catches in spring 2013 were dominated by juvenile Pacific sand lance, while 2013 summer and fall catches contained abundant age-0 Pacific herring. The habitat in Kalinin consisted largely of sand and detritus which likely influenced the abundance of snake pricklebacks and sand lance.

Whale Bay: Similar to Aialik Bay, the steep topography of much of the Whale Bay shoreline (Figs. 41 and 42) limited the number of potential nearshore habitats. Vegetated pockets were found at the head of each of the long arms (Small and Great subareas). The Krishka area was the only part of the bay with consistent vegetated nearshore habitat. Catches varied among subareas but not in a consistent manner. Juvenile Pacific cod were observed only once, in fall 2011, and age-0 Pacific cod were never encountered in Whale Bay. Pacific herring, Pacific sand lance, and eulachon *Thaleichthys pacificus* were all observed in Whale Bay during at least one survey. Shiner perch were abundant in the eelgrass beds of the Small subarea.





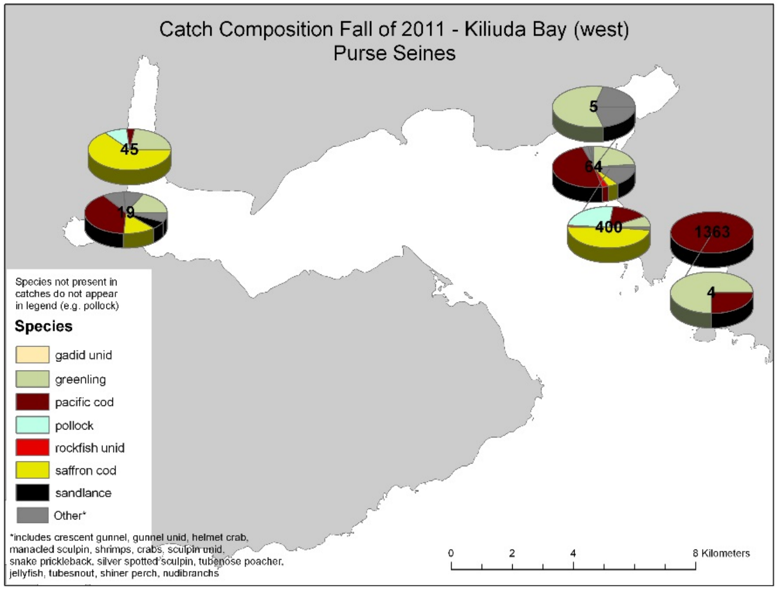
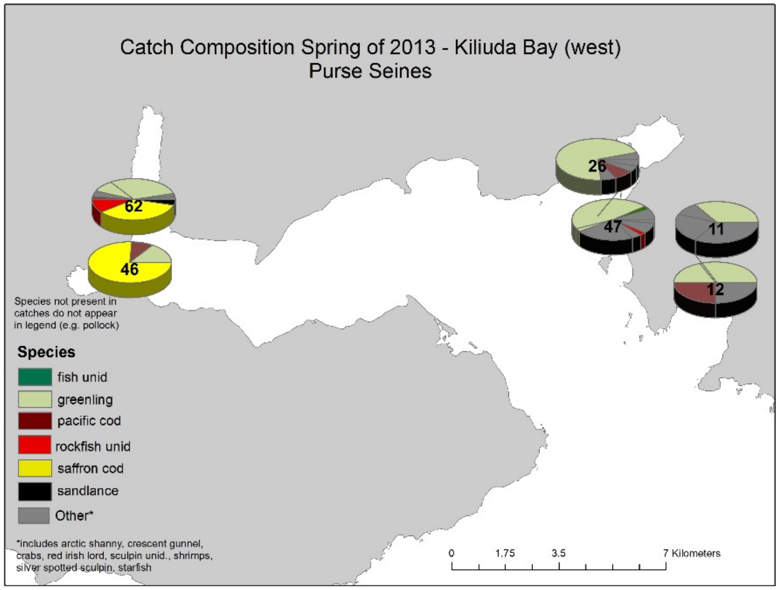
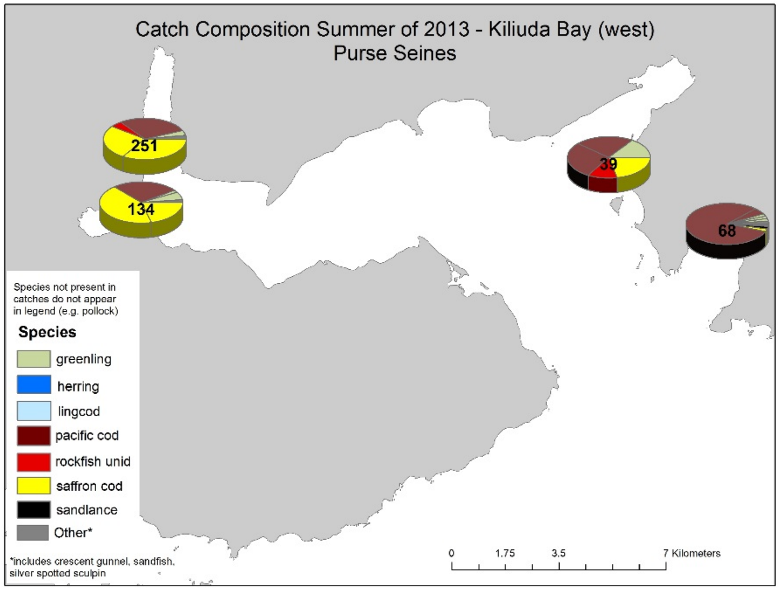


Figure 27. -- WGSR Kiliuda Bay catch composition for 2011 in the spring, summer, and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.





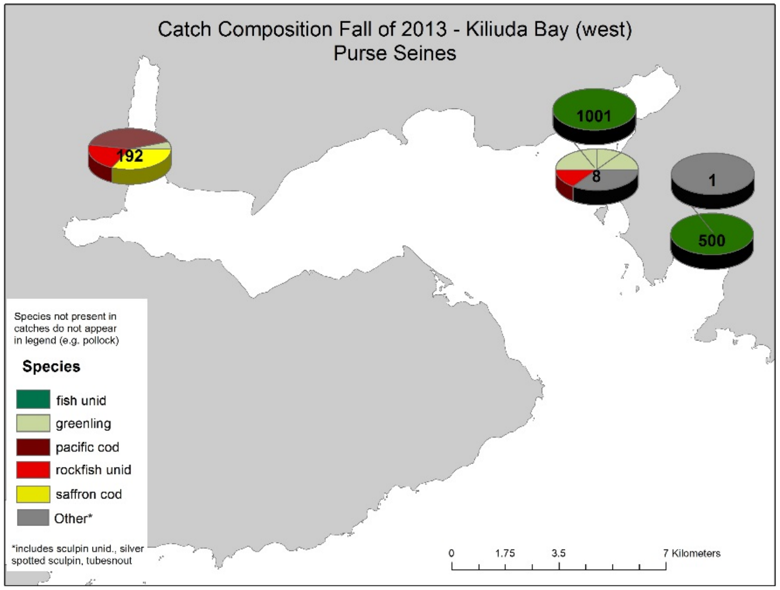


Figure 28. -- WGSR Kiliuda Bay catch composition for 2013 in the spring, summer, and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

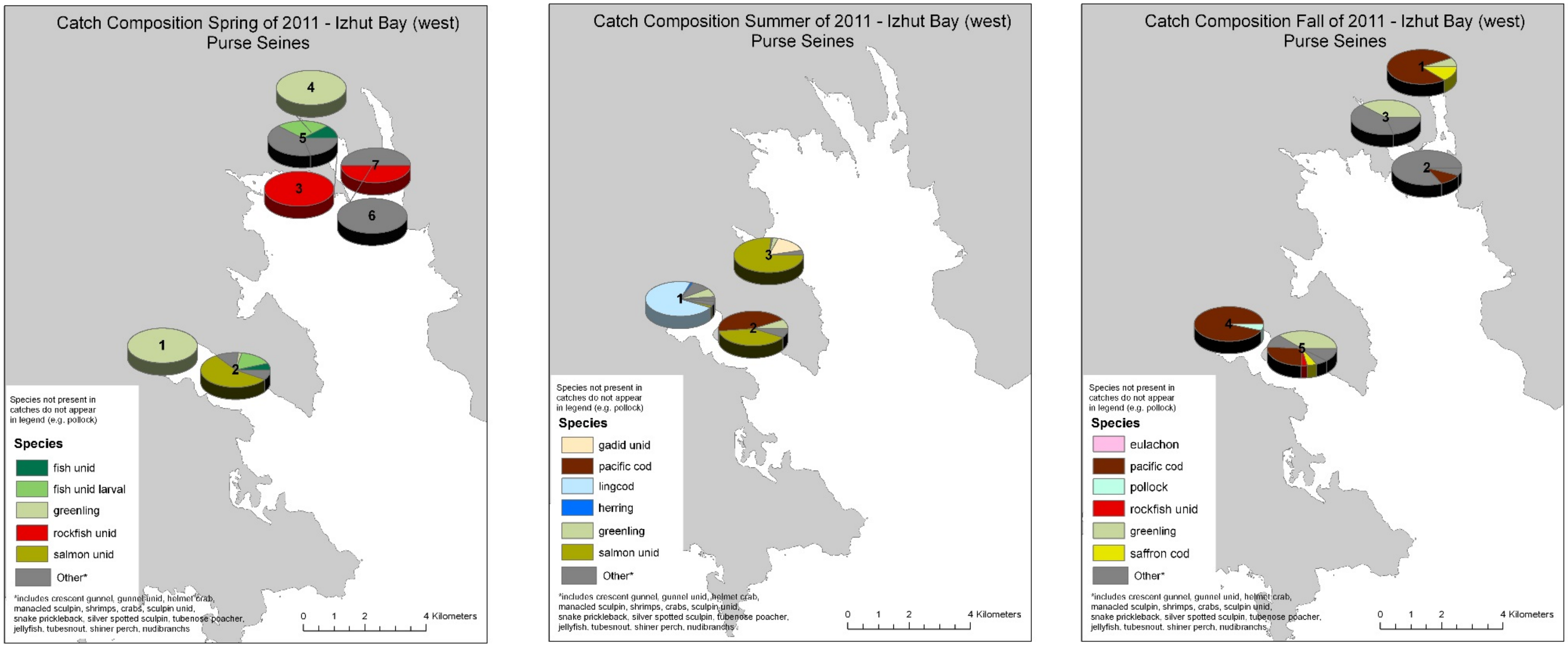


Figure 29. -- WGSR Izhut Bay catch composition for 2011 in the spring, summer, and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

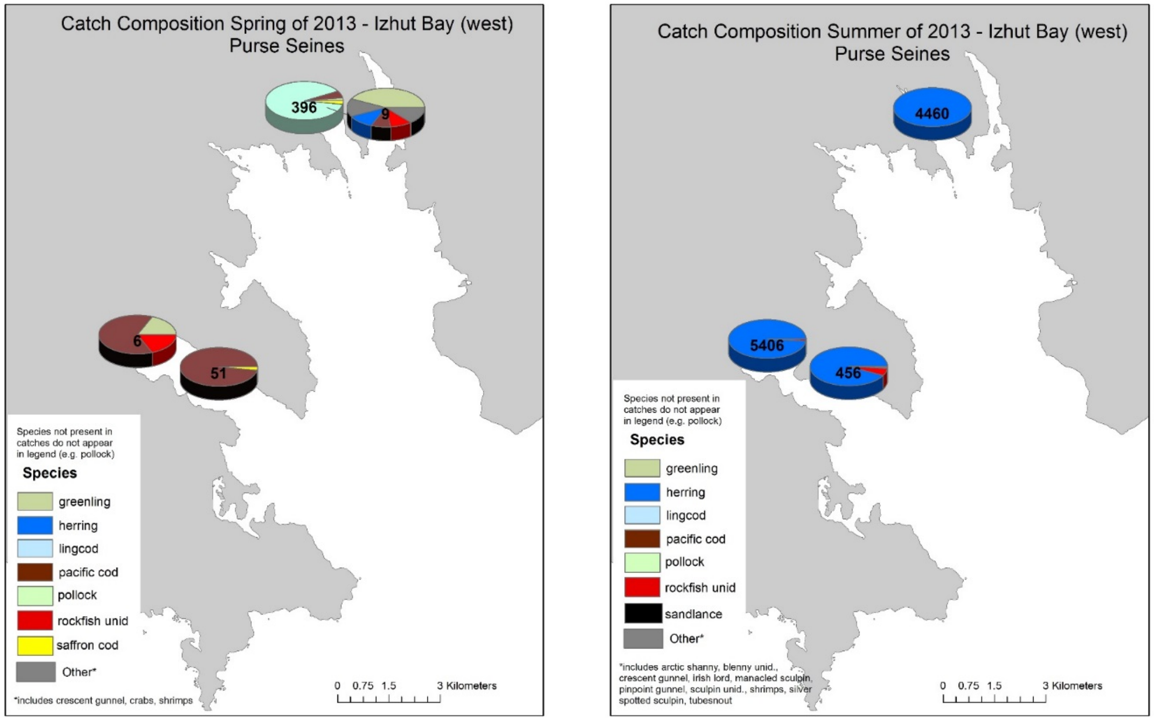
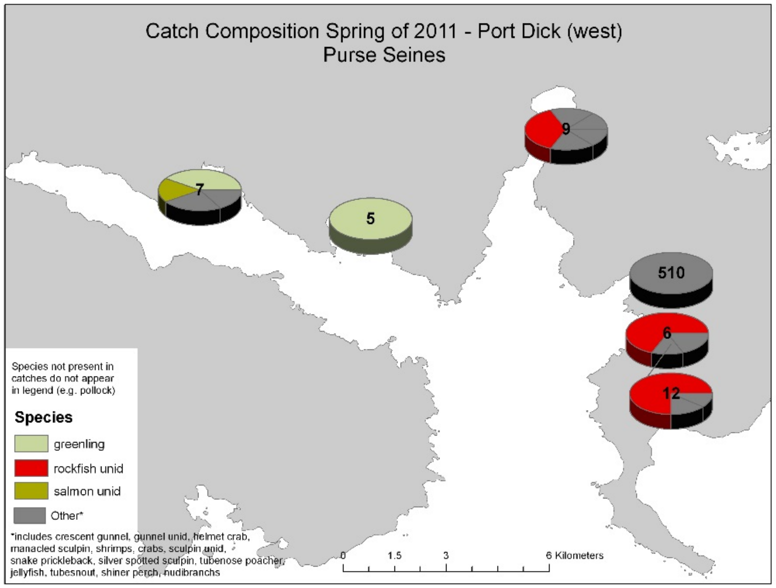
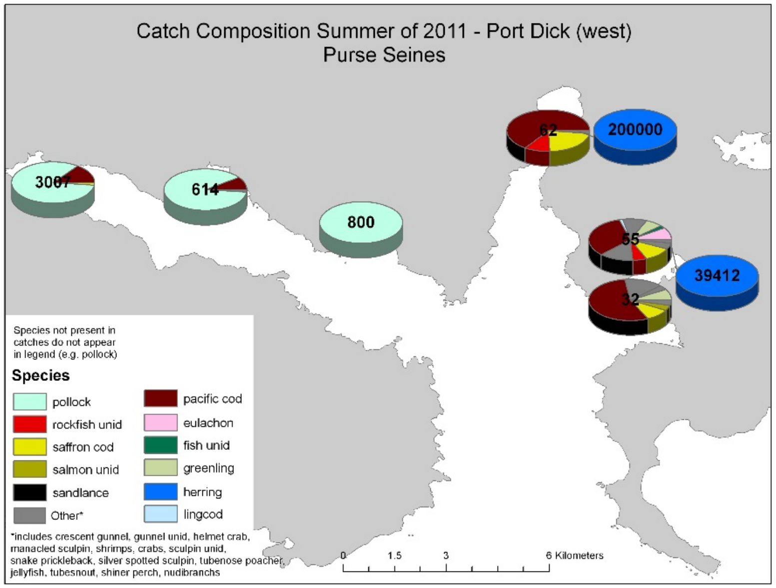


Figure 30. -- WGSR Izhut Bay catch composition for 2013 in the spring and summer. Sampling did not occur in fall 2013. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.





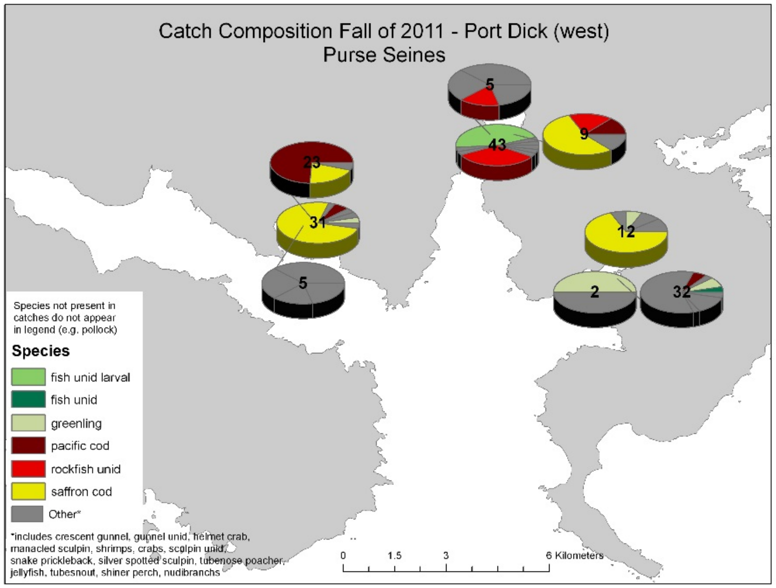
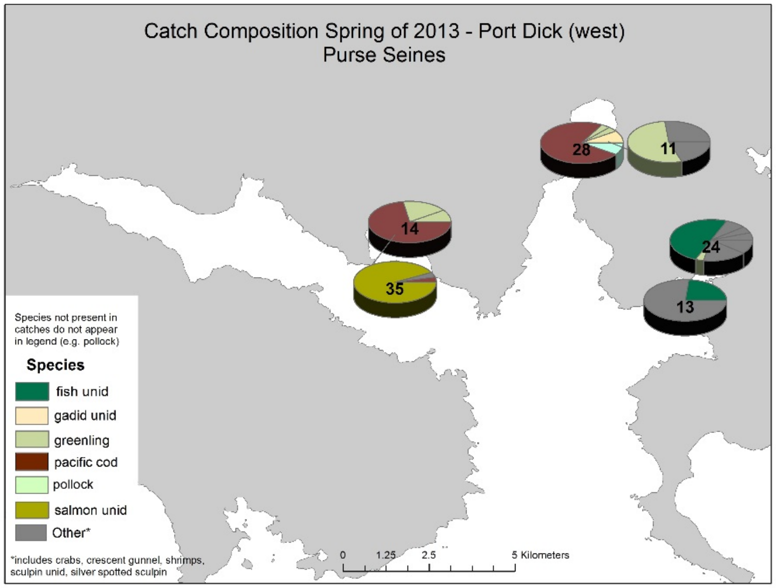
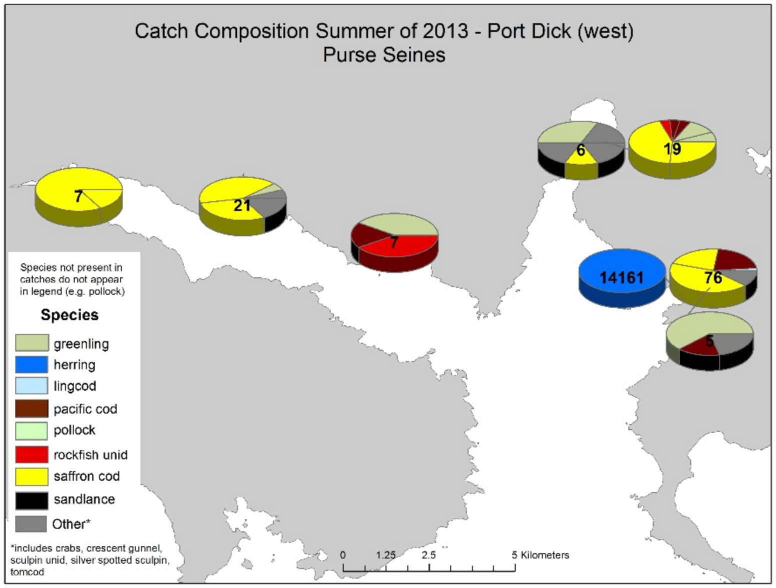


Figure 31. -- WGSR Port Dick catch composition for 2013 in the spring, summer, and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.





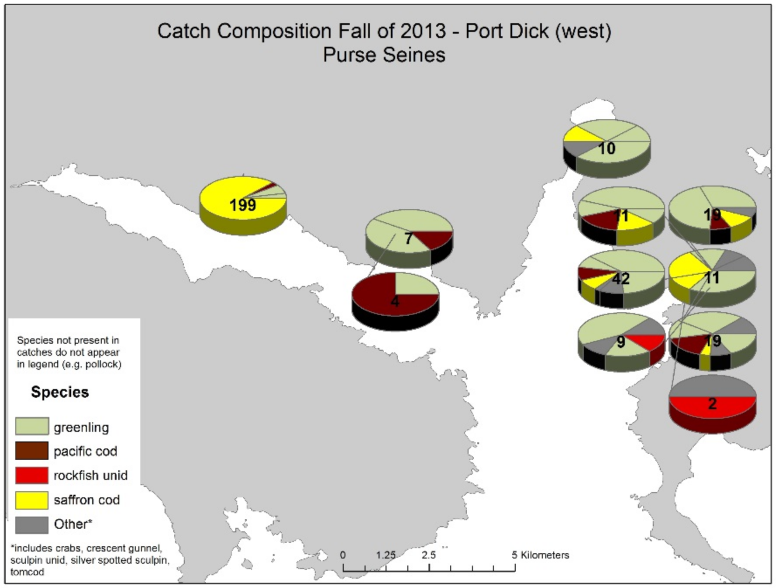


Figure 32. -- WGSR Port Dick catch composition for 2013 in the spring, summer, and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

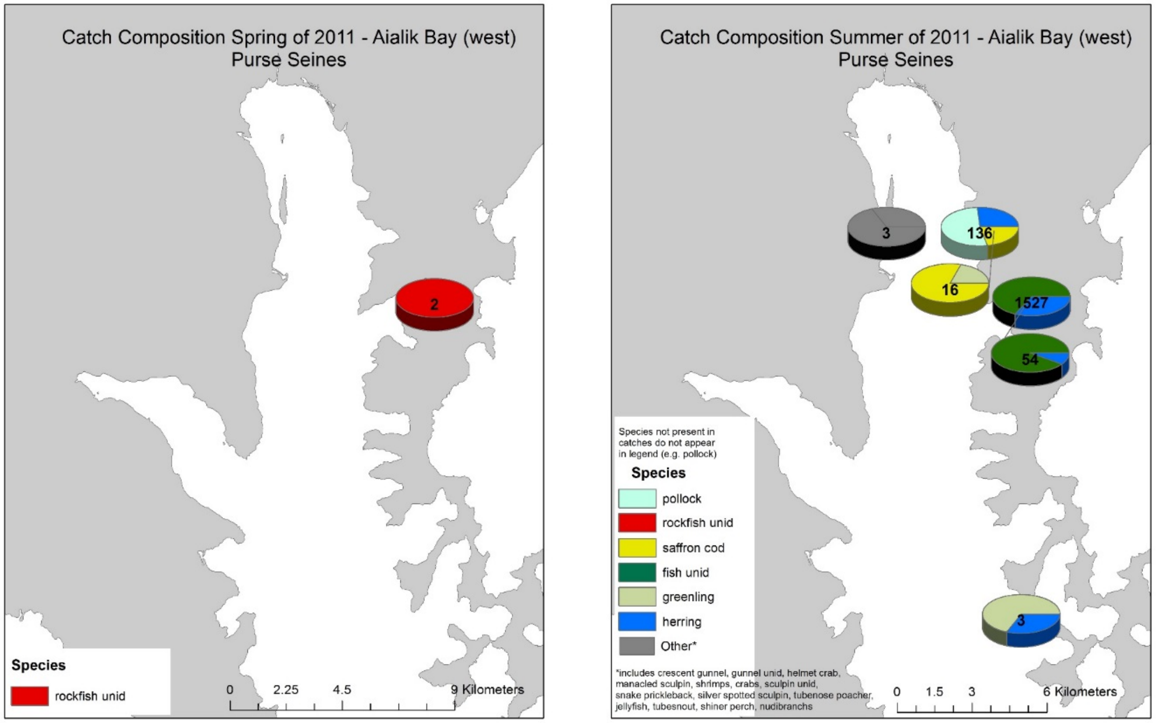


Figure 33. -- WGSR Aialik Bay catch composition for 2013 in the spring and summer. Sampling did not occur in fall 2013. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

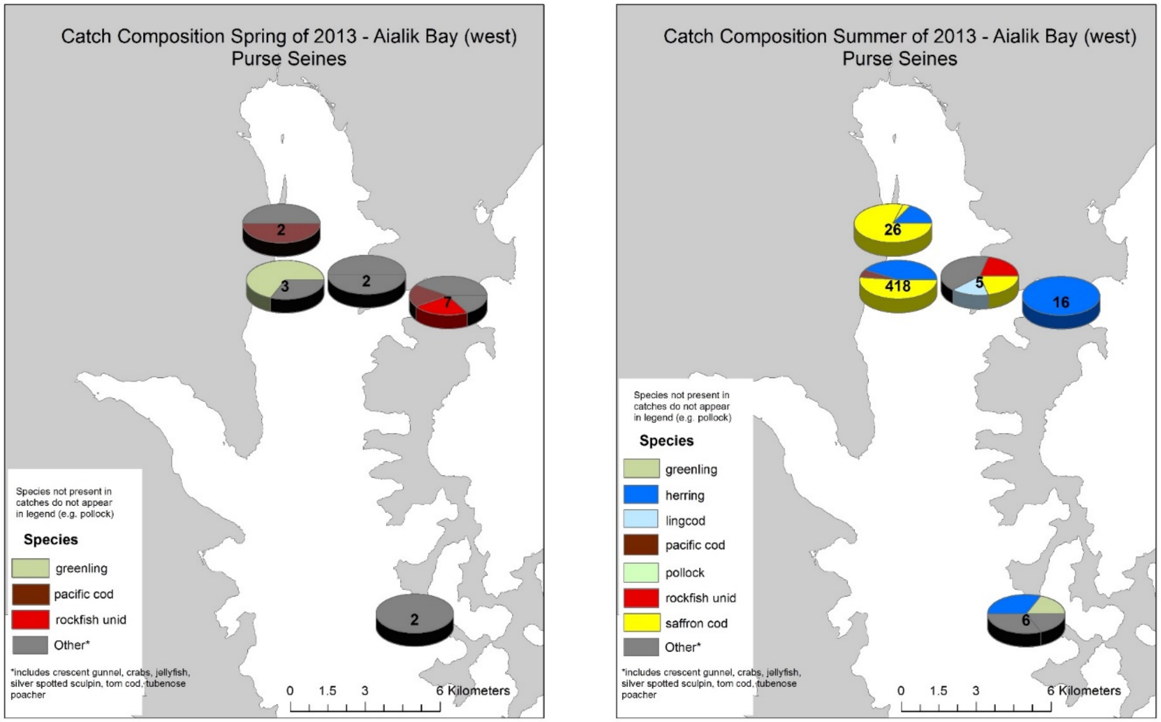


Figure 34. -- WGSR Aialik Bay catch composition for 2013 in the spring and summer. Sampling did not occur in fall 2013. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

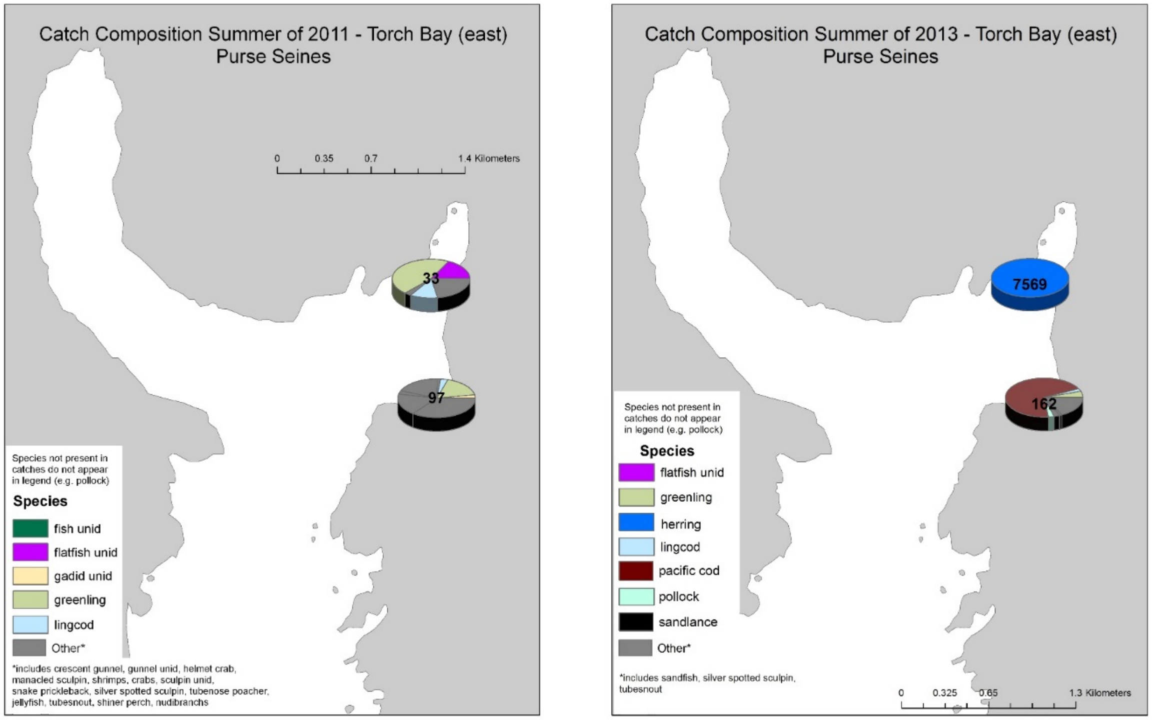
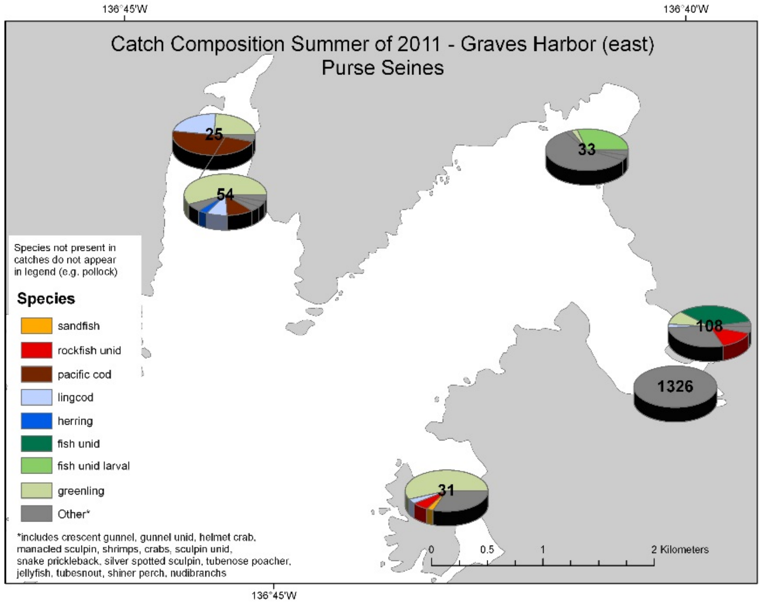
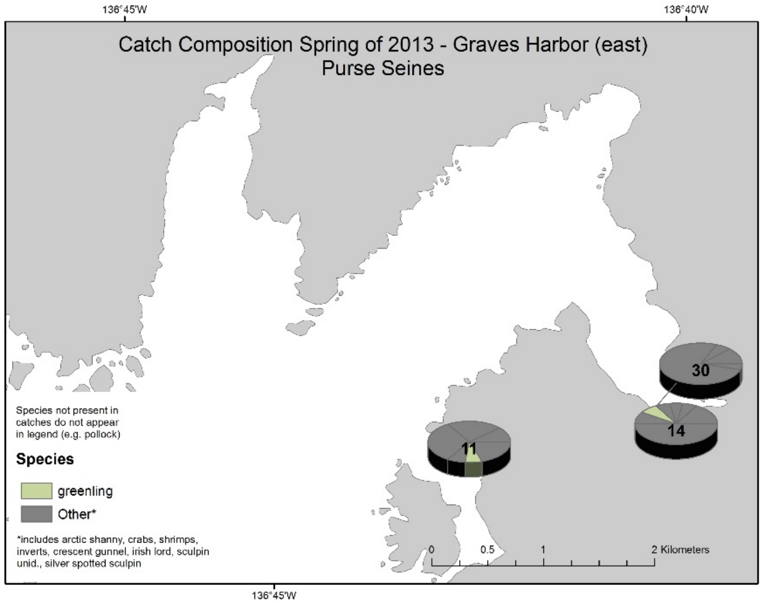


Figure 35. -- EGSR Torch Bay catch composition for 2011 in the summer and 2013 in the summer. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.





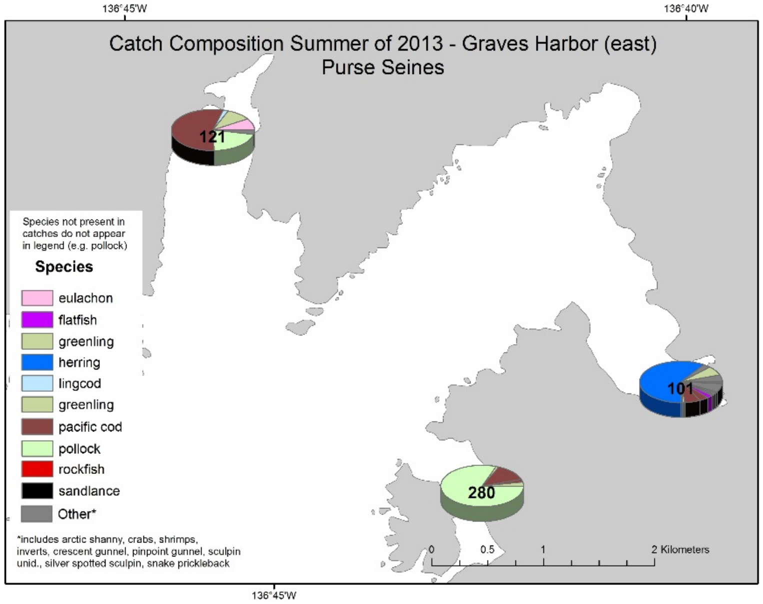


Figure 36. -- EGSR Graves Harbor catch composition for 2011 in the summer, and in 2013 for the spring, and summer. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

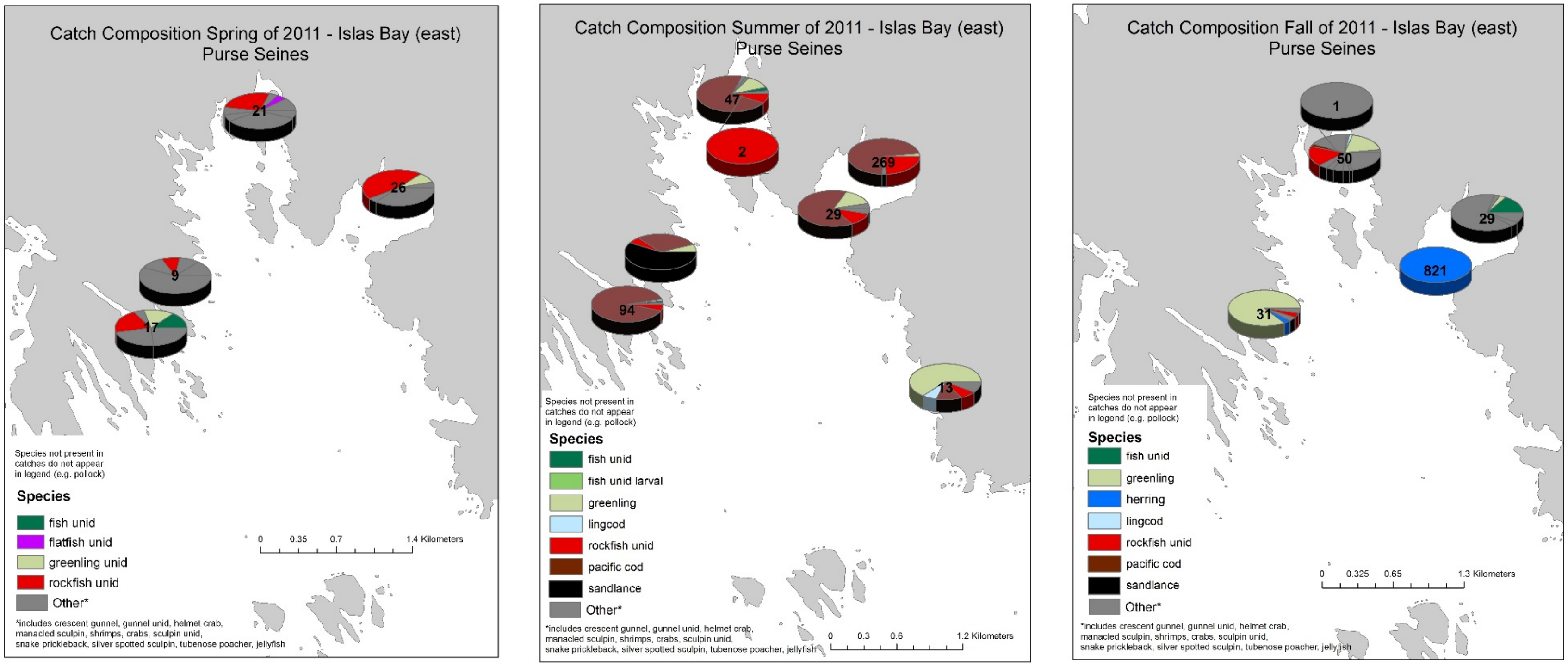


Figure 37. -- EGSR Islas Bay catch composition for 2011 in the spring, summer, and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

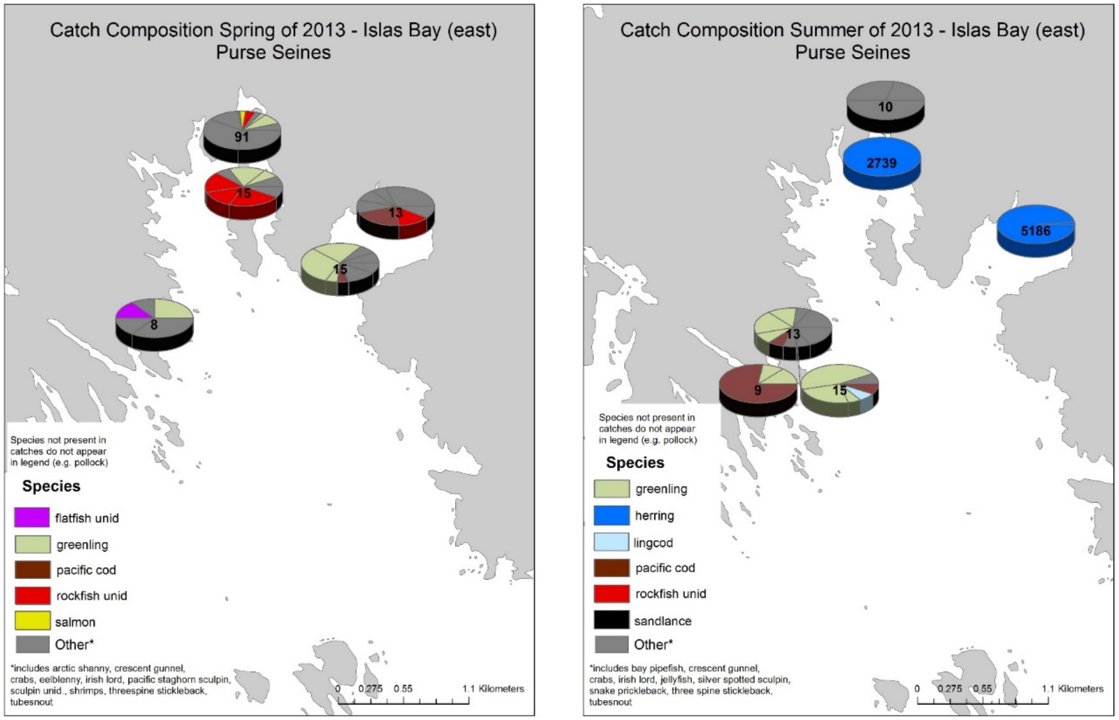
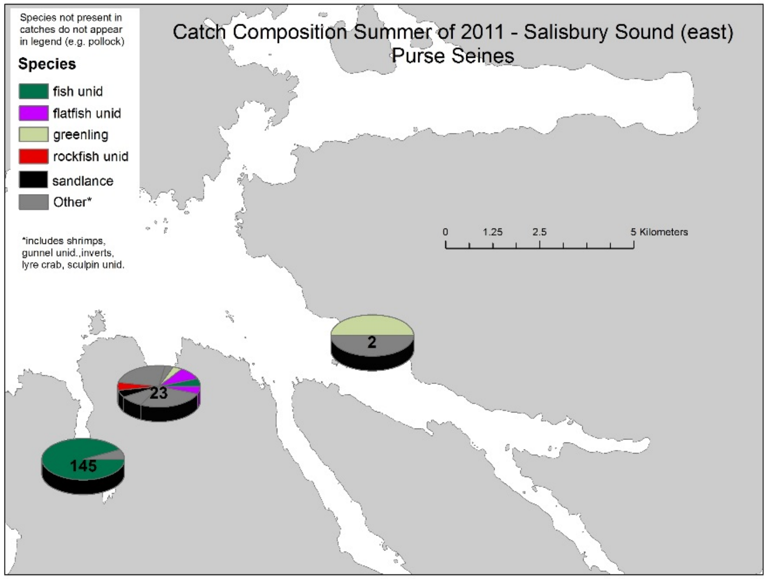
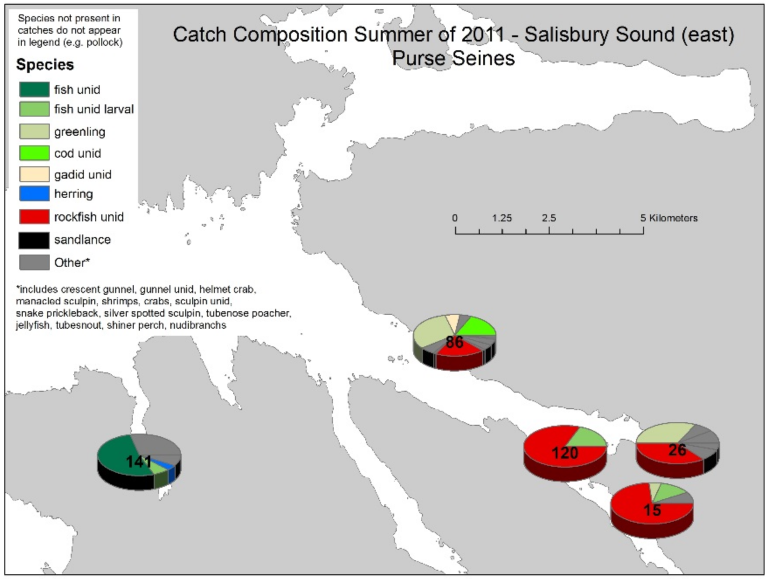


Figure 38. -- EGSR Islas Bay catch composition for 2013 in the spring and summer. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.





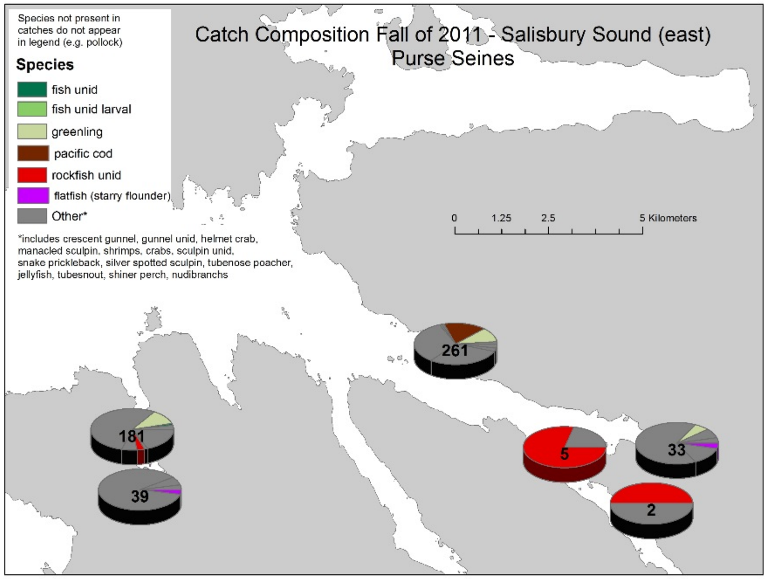
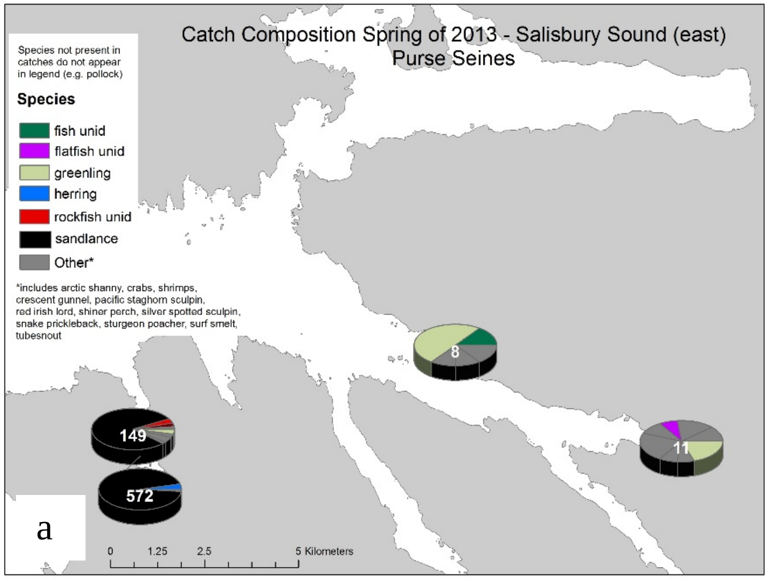
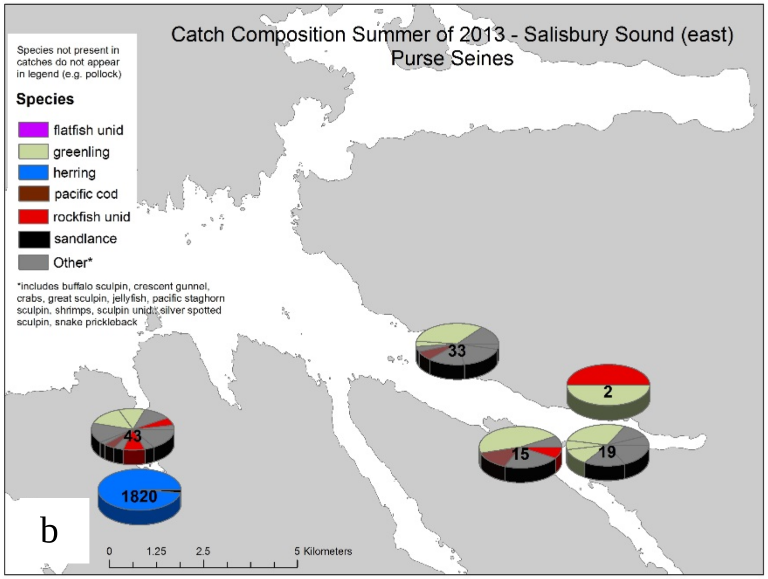


Figure 39. -- EGSR Salisbury Sound catch composition for 2011 in the spring, summer, and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.





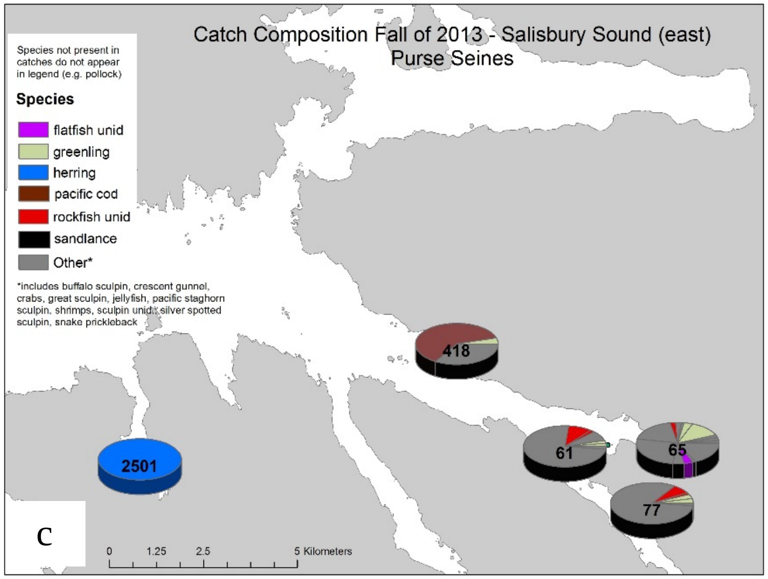


Figure 40. -- EGSR Salisbury Sound catch composition for 2013 in the spring, summer, and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

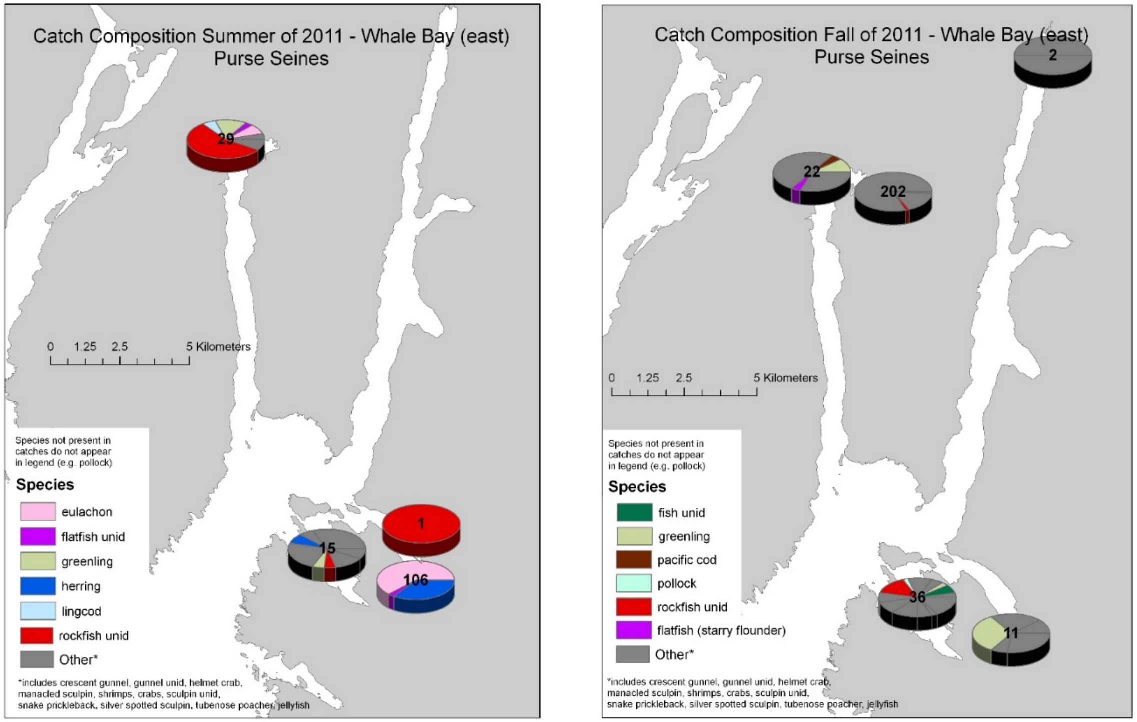


Figure 41. -- EGSR Whale Bay catch composition for 2011 in the summer and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

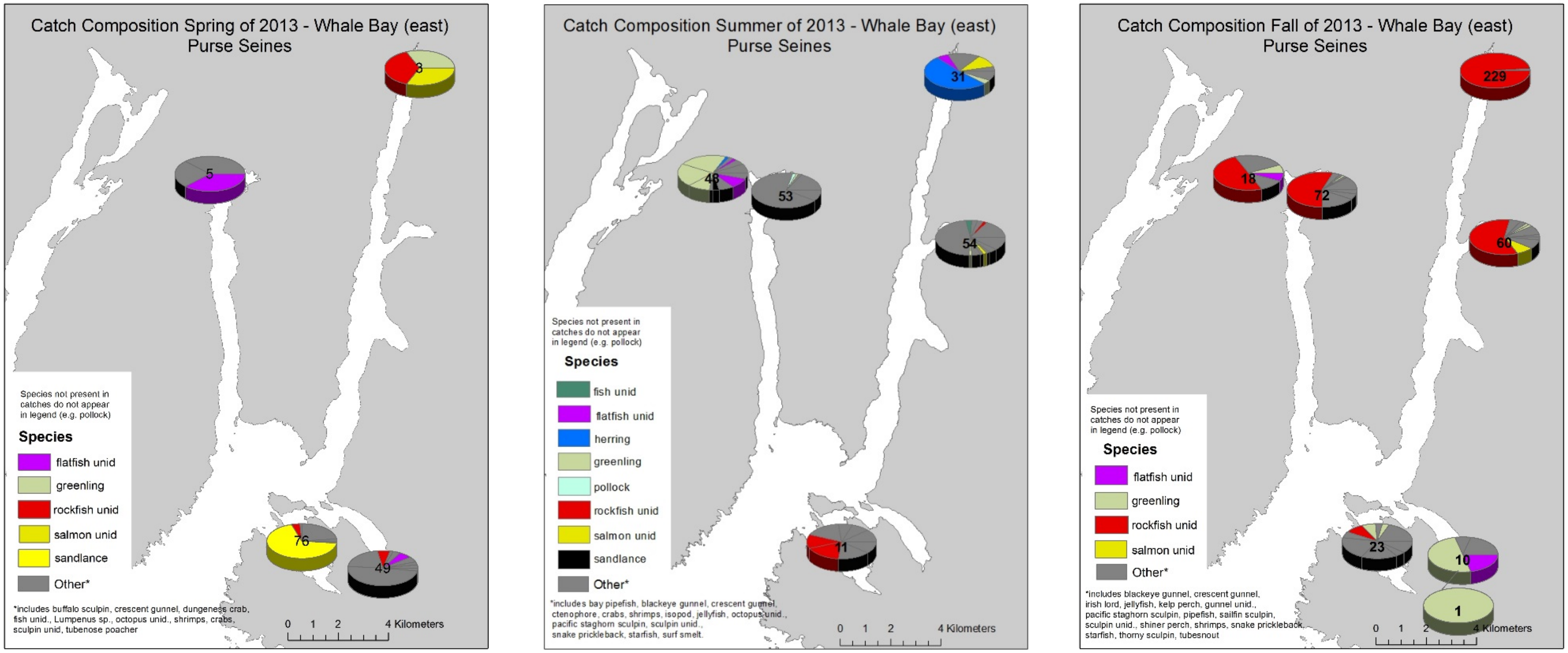


Figure 42. -- EGSR Whale Bay catch composition for 2013 in the spring, summer, and fall. The total number of fish captured in each seine set is shown in bold text in the middle of the pie chart.

Species Catch-Per-Unit-Effort (CPUE) and Length Compositions

Pacific cod -- Pacific cod are an important part of the GOA ecosystem and their range extends throughout the GOA. They are a demersal species that habituate the continental shelf edge and upper slope (100-250 m) before and during spawning season (winter) and move to shallower waters in the summer (< 100 m). Pacific cod larvae are epipelagic and are thought to be transported shoreward by the Alaska Coastal Current after hatching (Hurst et al. 2009). In general, little is known of their life history before they begin to recruit to the fishery at approximately age-3. In particular, little is known regarding the distribution of juvenile Pacific cod within the GOA.

The catch-per-unit-effort (CPUE) observed for Pacific cod in both the WGSR and EGSR presented some seasonal and regional patterns. Very few Pacific cod were captured in 2011 in the springtime in either region's study areas (Table 3); this is likely due to age-0 not being available to the gear either because of size (too small), habitats that were not sampled, or have not yet settled into the nearshore areas (Table 3). The majority of the Pacific cod that appear in the summer and fall surveys in 2011 are likely age-0 Pacific cod (Table 3). In 2013 the higher numbers of Pacific cod that appeared in the spring survey can be considered age 1+ fish from the previous year (2012) (Table 4). In general, age-0 Pacific cod were ubiquitous among bays during the summer months in 2013 (Table 4).

Fish length frequencies indicated the presence of YOY Pacific cod in four of the bays in summer 2011 (Fig. 43, blue line). The age-0 modes occurred in Kiliuda Bay, Port Dick, and Graves Harbor in the WGSR and Islas Bay in the EGSR. The fall modes at Kiluda Bay and Port Dick in 2011 illustrate the growth of the age-0 cod from the summer to fall months (Fig. 43, yellow line). In 2013, the age 1+ Pacific cod from the previous winter (2012) were found in all the WGSR bays (Kiliuda, Izhut, Port Dick, Aialik). Age-0 cod, in the summer, were also found in all the bays in both the WGSR and EGSR regions (Fig. 44, green line). Age-0 cod in the fall were only found in Kiliuda Bay and Port Dick in the WGSR and Salisbury Sound in the EGSR (Fig. 44, yellow line).

Table 3. -- Pacific cod CPUE (total number of fish /total number of hauls) in 2011 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 2).

2011			
WGSR	Spring	Summer	Fall
Kiliuda Bay	6.0	131.2	243
Izhut Bay	*	3.0	115.3
Port Dick	*	71.6	5.5
Aialik Bay	*	*	*
EGSR			
Torch Bay	*	*	*
Graves Harbor	*	9.5	*
Islas Bay	*	65.5	1.0
Salisbury Sound	*	*	54
Whale Bay	*	*	1.0

Table 4. -- Pacific cod CPUE (total number of fish /total number of hauls) in 2013 by season and bay, using a purse seine. Note: the cod captured in the spring 2013 will be age-1 rather than YOY. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 2).

2013			
WGSR	Spring	Summer	Fall
Kiliuda Bay	2.8	34.0	41.0
Izhut Bay	18.0	2.3	NA
Port Dick	11.0	4.5	2.38
Aialik Bay	1.0	20.0	NA
EGSR			
Torch Bay	*	48.3	NA
Graves Harbor	*	19.7	NA
Islas Bay	2.0	2.4	NA
Salisbury Sound	3.5	2.0	122.0
Whale Bay	*	*	*

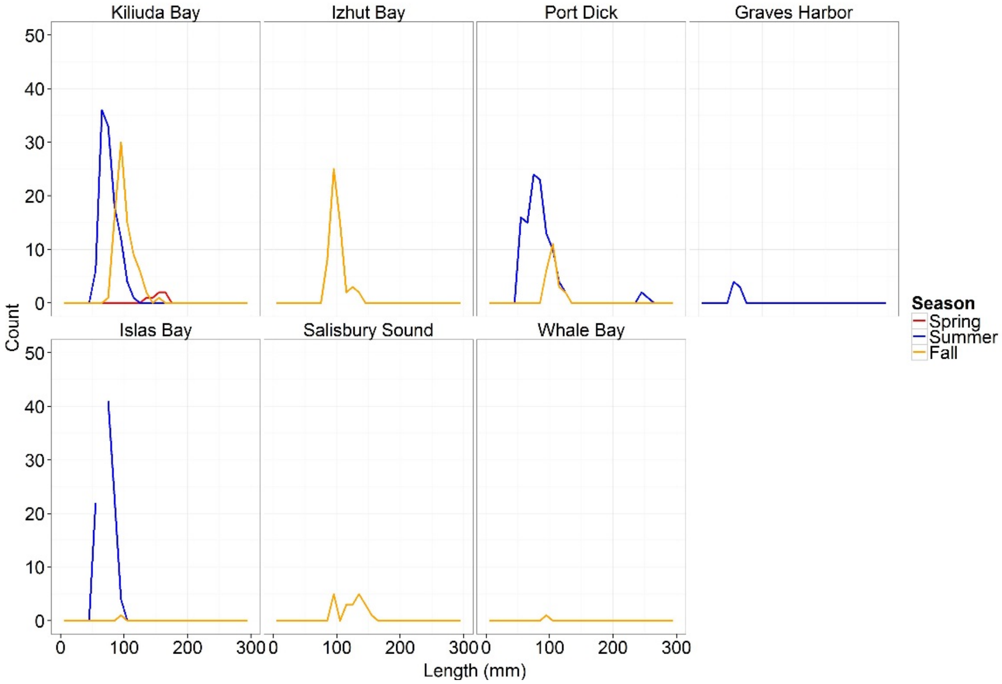


Figure 43. -- Length frequencies of Pacific cod collected in 2011 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

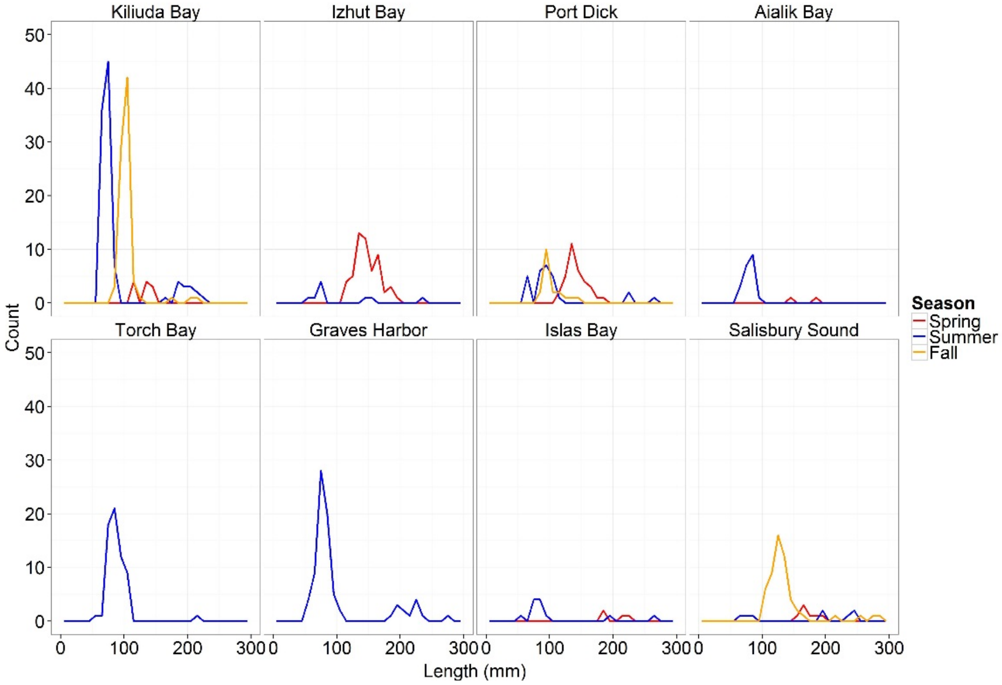


Figure 44. -- Length frequencies of Pacific cod collected in 2013 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

Walleye pollock -- Walleye pollock also play an important role in the GOA ecosystem and their range extends throughout the GOA; however, their presence in the EGSR is less well known than in the WGSR. Walleye pollock are considered semi-pelagic and they spawn in shallow, outer continental shelf waters during March and April. The largest concentrations of spawning pollock occur in the WGSR near Shelikof Strait and the Shumagin Islands; to date, spawning pollock concentrations have not been observed or documented in the EGSR; however, it is assumed that spawning does occur on some level. In the EGSR, adult pollock do not cannibalize YOY or juvenile pollock to the degree that cannibalism occurs in the eastern Bering Sea. Juvenile and YOY pollock are known to feed mostly on planktonic species such as ceuphausiids, mysids, and copepods.

The CPUE observed for walleye pollock in the GOA presented some seasonal and regional patterns. No walleye pollock were captured by purse seine in 2011 or 2013 in the EGSR region during springtime. In general, walleye pollock CPUE was lower in the EGSR, at least in the bays that were sampled (Tables 5 and 6). There is no pattern of consistent CPUE between the two years or among bays within the same region (Tables 5 and 6). The highest CPUE for walleye pollock occurred in the WGSR, in Port Dick, during the summer survey in 2011.

Fish length frequencies reflected the presence of YOY walleye pollock in all four bays in the WGSR and two of the four bays in in the EGSR in summer 2011 (Fig. 45, blue line). In 2013, the YOY modes (summer) occurred in Izhut and Aialik Bays in the WGSR, and Torch Bay/Graves Harbor in the EGSR (Fig. 46, blue line). The fall modes in 2011 at Kiliuda and Izhut Bays in the WGSR illustrate the growth of the YOY cod from the summer (blue line) to fall (yellow line) months (Fig. 45, yellow line). There were no walleye pollock lengths for the spring cruise in 2011 for both the WGSR and EGSR (Fig. 45); in 2013, the age-1+ walleye pollock from the previous winter (2012) were found only in Izhut Bay and Port Dick in the WGSR (Fig. 46, red line).

Table 5. -- Walleye pollock CPUE (total number of fish /total number of hauls) in 2011 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 2).

2011			
WGSR	Spring	Summer	Fall
Kiliuda Bay	*	29.0	53.5
Izhut Bay	*	12.5	7.0
Port Dick	*	1311.7	*
Aialik Bay	*	72.0	*
EGSR			
Torch Bay	*	2.0	*
Graves Harbor	*	*	*
Islas Bay	*	*	*
Salisbury Sound	*	7.0	*
Whale Bay	*	*	1.0

Table 6. -- Walleye pollock CPUE (total number of fish /total number of hauls) in 2013 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 2).

2013			
WGSR	Spring	Summer	Fall
Kiliuda Bay	*	*	*
Izhut Bay	359.0	4.0	NA
Port Dick	2.0	*	*
Aialik Bay	*	3.0	NA
EGSR			
Torch Bay	*	5.0	NA
Graves Harbor	*	126.0	NA
Islas Bay	*	1.0	NA
Salisbury Sound	*	*	*
Whale Bay	*	1.0	*

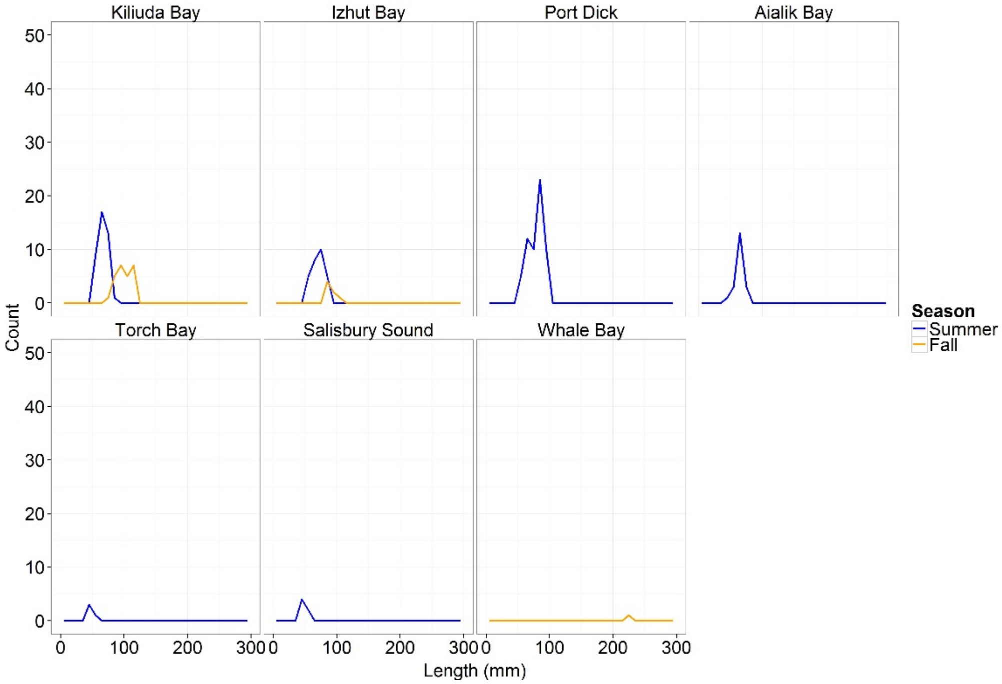


Figure 45. -- Length frequencies of walleye pollock collected in 2011 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

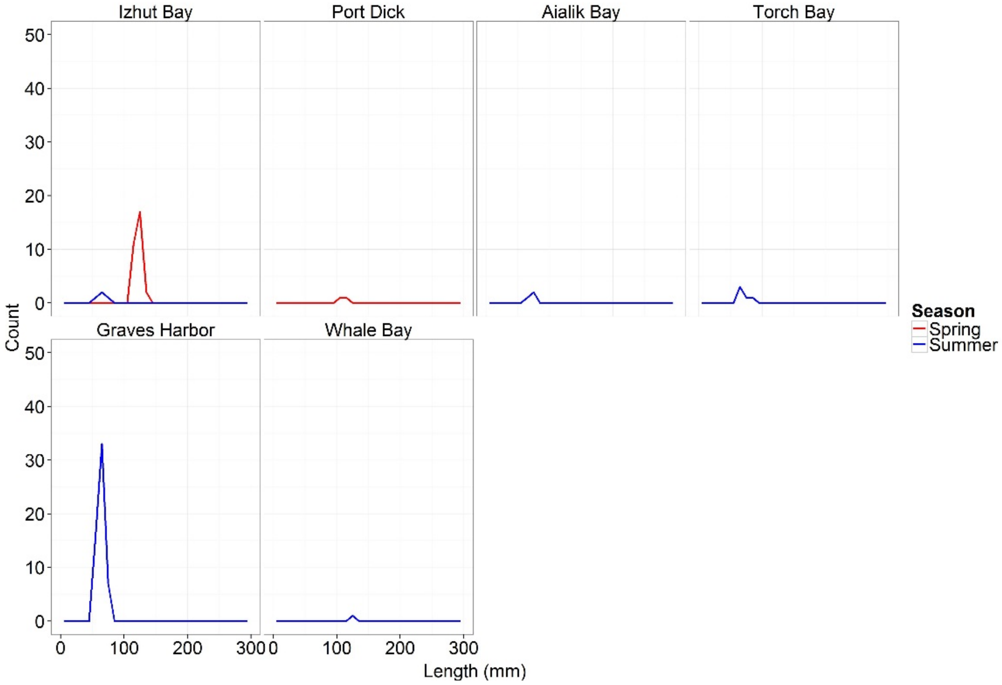


Figure 46. -- Length frequencies of walleye pollock collected in 2013 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

Rockfishes -- For the MTL portion of the GOAIERP, sampling was focused primarily nearshore and within bays. Pacific ocean perch (POP) was chosen as a focal species within the framework of the GOAIERP (see Abstract). In general, post-larval and juvenile Pacific ocean perch are believed to inhabit offshore habitats in the GOA and migrate to deeper, rockier habitats around the age of 3 years. In this nearshore work, several species of rockfish other than Pacific ocean perch were encountered, building on the evidence that juvenile Pacific ocean perch do not inhabit these nearshore, rocky habitats as once hypothesized. Due to the difficulty of juvenile rockfish identification, rockfish species were aggregated under the “rockfish” category.

The CPUEs for rockfish were consistently less than 10 fish per haul for most bays in both 2011 and 2013, with a few exceptions (e.g., Salisbury Sound, summer 2011) (Tables 7 and 8). No rockfish were captured in Torch Bay in the EGSR during any season in 2011 and 2013, whereas rockfish were captured in Graves Harbor (EGSR) only during the summer months in both years (Tables 7 and 8).

Length frequencies for rockfish, all species aggregated, presented both spatial and temporal variation. All modes for all bays, seasons, and years are less than 110 mm (Figs. 47 and 48). These modes may represent different species or several age classes from the same species). Rockfish were present in each bay and year, even though some bays saw very small numbers (e.g., Aialik Bay in 2013) (Figs. 47 and 48). In 2011, Port Dick in the WGSR study region had spring and summer modes between 50-100 mm and the fall mode at less than 50 mm (Fig. 47). Interestingly, the summer modes occurred in all the bays at approximately the same size, ~75 mm (Figs. 47 and 48). In 2013, a similar pattern is evident, in that most of the modes, regardless of season or bay, occurred at lengths less than 100 mm (Fig. 48).

Table 7. -- Aggregate rockfish CPUE (total number of fish /total number of hauls) in 2011 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2011			
WGSR	Spring	Summer	Fall
Kiliuda Bay	*	1.0	3.0
Izhut Bay	2.0	*	1.5
Port Dick	5.3	5.0	6.3
Aialik Bay	2.0	1.0	*
EGSR			
Torch Bay	*	*	*
Graves Harbor	*	8.3	*
Islas Bay	5.5	12.0	4.0
Salisbury Sound	1.0	35.0	3.5
Whale Bay	*	6.0	4.5

Table 8. -- Aggregate rockfish CPUE (total number of fish /total number of hauls) in 2013 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2013			
WGSR	Spring	Summer	Fall
Kiliuda Bay	3.0	4.8	17.5
Izhut Bay	1.0	25.7	NA
Port Dick	*	2.0	1.0
Aialik Bay	2.0	1.0	NA
EGSR			
Torch Bay	*	*	NA
Graves Harbor	*	2.08	NA
Islas Bay	3.0	2.8	NA
Salisbury Sound	4.0	2.3	3.2
Whale Bay	3.0	1.3	44.6

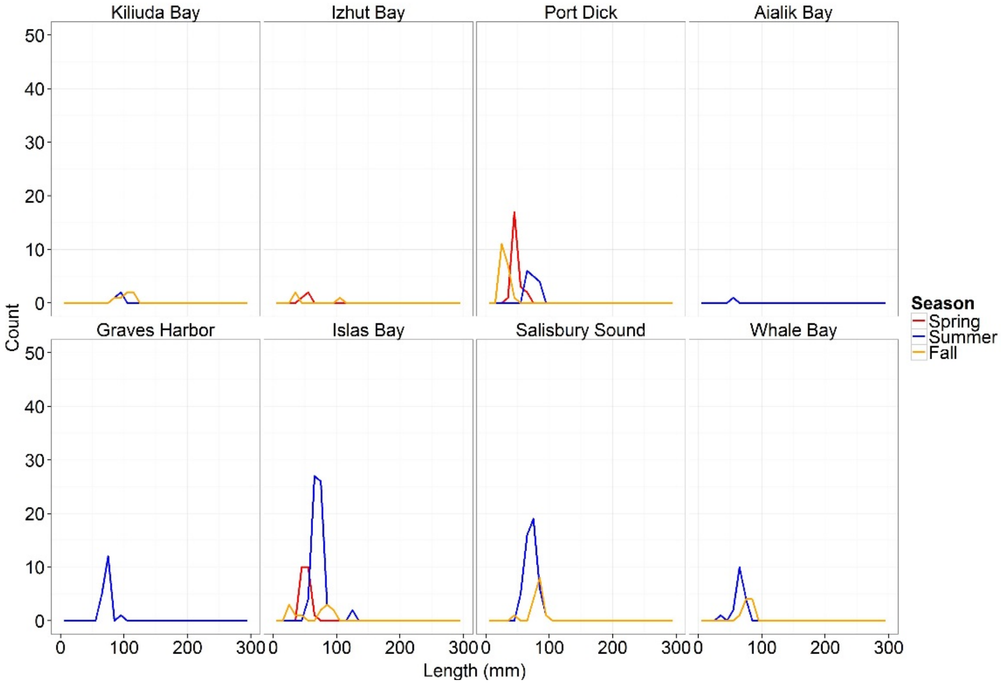


Figure 47. -- Length frequencies of aggregated rockfish species collected in 2011 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

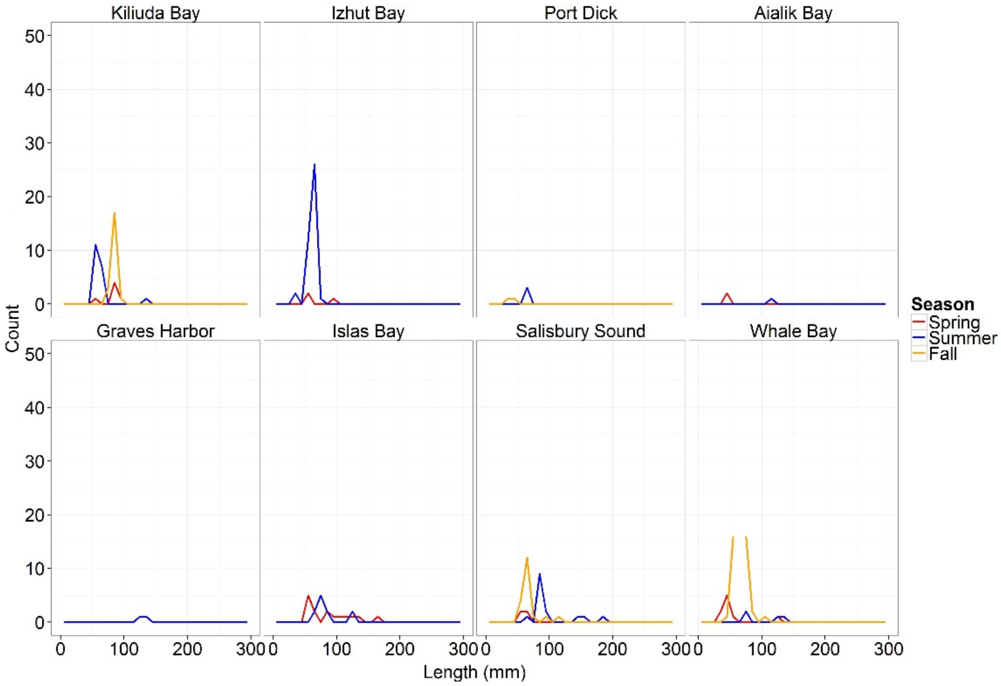


Figure 48. -- Length frequencies of aggregated rockfish species collected in 2013 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

Pacific herring -- Pacific herring in the GOA have often been referred to as a “keystone” species in that they connect the secondary producers (e.g., zooplankton) to larger predators such as other fish, birds, and marine mammals. Herring in the GOA spawn in spring, usually in intertidal and sub-tidal habitats on submerged vegetation such as eelgrass (preferred) and kelp. Herring reach maturity between 3 and 4 years of age and are capable of spawning in successive years. Young-of-year and age-1 herring use sheltered bays and inlets as nursery areas into the fall, when the older cohorts (age-1) move to deeper water to spend the next 2 to 3 years, where they remain separate from the adult population until sexual maturity.

The CPUEs for herring were highly variable, reflecting the schooling nature of herring. For example, the very high CPUE estimate reported in 2011 at Port Dick in the summer is likely due to catching some portion of a herring school (Table 9). In almost all cases, either herring were captured in large numbers or not captured at all. In general, herring were not observed in most bays in the spring, both years and when they were observed in the seines, it was in relatively low numbers (Tables 9 and 10). Herring were observed in most bays in the summer months, both study regions, and years in fairly high numbers (Tables 9 and 10). In the fall, herring were only captured in in the EGSR, in Islas Bay in 2011 and Salisbury Sound in 2013 (Tables 9 and 10).

The length frequencies for herring in the WGSR in 2011 show strong modes around 50 mm primarily in the summer months (Port Dick and Aialik Bay) (Fig. 49). There was a mode at ~250 mm that occurred in Kiliuda Bay, spring 2011 (Fig. 49). In the EGSR in 2011, three modes are evident in Graves Harbor, all ~100 mm or less in the summer (Fig. 49). We also observed a strong fall mode at just over 50 mm in Islas Bay in 2011. In 2013, the patterns are similar to those in 2011, in the summer months, where the strongest modes occurred between 50 and 100 mm for those bays where herring were captured (Fig. 50, blue line). Aialik Bay was the only bay in the WGSR where herring lengths were collected in the summer of 2013 (Fig. 50, blue line). Herring were measured in all bays in the summer of 2013 in the EGSR and modes occurred around 50 mm (Fig. 50). In the spring, a single mode occurred in Salisbury Sound around 100 mm, and in the fall, a single mode also occurred in Salisbury Sound around 75 mm (Fig. 50).

Table 9. -- Pacific herring CPUE (total number of fish /total number of hauls) in 2011 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2011			
WGSR	Spring	Summer	Fall
Kiliuda Bay	219.0	1.0	*
Izhut Bay	*	1.0	*
Port Dick	*	119604.0	*
Aialik Bay	*	341.0	*
EGSR			
Torch Bay	*	200.0	*
Graves Harbor	*	438.0	*
Islas Bay	*	1.0	406.5
Salisbury Sound	*	11.7	*
Whale Bay	*	20.0	*

Table 10. -- Pacific herring CPUE (total number of fish /total number of hauls) in 2013 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2013			
WGSR	Spring	Summer	Fall
Kiliuda Bay	*	1.0	*
Izhut Bay	1.0	2545.8	NA
Port Dick	*	14049.0	*
Aialik Bay	*	50.8	NA
EGSR			
Torch Bay	*	7422.0	NA
Graves Harbor	*	31.5	NA
Islas Bay	*	1569.0	NA
Salisbury Sound	17.0	888.5	2500.0
Whale Bay	*	8.5	*

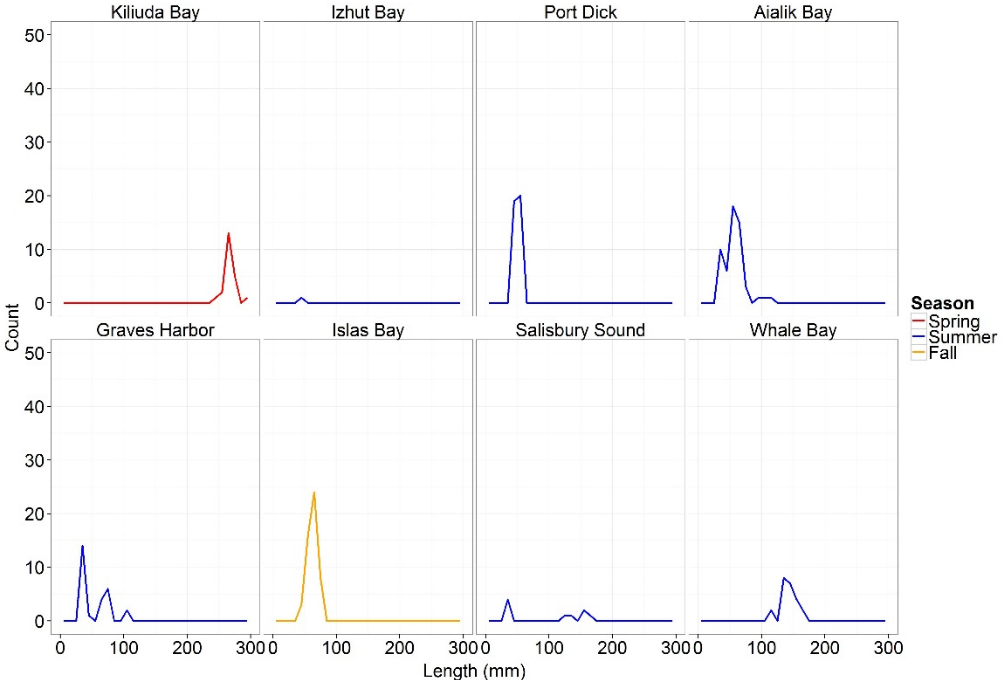


Figure 49. -- Length frequencies of Pacific herring collected in 2011 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

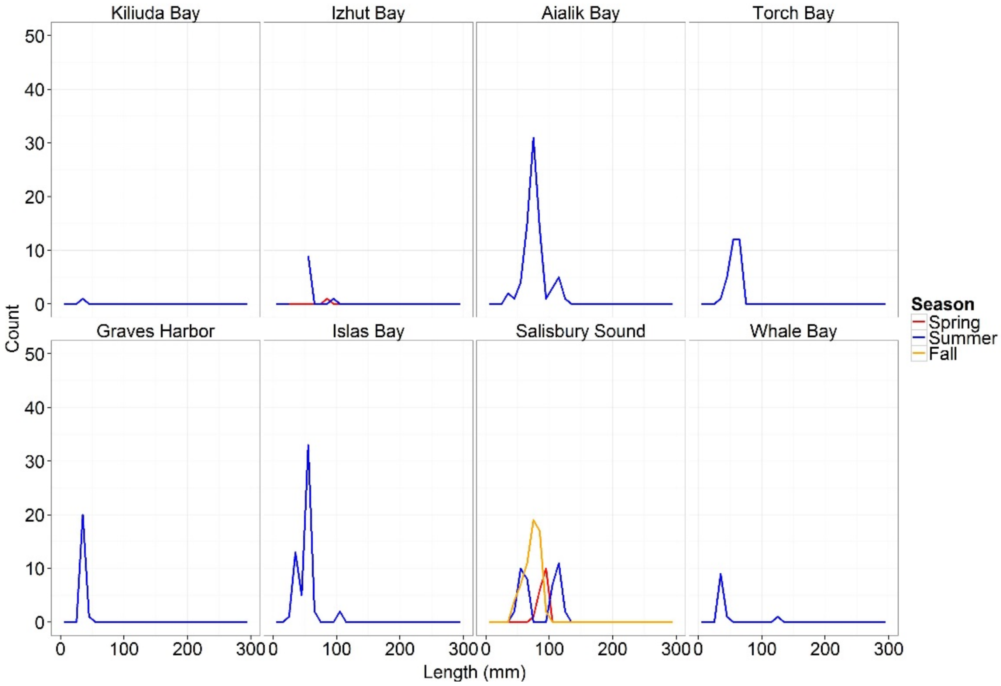


Figure 50. -- Length frequencies of Pacific herring collected in 2013 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

Pacific sand lance -- Pacific sand lance in the GOA are widespread and abundant in coastal waters. Similar to Pacific herring, sand lance are an important component of the ecosystem and are also considered a key forage fish prey species for many marine mammals, birds and other fishes. Sand lance are closely associated with sandy substrates in the intertidal zone, where they burrow for protection from both the environment and predators. They are generally most common in depths less than 50 m, where they feed in schools, and spawn once a year within the intertidal zone. Spawning occurs in late September through winter in Alaska and occurs at the same locations every year; age-1 and age-2 fish dominate the spawning schools.

The observed CPUEs for Pacific sand lance showed no strong seasonal patterns in the spring or summer in either 2011 or 2013 (Tables 11 and 12). Sand lance were only captured in one bay in each study region in 2011; Kiliuda Bay in the WGSR and Salisbury Sound in the EGSR (Tables 11 and 12). Similar to the CPUE estimates in the spring for fall 2011, sand lance were only captured in one bay in each study region; Kiliuda Bay in the WGSR and Islas Bay in the EGSR (Tables 11 and 12). The CPUE estimates for both years and study regions were highest during the summer months (Tables 11 and 12). Pacific sand lance were observed in the EGSR, all bays, in the summer in 2013 (Table 12).

Pacific sand lance were measured from two bays in the WGSR and one bay in the EGSR in the summer of 2011; the modes for Kiliuda Bay and Port Dick in the WGSR and Islas Bay in the EGSR occurred at almost the same length, ~75 mm (Fig. 51). In summer 2013, the length mode at Port Dick in the WGSR occurred just under 50 mm (Fig. 52). This bay was the only bay in 2013 where a significant amount of fish were measured. In 2013, Salisbury Sound in the EGSR had two modes at ~100 mm and ~120 mm that occurred in the spring and a mode between 100 and 120 mm that occurred in the summer (Fig. 52). A spring mode at 100 mm also occurred in the spring in Whale Bay in the EGSR in 2013 (Fig. 52).

Table 11. -- Pacific sand lance CPUE (total number of fish /total number of hauls) in 2011 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2011			
WGSR	Spring	Summer	Fall
Kiliuda Bay	7.0	602.3	1.0
Izhut Bay	*	*	*
Port Dick	*	183.0	*
Aialik Bay	*	*	*
EGSR			
Torch Bay	*	*	*
Graves Harbor	*	*	*
Islas Bay	*	50.5	4.0
Salisbury Sound	1.0	1.0	*
Whale Bay	*	*	*

Table 12. -- Pacific sand lance CPUE (total number of fish /total number of hauls) in 2013 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2013			
WGSR	Spring	Summer	Fall
Kiliuda Bay	2.0	*	*
Izhut Bay	*	7.0	NA
Port Dick	*	50.0	*
Aialik Bay	*	*	NA
EGSR			
Torch Bay	*	1.0	NA
Graves Harbor	*	1.0	NA
Islas Bay	*	26.0	NA
Salisbury Sound	334.0	33.0	*
Whale Bay	51.0	2.0	*

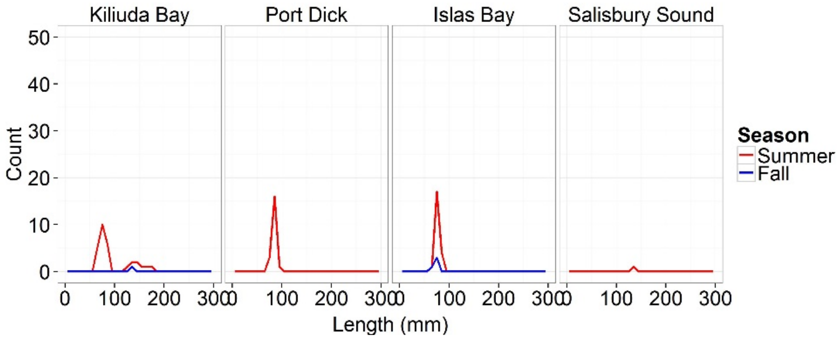


Figure 51. -- Length frequencies of Pacific sand lance collected in 2011 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

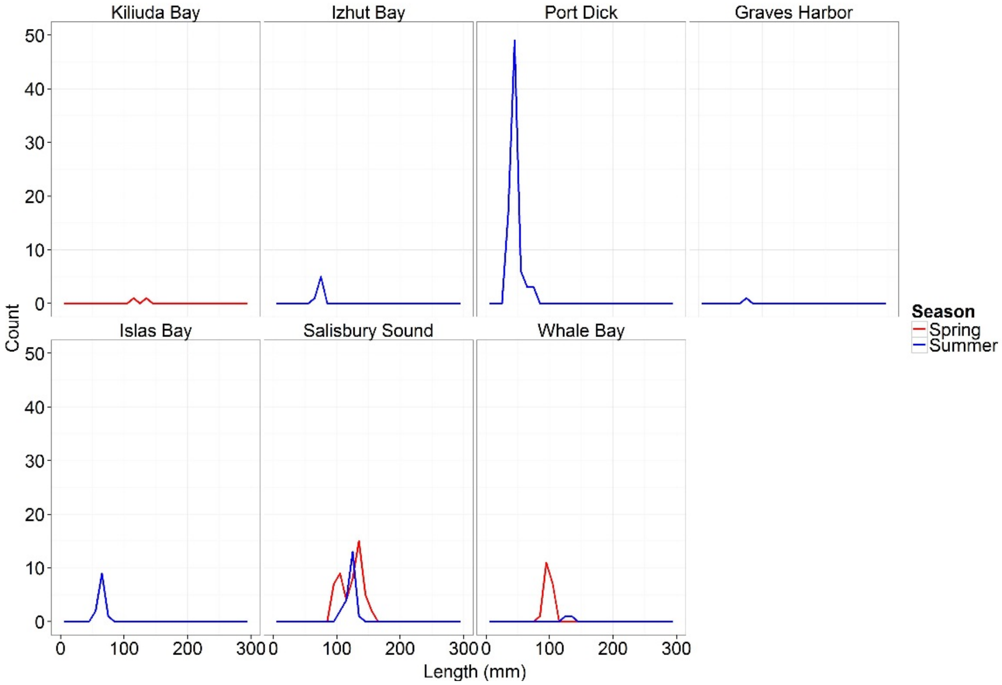


Figure 52. -- Length frequencies of Pacific sand lance collected in 2013 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

Greenlings -- In this study, most greenlings were not identified to species; therefore CPUE and length frequencies are by reported as an aggregation, which most likely includes a combination of kelp *Hexagrammos decagrammus*, rock *H. lagocephalus*, masked *H. octogrammus*, whitespotted *H. stelleri*, and painted greenlings *Oxylebius pictus*. In general, greenlings inhabit various habitats nearshore that include eelgrass, kelp, bedrock and sand. The timing of spawning for many of these species differs; kelp greenling spawn in the late fall (Oct/Nov), whereas the rock greenling spawning season starts in the spring (June) and can extend to the late fall (Sept/Oct). The greenling species listed here are known batch spawners producing demersal eggs which attach to substrate (e.g., rocks, kelp, etc.) and are guarded by males.

The CPUEs for greenlings were similar to those of rockfishes in that greenlings were captured in all bays in one or more seasons in both 2011 and 2013 (Tables 13 and 14). The CPUE estimates were generally less than 10 fish per haul for both years, with a few exceptions (e.g., Izhut Bay in the fall of 2011) (Tables 13 and 14).

Greenling length frequencies in summer in 2011 showed a strong mode at ~75 mm in several bays (Fig. 53, blue line). In 2011, the modes from the summer (~75 mm) shifted to ~100 mm in the fall, possibly representing body growth between the summer and fall months (Fig. 53, yellow line). Alternately, the seasonal differences in size modes may represent different species of greenling. In 2013, a strong spring mode in Kiliuda Bay in the WGSR occurred at ~100 mm (Fig. 54, red line). A mode at ~100 mm did not occur in any of the other bays during the springtime. The multiple modes that appear in most bays within a season (e.g., Kiliuda Bay, Port Dick, Salisbury Sound) likely represent several cohorts and/or species (Fig. 54). There is a spring mode that occurred in 2013 at ~75 mm only in Torch Bay, Graves Harbor and Salisbury Sound in the EGSR, which may be the same species observed at the same length mode in 2011 (Figs. 53 and 54, blue line).

Table 13. -- Aggregate greenling CPUE (total number of fish /total number of hauls) in 2011 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2011			
WGSR	Spring	Summer	Fall
Kiliuda Bay	2.0	4.0	8.7
Izhut Bay	1.0	3.0	15.0
Port Dick	4.0	2.40	1.25
Aialik Bay	*	2.0	*
EGSR			
Torch Bay	*	15.5	*
Graves Harbor	*	11.7	*
Islas Bay	2.5	6.2	10.3
Salisbury Sound	1.0	8.8	10.8
Whale Bay	*	2.3	2.0

Table 14. -- Aggregate greenling CPUE (total number of fish /total number of hauls) in 2013 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2013			
WGSR	Spring	Summer	Fall
Kiliuda Bay	8.4	3.0	2.3
Izhut Bay	3.3	5.0	NA
Port Dick	2.2	2.0	4.2
Aialik Bay	2.0	1.0	NA
EGSR			
Torch Bay	*	7.3	NA
Graves Harbor	1.0	5.2	NA
Islas Bay	3.0	2.0	NA
Salisbury Sound	2.4	4.7	3.8
Whale Bay	1.0	5.0	1.6

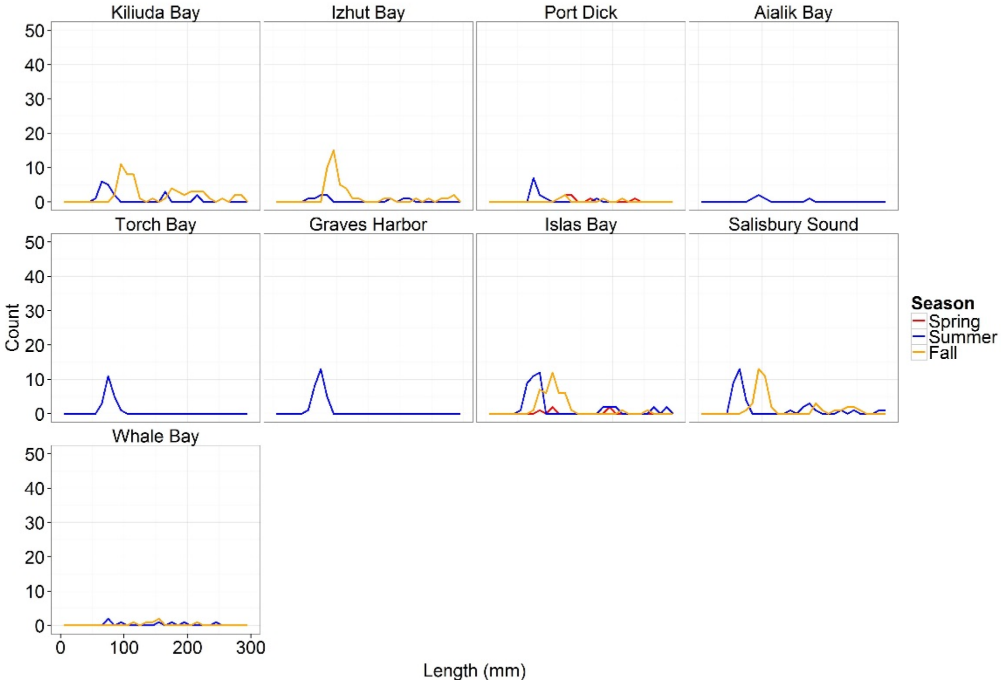


Figure 53. -- Length frequencies of greenlings collected in 2011 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

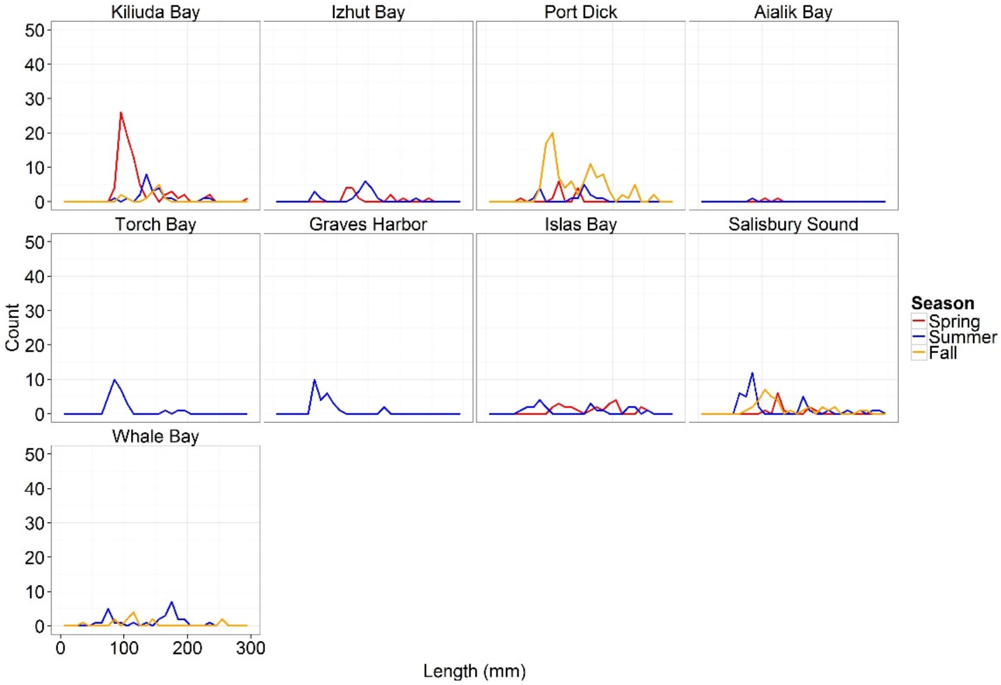


Figure 54. -- Length frequencies of greenlings collected in 2013 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

Saffron cod -- Saffron cod in the GOA are considered a forage fish for other species of fish, birds, and marine mammals. Spawning generally occurs December through March in shallow coastal zones in bays, gulfs, and inlets with strong tidal currents on sand-gravel substrate. Approximately 50% of adult saffron cod reach sexual maturity between the ages of 3 and 4 years. Adult saffron cod in the GOA are generally assumed to inhabit depths less than 50 m in eelgrass beds (preferred), kelp, and bedrock. Age-0 saffron cod are known to inhabit even shallower waters, less than 5 m, and preferentially utilize eelgrass beds.

The CPUE for saffron cod was variable in both 2011 (range from 10.5-261.0 average fish per haul) and 2013 (range from 4.5-65.0 average fish per haul) (Tables 15 and 16). Saffron cod were only captured in the nearshore region in the WGSR in 2011 and 2013 (Tables 15 and 16). Kiliuda Bay in the WGSR was the only bay where saffron cod were captured in all three seasons, in both years (Tables 15 and 16).

Length frequencies for saffron cod in 2011 (WGSR only), Kiliuda Bay, have two modes in the spring, one at 200 mm and another just under 300 mm (Fig. 55, red line). The modes that occurred in the summer for three of the four bays, both 2011 and 2013, were ~75 mm (Fig. 55, blue line). In 2013 (WGSR only), Kiliuda Bay is the only bay with a mode (150 mm) in the spring (Fig. 56). The modes in the summer and fall months for Kiliuda Bay, Port Dick, and Aialik Bay (summer only) are almost identical to the results of the length frequencies in 2011 (Figs. 55 and 56).

Table 15. -- Saffron cod CPUE (total number of fish /total number of hauls) in 2011 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2011			
WGSR	Spring	Summer	Fall
Kiliuda Bay	261.0	182.3	45.2
Izhut Bay	*	*	14.7
Port Dick	*	12.0	10.5
Aialik Bay	*	20.5	*
EGSR			
Torch Bay	*	*	*
Graves Harbor	*	*	*
Islas Bay	*	*	*
Salisbury Sound	*	*	*
Whale Bay	*	*	*

Table 16. -- Saffron cod CPUE (total number of fish /total number of hauls) in 2013 by season and bay, using a purse seine. An asterisk represents effort but no catch and NA means the bay was not visited (see Table 3).

2013			
WGSR	Spring	Summer	Fall
Kiliuda Bay	29.5	38.8	65.0
Izhut Bay	4.5	*	NA
Port Dick	*	9.9	23.5
Aialik Bay	*	47.4	NA
EGSR			
Torch Bay	*	*	NA
Graves Harbor	*	*	NA
Islas Bay	*	*	NA
Salisbury Sound	*	*	*
Whale Bay	*	*	*

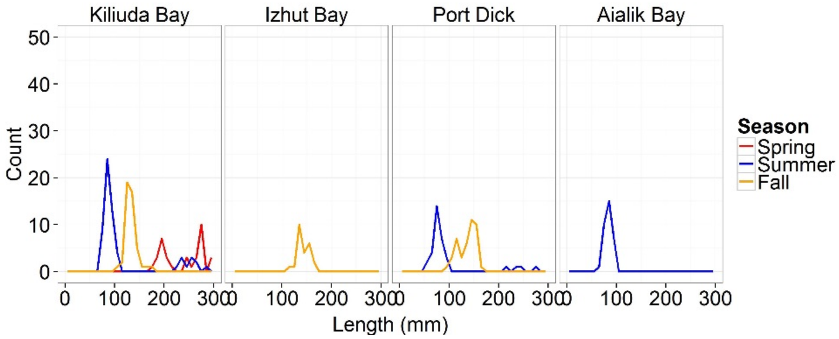


Figure 55. -- Length frequencies of saffron cod collected in 2011 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

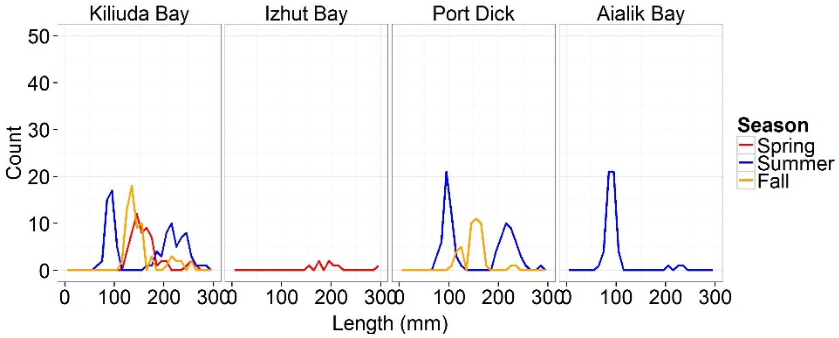


Figure 56. -- Length frequencies of saffron cod collected in 2013 by season and bay, using a purse seine (Note: if a bay isn't shown, lengths were not collected).

Conclusions

1) Comprehensive ecological surveys like those described in this report inherently involve trade-offs regarding geographic coverage, sampling resolution, and areas of research focus. Logistical factors such as time, funding, and weather pose additional constraints on survey design. Resolving such conflicts depends on the objectives of the survey. For example, we could have sampled a fewer number of sites and spent more time at each site. However a primary study objective was to sample over a broad geographic range according to the overall GOAIERP research design. We were only able to achieve that by spending a maximum of 3 days at each site. Similarly, we wanted to conduct more sampling with the beam trawl, but the acoustic and nearshore sampling were given a higher priority. The results presented here provide a broad-scale baseline for inshore research in the GOA; we suggest that future studies focus on sampling single sites at a higher resolution and with more gear types.

2) The purse seine used during these surveys is an ideal gear for sampling in nearshore areas ≤ 20 ft depth. It is easily deployed by two people from a small inflatable skiff, which is easily transported by most vessels; its use does not depend on access to the shore, greatly increasing the number of areas that can be accessed and reducing limitations due to tide state, and it creates a consistent sampling footprint allowing direct comparisons of catches among hauls. There is a possibility that catchability of the purse seine is reduced relative to a beach seine (mainly due to unavoidable lifting of the leadline during some parts of the deployment). This was not tested during the study but we feel confident that the purse seine provided a representative sample at each location.

3) The ability to take trawl samples of acoustic backscatter is important for maximizing the usefulness of acoustic data. Jigging provided valuable groundtruthing data, but in many cases we were unable to identify backscatter to species. We encourage the development of single-warp trawls that can be reliably deployed from vessels not rigged for standard trawling, as well as the development of effective camera systems for visualizing fish and zooplankton at depth.

4) Most bays contained similar nearshore habitat types, although the proportion of each varied among sites. Temperature and salinity varied consistently among all bays, with higher temperatures and lower salinity in the summer. This reflects an annual cycle of warming and freshening that begins in spring and peaks in summer; by fall temperatures begin to decline and salinity increases. Temperatures were fairly consistent among all sites regardless of geographic position, with summer nearshore temperatures commonly between 11°C and 13°C. Salinity was more variable among sites, with sheltered bays (e.g., Port Dick) regularly displaying lower salinities.

5) Acoustic backscatter attributed to fish and zooplankton varied substantially among sites and with year and season, but some broad trends were visible. Echosign generally increased with depth, and large, deep bays had higher backscatter values. Fish backscatter was higher in 2013, while zooplankton were more abundant in 2011. Sampling of echosign was limited but typically produced Pacific herring, walleye pollock, and *Sebastes* spp.

6) Nearshore species composition differed among sites, habitats, years, and seasons. Zoogeographic limits were evident for some species, for example, saffron cod were found only in the western region and shiner perch occurred only in the east. The most notable features of the nearshore fish communities observed

during this project were the strong seasonal changes in abundance and species composition that were driven mainly by the arrival of juvenile fishes (especially Pacific cod, walleye pollock, saffron cod, and *Hexagrammos* spp.) in the nearshore during summer. Juvenile herring also contributed to seasonal changes and their effect was not limited to summer; at several sites high abundance of herring were observed mainly in fall. Pacific cod were widely distributed, occurring in all bays except for Whale Bay. Pacific cod and pollock occurred in both regions but were more abundant in the western region. Pacific sand lance occurred occasionally in high abundance; this species is difficult to sample and these catches likely represent random encounters with individuals that are often buried in nearshore sediments. The nearshore studies of this project confirmed the importance of nearshore vegetated habitats as refuges for juvenile fishes.

7) The research conducted during these surveys contributed a great deal of new information regarding the inshore environment of the GOA. These areas appear to be important for juvenile fishes, partly because they provide suitable physical habitats. In addition, the similarity in nearshore temperatures among sites and the consistent seasonal changes in all areas suggest that the inshore may provide a relatively stable, predictable environment for marine organisms.

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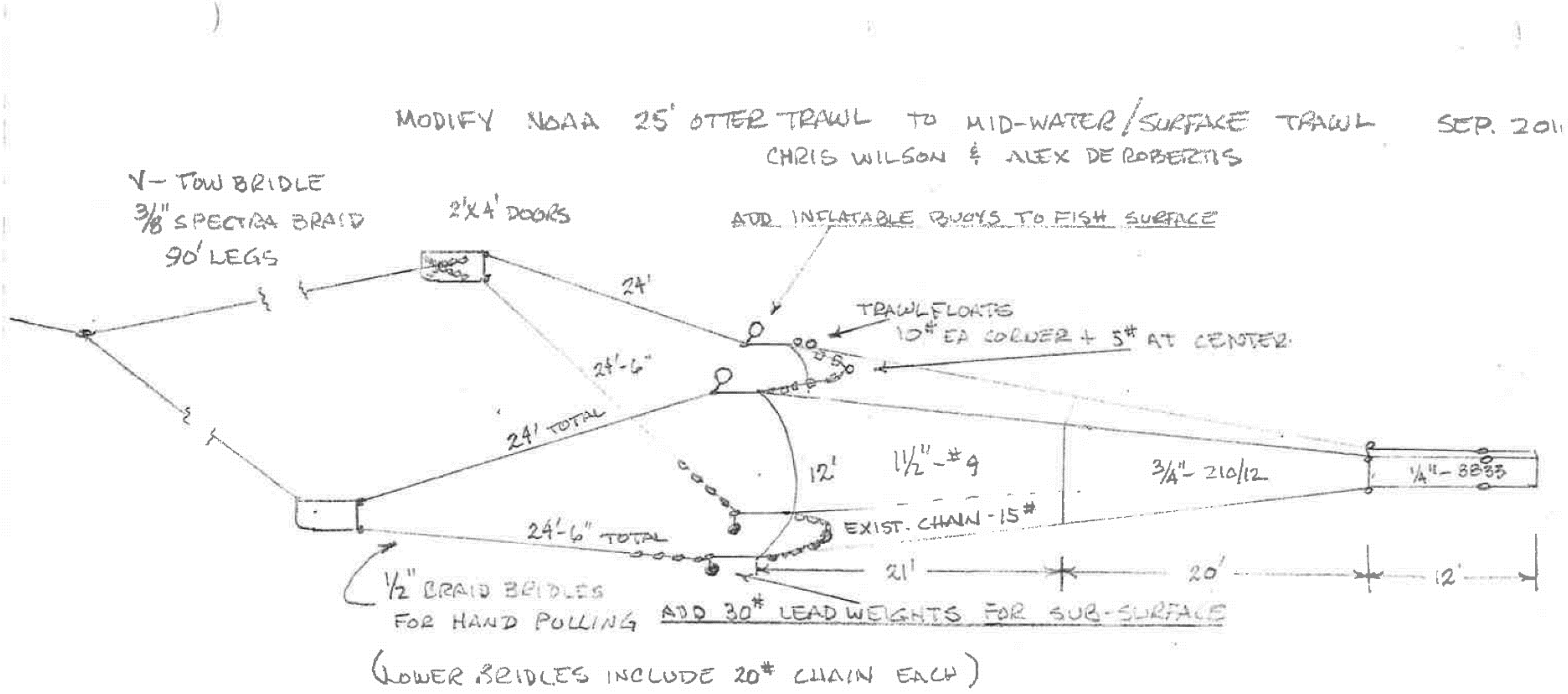
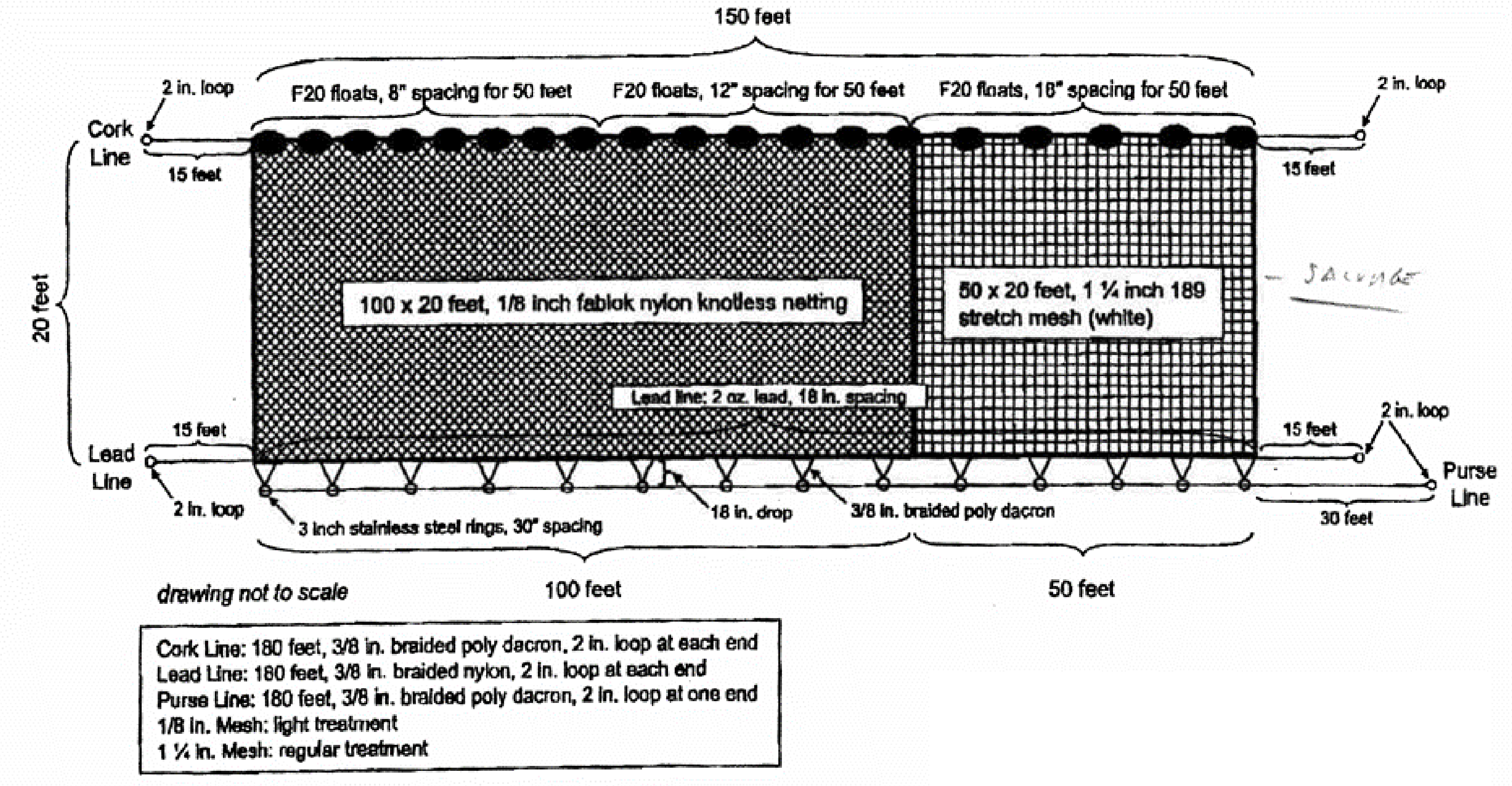
Appendices

Appendix A

Net Plans

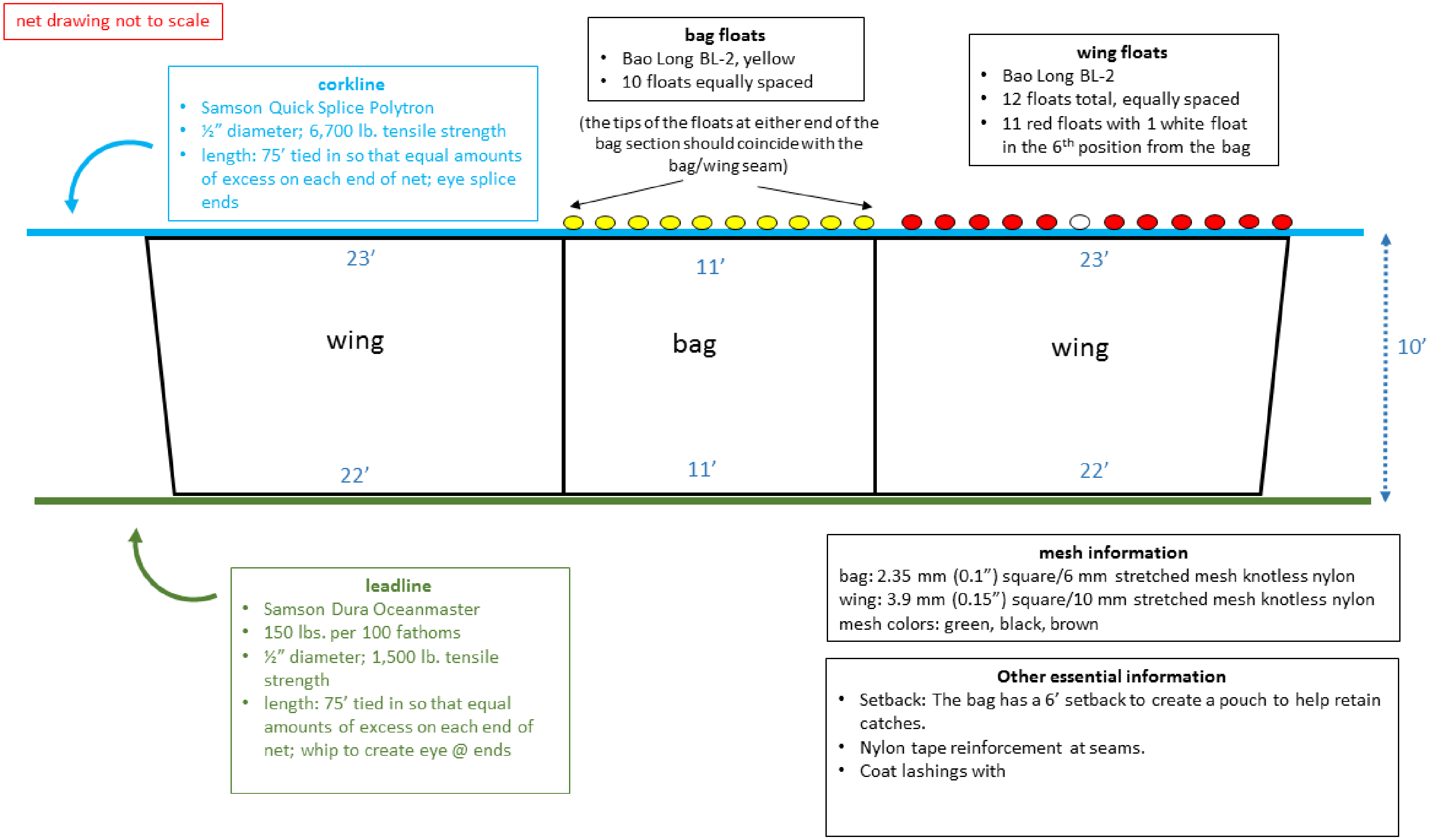


Appendix Fig. A-1. -- Plan for the “MiniMe” small midwater trawl**.**



Cork Line: 180 feet, 3/8 in. braided poly dacron, 2 in. loop at each end
Lead Line: 180 feet, 3/8 in. braided nylon, 2 in. loop at each end
Purse Line: 180 feet, 3/8 in. braided poly dacron, 2 in. loop at one end
1/8 in. Mesh: light treatment
1 ¼ in. Mesh: regular treatment

Appendix Fig. A-2. -- Plan for the LT150 small purse seine.



Appendix Fig. A-3. -- Plan for the 57 ft (17.4 m) beach seine used during 2013.

Appendix B

Instructions for Setting up and Using the “LitenTorsk150” Small Purse Seine

Net Structure and Terminology (see annotated net plan, Appendix Fig. B-1)

1) Each end of the net has different mesh sizes. The end with the fine mesh is called the “**bunt**”. This is where the captured fish will end up once the net has been retrieved, which is also why it’s called the “moneybag” on a commercial seiner. The end with the coarse mesh is called the “**weep**”. This is the last part of the net to be deployed and the first to be retrieved after the pursing is done.

2) The line with floats is the “**corkline**”, the line with the leads, purse rings, and purse line is the “**leadline**”. The person who handles the corks is “on corks” and is sometimes nicknamed “Corks”; the person handling the leadline is “on leads” (nickname “Leads”).

3) The bunt end of the corkline should have a line about 10-15 ft long attached to it, with loops at the end and at 5 ft from the bunt. At the end of this line should be clipped a 5-gallon bucket, which is called the “**jitney bucket**” (a commercial seiner uses a skiff or jitney to pull the net out; the bucket is the LT150 version of the skiff). The buoy is a medium-size Polyform buoy and should have a short line leading from the buoy to the clipping point on the bucket line.

4) The weep end of the corkline should have a line about 10 ft long attached to it; this is used to clip that end of the net to the skiff once the net is fully deployed.

5) Each end of the net should have “**breastlines”** that lead from the corkline to the leadline, and to which the net ends are laced. These strengthen the edges of the net web and are also needed for pulling the leadline up to the surface. If they are not present, an alternative is to tie “**lifting lines**” that lead directly from the corkline end to the leadline end. It is best to use a different color of line (or mark the line) so it is obvious which are the lifting lines. Also don’t make these too thin as they will be difficult and painful to yard on.

6) You will need a number of large stainless steel carabiners (minimum of four) just for the net. You will also need a couple of smaller carabiners for the buoy & jitney bucket. The best kind (and the most expensive) are those that have a “keyhole” closing system (Fig. B-2) rather than a hook. The carabiners with the hooks can snag the net.

7) Finally you will need a hook to hold the purse rings (Fig. B-3). This is called the “**hairpin**” or the “question mark”. You could probably come up with an alternative (a rod with a stop at the end might work), but the one shown here worked very well and it is worth spending the money to have one fabricated. You will need another carabiner to clip the hairpin to the skiff.

Preparing for Net Deployment (Appendix Fig. B-4)

1) These instructions will help, but it will still take practice to get the technique figured out!

2) A 16-ft inflatable skiff works well for deploying the LT150, but any open skiff should work. The 16-ft skiff gets a bit cramped but its maneuverability is a big plus. Only two people are needed for deploying and retrieving the net: Corks and Leads. Leads is also the driver, while Corks is responsible for getting the net out during deployment.

3) Another nice thing about an inflatable is that the D-rings and safety lines along the tubes make perfect clipping points for all aspects of the process. If you are in an aluminum work skiff or similar, you will need to create suitable attachment points.

4) The net should be stacked into the boat so that Corks and Leads are on opposite sides of the net. The corkline is stacked forward, the leadline is stacked aft, with the web stacked in between. The neatness of the stack will depend on the amount of room available (i.e., in a small skiff the stack can get pretty darn messy! But as long as you don't have the net rolled on itself or have lines tangled, it deploys from the skiff pretty cleanly.)

5) The weep (coarse mesh) end goes into the skiff first. It is easiest to have a clip pre-attached to the weep-end line before you stack the rest of the net. The bunt should end up on top of the stack, with the buoy and bucket clipped into the bucket line.

6) The net is deployed by backing the skiff in a circle until the two ends of the net are brought together (Fig. B-5). The meeting point of the bunt and weep should be downwind or downcurrent from the rest of the net so that the skiff is pushed away from the net during recovery. Since the meeting point is the same as the starting point, when starting the deployment the skiff should be positioned perpendicular to the wind/current, with the wind/current coming in on the starboard side of the skiff. (Use the figures shown here for orientation.) Also it is very difficult to consistently achieve a perfect downwind orientation!

7) We used the seine primarily to sample nearshore habitat where the leadline hits the bottom. However we successfully captured midwater herring schools using the seine on a couple of occasions by working very quickly

Deploying the Net (Appendix Fig. B-5)

1) The driver (Leads) sets up in the right spot and with correct alignment with the current and wind. Leads kicks it into reverse and gives the go-ahead to Corks. Corks gives Leads a sour glance for sitting in the back while Corks does all the work. Corks then throws the bucket as hard as they can in the 1 o'clock direction when facing forward. The best way to do this is to have the bucket in one hand and the buoy in the other so that they can be thrown at the same time. Once the bucket hits the water, Corks quickly feeds a bunch of the net into the water (at this point, both corkline and leadline will have to be manually fed over the side). All this time Leads is backing the skiff slowly away from the bucket and buoy. The bucket by itself is not enough to anchor the net in the water; until a certain amount of web is in the water, backing the skiff will tow the net. You don't want to do this too much as it messes up the orientation of the net with the wind/current or gets you away from the fishing target. It's very hard not to tow the net at least a little bit, and this should be accounted for in setting up the deployment. But Leads should also adjust their speed continuously so that the backing is very slow until there is enough web in the water.

2) Leads continues to back the skiff around in a circle, while Corks feeds the net over the side. At some point the net will be sufficiently anchored in the water so that it will feed over the side by itself, and Corks just needs to monitor it. It's not unusual for the web or rings to get hung up on parts of the skiff, so Corks needs to pay close attention during deployment.

3) There are many ways of completing the setting circle, depending on conditions. Generally we try to have the entire net out by the time the circle is 75-80% complete and then tow the weep end to the buoy. In some cases, however, it makes more sense to set it up so that you end up right at the buoy. If you still have net in the boat when you get to the buoy it makes the retrieval process much more difficult, and purposefully falling a bit short, and then towing, makes sure that you have all the net out of the boat. It also seems to help spread the net a bit. This is the part where practice will be required! As well as patience.

4) Once the skiff has reached the buoy, Corks grabs the buoy and begins to haul in the bucket and bucket line while Leads stops the motor and raises it out of the water. Leads clips the bunt end of the corkline to the side of the skiff, then hauls in the weep end of the corkline and clips it to the bunt end. You should end up with a complete circle of corkline clipped to the boat.

5) At this point you must do everything **quickly** until the net is pursed! Until the net is pursed there are gaps in the net and if the net is not touching bottom, fish can swim under the leadline. There are some exceptions (see below) but in general you cannot waste any time until the pursing is complete.

6) The next step is to haul up each end of the net so that the leadlines can be clipped together just like the corklines. If you don’t do this there will be a large gap in the net. Corks pulls up the weep side of the net; Leads pulls up the bunt side of the net. Leads clips the two ends together. DO THIS AS QUICKLY AS POSSIBLE!

7) We have tested two additional steps here: a) attaching a weight to the point where the leadline ends are clipped together which helps keep the leadline down while pursing, and b) clipping the two net ends together at the midway point of the breastlines to reduce the gap between the net ends. Both of these methods are possible but we found that they make the retrieval more difficult and we felt in balance it was better just to act quickly. Experimentation might be a good idea depending on your application. Salmon seiners use a plunge pole to scare fish away from net gaps, which may be worth considering.

8) Once the leadlines are clipped together, Leads grabs the end of the purseline attached to the bunt end of the net, then the leadline is allowed to drop down into the water. Leads should walk their hand along the purseline as the leadline falls so that the purseline doesn’t keep the leadline from falling. Once the leadline has dropped back down and the net is vertical in the water column, Leads can begin to retrieve the purseline.

9) At this point the net should appear as a complete circular curtain surrounding your target, with the skiff on one side where the two ends come together. Leads is now going to pull the purseline in and stack it in the skiff, pulling the lower edge of the net curtain into a single point and creating the purse. The purseline should be stacked aft of the areas where the net was stacked.

10) Pursing is done either quickly or slowly depending on what you’re trying to catch. If you are trying to maintain bottom contact it is better to purse relatively slowly to reduce the tendency of the leadline to lift off the bottom while pursing. In contrast, if you are surrounding a midwater school, you want to get that purseline in as quickly as you possibly can. You will notice that as the rings come together, the weight of the accumulated rings will tend to keep the leadline down.

11) While Leads is pursing, Corks can do tasks like recording waypoints or taking CTD measurements. Corks might also have to use a paddle or boathook to keep the corkline under control during pursing. Pursing has the effect of drawing the skiff into the center of the net; that’s why setting downwind is so important, because the wind/current will counteract this action. Even so, the skiff usually gets drawn into the net and Corks can help to minimize this.

12) When the entire purseline has been brought aboard, Leads will feel the purseline grow tight. This is because they have reached the other (weep) end of the net where the purseline has another fixed attachment point and are starting to lift the entire pursed bottom of the net (the gathered leadline and purse rings). When Leads feels this weight, Corks should grab the lifting line on the weep end of the net, and together they bring the bunch of rings to the surface.

13) When the rings come to the surface, they should ideally be arranged in a perfect U-shape (see drawing in Fig. B-6). That rarely happens: usually you have to pull out some parts of the web that have become pinched between rings or straighten rings and ring droplines that have become twisted.

14) Once the rings are sorted out, insert the hairpin from the bunt (aft) end of the rings and make sure all the rings are on the hairpin. Clip the hairpin line to the opposite side of the skiff so that the rings are out of the water.

15) Now you have to sort out the net in preparation for retrieving it. There is no good way to explain this; practice makes perfect. You will be pulling the net back into the boat starting with the weep end and will bring the bunt end in last, hopefully full of fish. To set this up, you need to make sure that the entire bunt end of the net is aft of where the rings and net folds are, and that the weep end of the rings and net are forward of the rings.

16) Leads unclips the bunt end of the corkline, brings it aft, and clips it to the skiff a foot or two aft of the rings. This will involve pulling the bucket line free with it. Usually the rings are in the way of all this. If you have to lift the rings, Corks should hang on to the free end of the hairpin so the rings don't fall off!

17) Leads pulls up the bunt end sideline, then unclips the two ends of the leadline, clips the bunt-end of the leadline to where the bunt-end of the corkline is, and stashes the folded up bunt end of the net somewhere out the water (with the Zodiac's safety lines we just fold them through the safety line). **If you don't pull up the bunt-end breastline, you will have a big gap in your moneybag at the end and will lose all your fish**!

18) While Leads does that, Corks is similarly gathering the entire weep end of the net (corkline, breastline, leadline) forward of the net.

19) Before starting the retrieval, it's helpful to "mend" the net. It's likely that you will have corkline floating around on different sides of the boat, and this will make a mess when retrieving. Use a boathook or paddle to get the entire net on the starboard side of the boat. You might have to repeatedly stop retrieving and mend the net, depending on how the boat is moving.

20) Leads then moves forward to stand at the rings or slightly forward of the rings. Corks grabs the corkline, Leads grabs the leadline, and they begin to pull the net in and stack it in the boat in the same way it was originally stacked when you started. Leads needs to make sure that the purseline is being matched back up with the leadline - they will be pulling the purseline back through the rings. Then, as each ring attachment point on the leadline is reached, the ring will be lifted off the hairpin and pulled into the net stack. So, you are basically stretching the entire purseline back into its original pairing with the leadline.

21) Leads and Corks will both have to regularly pull in web along with the corkline/leadline. Usually we just take turns.

22) It’s important to pull the corkline and leadline in evenly. The transition from the coarse to fine mesh is a good time to check this; if one is ahead, they stop pulling in until the other has caught up. Typically Corks is ahead of Leads at this point, so they wait for Leads to catch up. If you are way out of sync it really messes up the lay of the net.

23) **Watch for fish coming up in folds of the net or gilled in the coarse meshes, this happens frequently.**

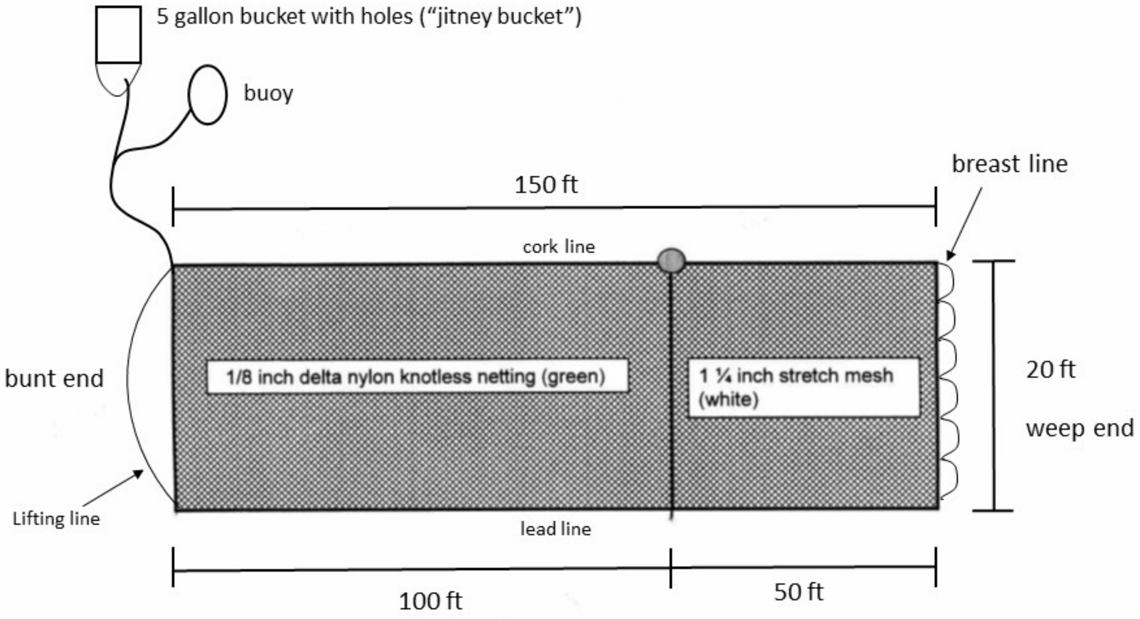
24) Once you get to the bunt end (the moneybag), you need to be really careful to maintain a nice bag for all of your fish. There is so much web that it can get really confusing as to where the money bag is. Practice is really the only way to master this, but in general go slowly and communicate so that you’re not working against each other.

25) When Corks is close to the end of the corkline, Leads pulls out the hairpin and rapidly pulls in the rest of the leadline. You then have a nice bag, but it has lots of web. Corks holds the corkline away from the boat while Leads carefully pulls in web so that you have a nice small, clearly defined bag. The two then work together to bring the bag into the skiff. Here again, go slow and make sure you know what’s going on with the net before trying to lift it into the boat. If you aren’t careful you can dump the catch overboard or lose it in the innumerable folds of net web. Venomous jellies can and should be lifted out of the bag before bringing it on board. We developed a nifty technique using a paddle blade to flip them up and over the corkline.

26) Sometimes it is easiest just to dump the catch en masse into a tote for sorting; if it is a small catch or there is lots of kelp in it you can sort it out of the moneybag and hand-sort the fish into tubs.

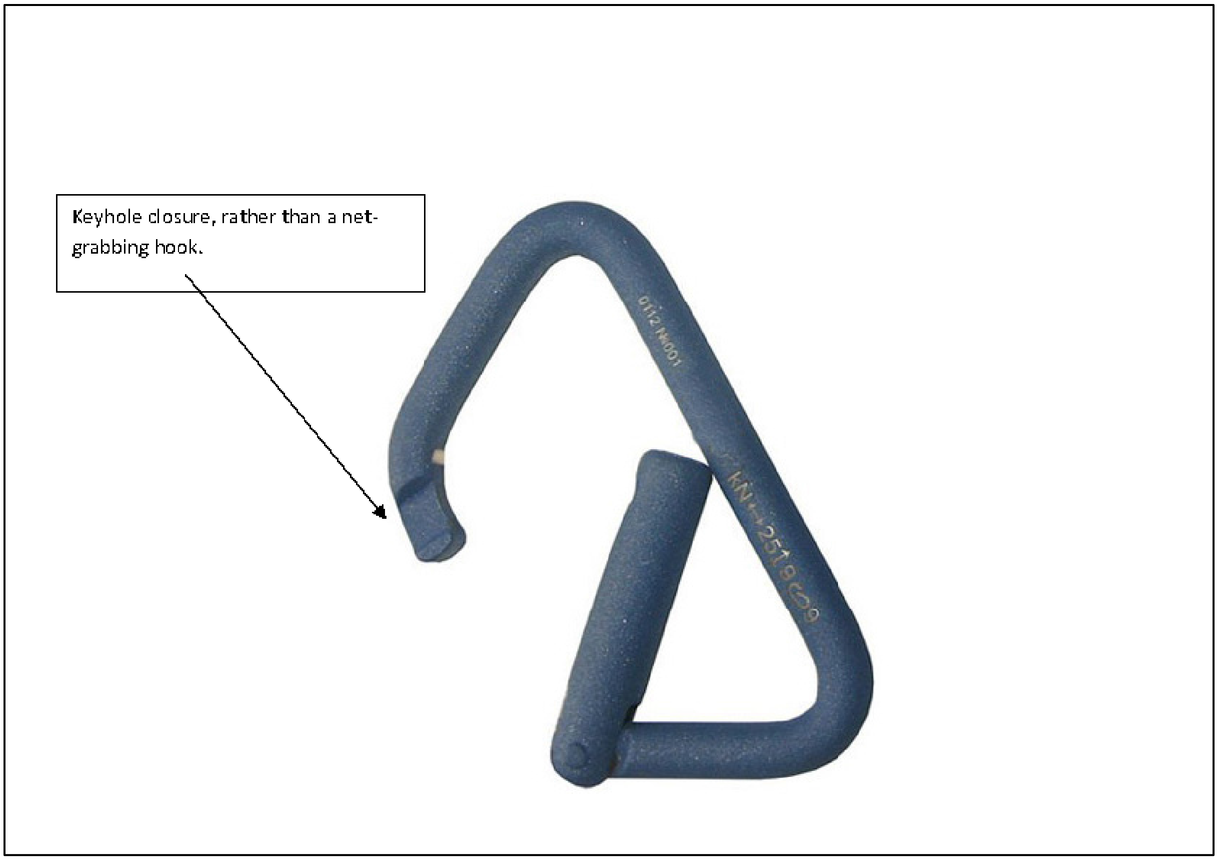
27) Once you are ready to move on (have either worked up the catch or are going to transport it somewhere else for processing), the bunt end of the net should be rearranged for the next deployment. Usually the bunt end and its various lines will be disorganized, and the web will have fish slime, kelp, etc. If you dump the top 10 ft or so of the net (corkline, web, leadline) over the side, that will clean it and also allow for orderly restacking of the bunt end in the skiff.

28) Good luck!

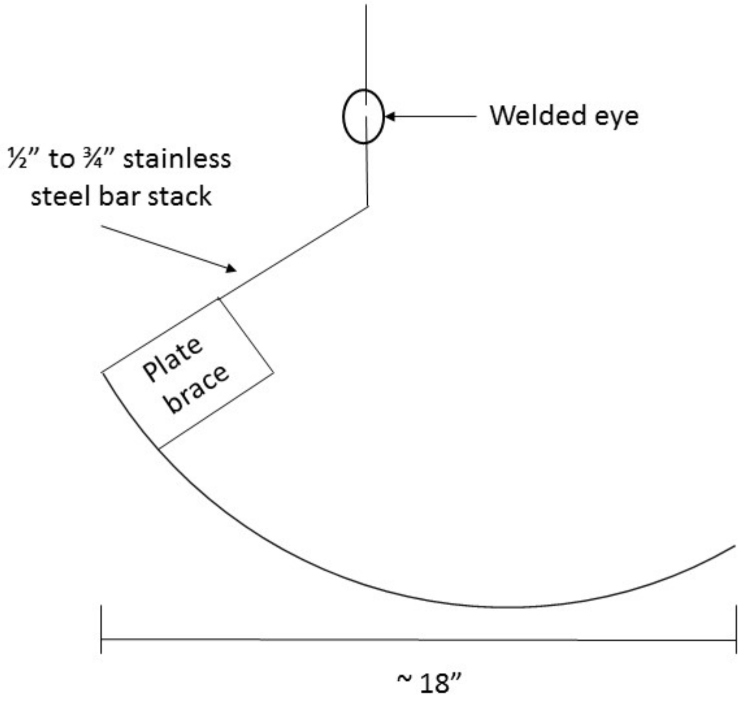


- Heavy leaded L6 (2.66 oz. leads every foot) (see "lead line" in graphic)
- SB4 floats every foot; different color float at transition (see "cork line" in graphic)
- Stainless steel purse rings every 2 feet with 18 inch drop
- Purse rope; 5/16 inch diamond braided nylon rope
- Green plasti-net coating

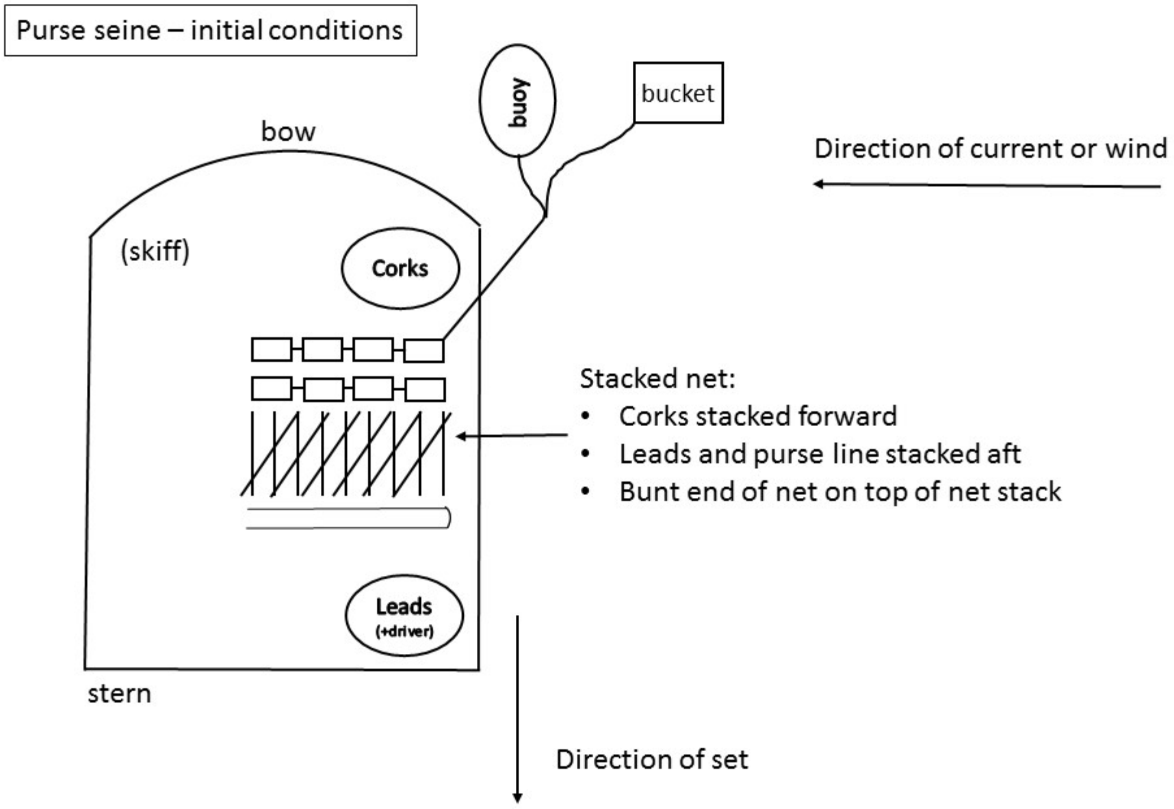
Appendix Figure B-1. -- Annotated purse seine diagram showing terminology, lines, and anchoring bucket.



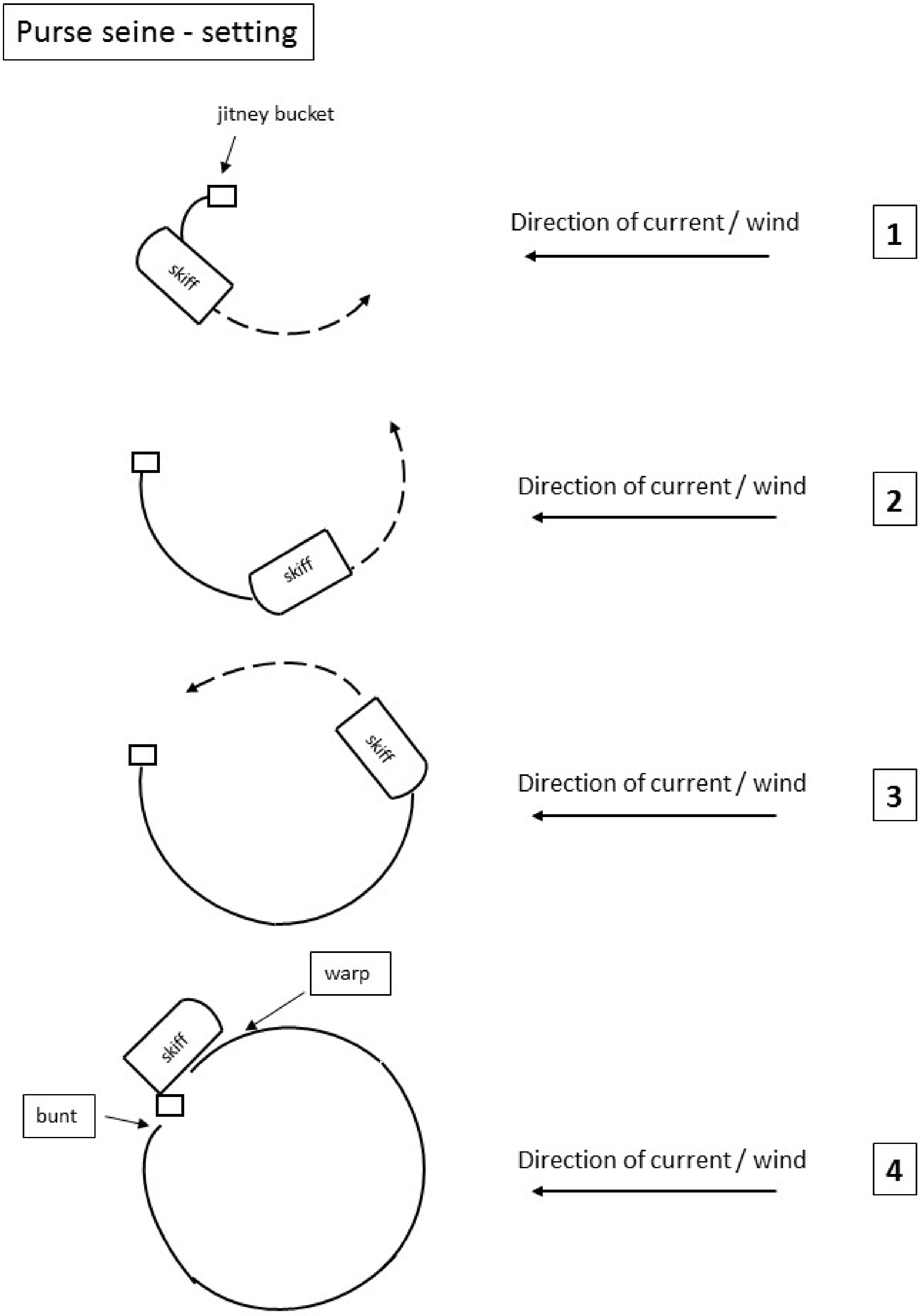
Appendix Figure B-2. -- Photgraph of the desired carabiner type for purse seining.



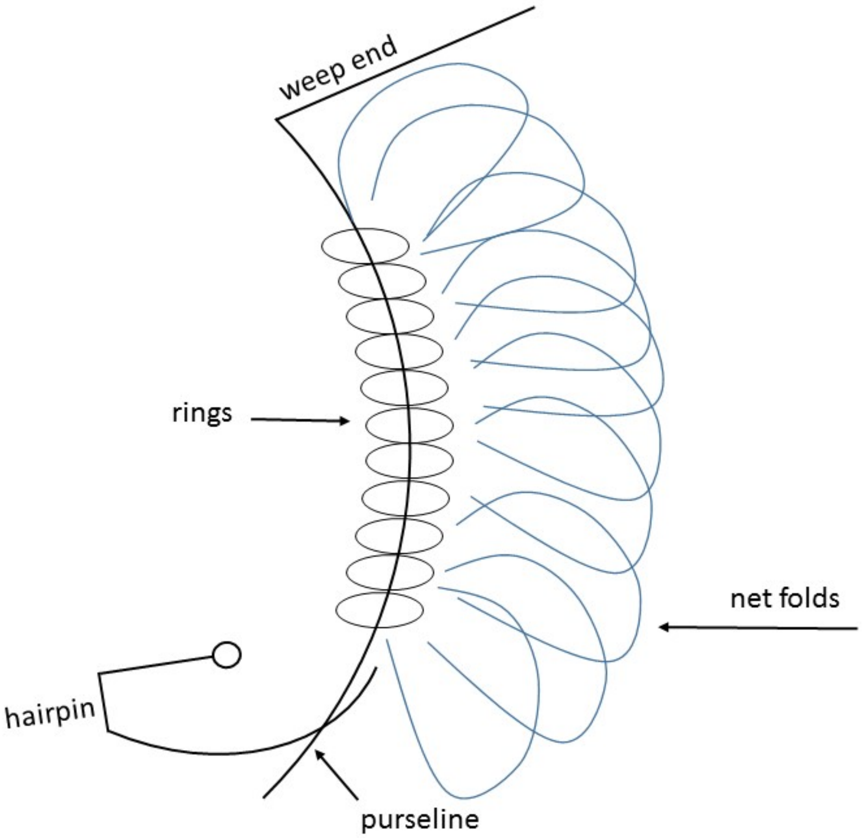
Appendix Figure B-3. -- Schematic of the custom stainless steel hook used for holding the purse rings.



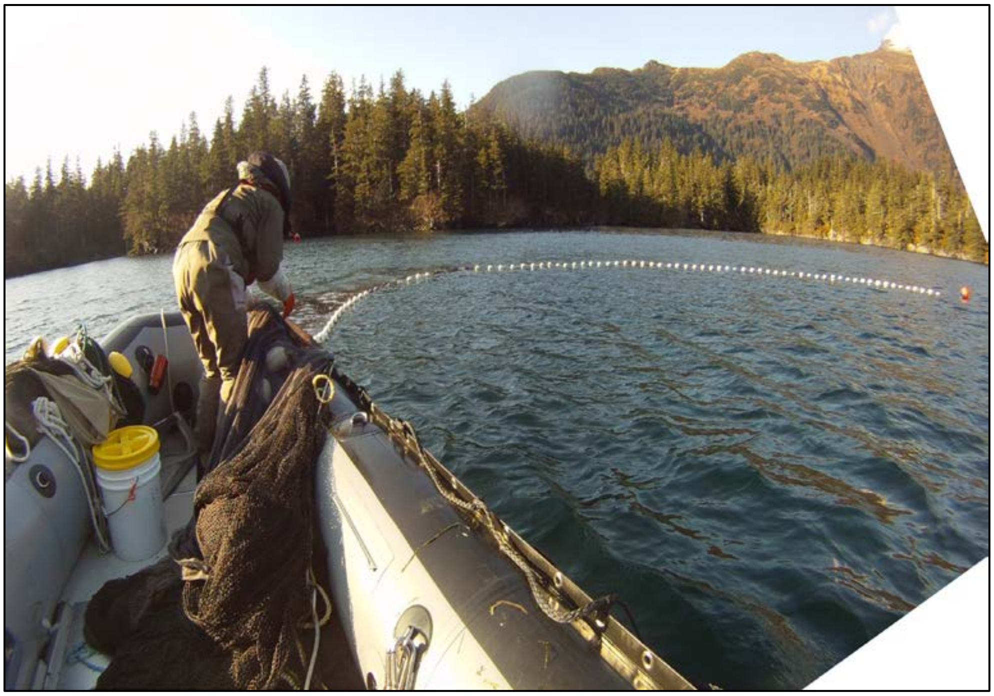
Appendix Figure B-4. -- Schematic of the seining skiff and correct placement of personnel and gear prior to setting the net.



Appendix Figure B-5. -- Schematic showing desired net-setting sequence when wind and/or current are present.



Appendix Figure B-6. -- Schematic of purse rings and hook after net is pursed and before net retrieval.



Appendix Figure B-7. -- Setting the purse seine.

Appendix Figure B-8. -- Sorting lines before pursing the net.

Appendix Figure B-9. -- Retrieving the purse seine.

Appendix Figure B-10. -- Typical kelp harvest (left panel) and fish harvest (right panel).

Appendix C

Catch Tables

Appendix Table C-1. -- The total number of hauls is summarized by regional area (CruiseID[1]), study site (SiteCode[2]), and gear type[3].

CruiseID	SiteCode	BS	BT	JG	MM	OS	PS	SJ	ST
EG201101	GH	13							
	IB	18					25		
	SL			7					
	SS	12		4			20		
	TB	4		2			1		
	WB	12							
EG201102	GH	8		4			38		3
	IB	16					38		
	SL			8					
	SS	39	12	2	1		32		
	TB	10		5			14		
	WB	13		5			21		
EG201103	DB						5		
	IB	9					29		
	RB					3			
	SS	4		2			37		
	WB	2		5		4	30	1	
EG201301	GH	14					17		1
	IB	20					38		
	SL		2	8					
	SS	25		5			37		3
	WB	21		2			25		5
EG201302	GH						32	1	
	IB	20				1	46		
	IZ						1		
	SL			1					
	SS						45	1	
	TB	16				2	18		
	WB	6		6			57	1	
EG201303	SL			7					
	SS	27		3			49	2	
	WB			11		1	54		
WG201101	AB	20		2			1		
	IZ	22					16		
	KB	18		5			20		
	PD	26	21	1			22		

CruiseID	**SiteCode**	**BS**	**BT**	**JG**	**MM**	**OS**	**PS**	**SJ**	**ST**
WG201102	AB			2			14		
	IZ	5					18		
	KB	12	14	7			39	4	3
	PD	11	14	5		3	48		7
WG201103	BI		1	2					
	IZ			10			39		
	KB	9					49	1	1
	PD					3	58		
WG201301	AB	4					12		
	IZ	18					20		
	KB	7					37		
	PD						25		
WG201302	AB	5				7	17		
	IZ	27		2		2	30	2	
	KB	10		3		4	31		
	PD	13		9		7	37		
WG201303	KB					4	17		
	PD					8	57		

1 CruiseID is a combination of study region (WG = western GOA, EG = eastern GOA), year (2011 and 2013) and survey leg (01 = spring, 02 = summer, 03 = fall).

2 SiteCode: TB = Torch Bay, GH = Graves Harbor, IB = Islas Bay, SL = St. Lazaria, SS = Salisbury Sound, WB = Whale Bay; KB = Kiliuda Bay, IZ = Izhut Bay, BI = Barren Islands, PD = Port Dick, AB = Aialik Bay.

3 BS = beach seine, BT = beam trawl, JG = jigging, MM = mini me (see acoustics), OS = opportunistic sampling, PS = purse seine, SJ = surface jigging; ST = surface trawl.

Appendix Table C-2. -- The species captured with the beam trawl (BT) and surface trawl (ST), all cruises (Cruise ID[1]), and sites (SiteCode[2]). The fields “Start Lat DD” and “Start Long DD” are in decimal degrees.

Cruise ID	**Haul**	**SiteCode**	**Gear**	**Date**	**Start Lat DD**	**Start Long DD**	**Common Name**	**Species Name**	**Genera**	**Count**
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	alligatorfish		Agonidae	2
WG201102	1	KB	BT	8/9/2011	57.34	-152.88	anemone		Actiniaria	1
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	arrowtooth flounder	*Atheresthes stomias*		2
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	bairdi crab	*Chionoecetes bairdi*		14
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	brittlestar	Ophiuroidea		6
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	chionoecetes crab	*Chionoecetes* sp.		3
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	chiton unid	Polyplacophora		1
WG201102	2	KB	BT	8/9/2011	57.31	-153.16	clam unid		Clam unident.	10
EG201301	2	SS	ST	4/24/2013	57.36	-135.75	crab unid			1
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	crangon shrimp		Crangonidae	5
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	crangon shrimp		Crangonidae	15
WG201102	2	KB	BT	8/9/2011	57.31	-153.16	crangon shrimp		Crangonidae	7
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	crescent gunnel	*Pholis laeta*		1
WG201102	1	KB	BT	8/9/2011	57.34	-152.88	crescent gunnel	*Pholis laeta*		1
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	dover sole	*Microstomus pacificus*		2
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	dungeness crab	*Cancer magister*		3
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	eastern pacific bobtail	*Rossia pacifica*		1
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	eelblenny unid		Blennidae	4
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	english sole	*Parophrys vetulus*		3
EG201301	2	WB	ST	4/20/2013	56.59	-134.97	eulachon	*Thaleichthys pacificus*		1
EG201101	1	SL	BT	4/18/2011	NA	NA	euphausid		Euphausiacea	20
EG201301	1	WB	ST	4/20/2013	56.73	-134.85	euphausid		Euphausiacea	5
EG201301	1	GH	ST	4/28/2013	58.29	-136.70	euphausid		Euphausiacea	1
EG201301	2	WB	ST	4/20/2013	56.59	-134.97	euphausid		Euphausiacea	23
EG201102	1	GH	ST	7/19/2011	58.29	-136.70	fish unid			1
EG201301	1	WB	ST	4/20/2013	56.73	-134.85	fish unid			2
EG201301	2	WB	ST	4/20/2013	56.59	-134.97	fish unid			11
EG201301	2	SS	ST	4/24/2013	57.36	-135.75	fish unid			5
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	flatfish unid		Pleuronectiformes	1
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	flathead sole	*Hippoglossoides elassodon*		25
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	flathead sole	*Hippoglossoides elassodon*		16
WG201102	1	PD	ST	8/13/2011	59.30	-151.26	flathead sole	*Hippoglossoides elassodon*		2
WG201102	2	KB	BT	8/9/2011	57.31	-153.16	flathead sole	*Hippoglossoides elassodon*		4
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	great sculpin	*Myoxocephalus polyacanthocephalus*		1
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	helmet crab	*Telmessus cheiragonus*		1
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	hermit crab unid		Paguridae	4
EG201101	1	SL	BT	4/18/2011	NA	NA	herring	*Clupea pallasi*		14

Appendix Table C-2. – Continued.

Cruise ID	Haul		Gear	Date	Start Lat DD	Start Long DD	Common Name	Species Name	Genera	Count
WG201102	1	PD	ST	8/13/2011	59.30	-151.26	herring	*Clupea pallasi*		2
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	leatherstar	*Dermasterias imbricata*		4
EG201301	1	SS	ST	4/24/2013	57.29	-135.58	lions mane	*Cyanea capillata*		75
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	lyre crab	*Hyas lyratus*		1
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	lyre crab	*Hyas lyratus*		13
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	lyre crab	*Hyas lyratus*		5
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	marine worms unid		marine worms unid	6
WG201102	2	KB	BT	8/9/2011	57.31	-153.16	mysids		Mysidae	5
WG201102	2	KB	BT	8/9/2011	57.31	-153.16	northern rock sole	*Lepidopsetta polyxystra*		1
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	northern ronquil	*Ronquilus jordani*		1
WG201102	1	PD	ST	8/13/2011	59.30	-151.26	northern ronquil	*Ronquilus jordani*		2
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	northern sculpin	*Icelinus borealis*		5
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	nudibranch unid		Nudibranchia	1
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	nudibranch unid		Nudibranchia	2
WG201102	1	KB	ST	8/8/2011	NA	NA	pacific cod	*Gadus macrocephalus*		5
WG201102	1	KB	BT	8/9/2011	57.34	-152.88	pandalid shrimp unid		Pandalidae	13
WG201102	2	KB	BT	8/9/2011	57.31	-153.16	plain sculpin	*Myoxocephalus jaok*		2
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	poacher unid		Agonidae	1
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	pollock	*Theragra chalcogramma*		8
WG201102	1	PD	ST	8/13/2011	59.30	-151.26	pollock	*Theragra chalcogramma*		56
WG201102	1	KB	ST	8/8/2011	NA	NA	prowfish	*Zaprora silenus*		2
WG201102	1	PD	ST	8/13/2011	59.30	-151.26	prowfish	*Zaprora silenus*		1
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	rex sole	*Glyptocephalus zachirus*		1
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	rex sole	*Glyptocephalus zachirus*		2
EG201102	1	GH	ST	7/19/2011	58.29	-136.70	rock greenling	*Hexagrammos lagocephalus*		4
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	rock sole	*Lepidopsetta* sp		1
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	rock sole	*Lepidopsetta* sp		2
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	rockfish unid	Sebastes sp.		2
WG201102	1	KB	ST	8/8/2011	NA	NA	saffron cod	*Eleginus gracilis*		1
WG201102	1	PD	ST	8/13/2011	59.30	-151.26	sand sole	*Psettichthys melanostictus*		1
EG201102	1	GH	ST	7/19/2011	58.29	-136.70	sandfish	*Trichodon trichodon*		471
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	scallop unid		Pectinidae	3
WG201103	1	BI	BT	10/23/2011	NA	NA	scallop unid		Pectinidae	5
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	sculpin unid		Cottidae	1
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	sculptured shrimp	*Sclerocrangon boreas*		1
WG201102	2	KB	BT	8/9/2011	57.31	-153.16	sculptured shrimp	*Sclerocrangon boreas*		0
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	sea star		Astroidea	10

Appendix Table C-2. – Continued.

Cruise ID	Haul	SiteCode	Gear	Date	Start Lat DD	Start Long DD	Common Name	Species Name	Genera	Count
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	sea urchin unid		Echinacea	2
WG201103	1	KB	ST	10/18/2011	57.26	-152.89	snailfish unid		Liparidae	1
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	snake prickleback	*Lumpenus sagitta*		2
WG201102	2	KB	BT	8/9/2011	57.31	-153.16	snake prickleback	*Lumpenus sagitta*		7
WG201102	1	KB	BT	8/9/2011	57.34	-152.88	spot shrimp	*Pandalus platyceros*		2
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	sturgeon poacher	*Podothecus accipenserinus*		1
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	sunflower sea star	*Pycnopodia helianthoides*		9
WG201102	1	PD	ST	8/13/2011	59.30	-151.26	tomcod	*Microgadus proximus*		3
WG201102	1	KB	BT	8/9/2011	57.34	-152.88	tube worm unident			0
EG201102	1	SS	BT	7/13/2011	57.29	-135.57	yellowfin sole	*Limanda aspera*		2
WG201101	1	PD	BT	5/16/2011	59.31	-151.29	yellowfin sole	*Limanda aspera*		2
WG201102	1	PD	BT	8/14/2011	59.92	-151.29	yellowfin sole	*Limanda aspera*		5
WG201102	2	KB	BT	8/9/2011	57.31	-153.16	yellowfin sole	*Limanda aspera*		1

1 CruiseID is a combination of study region (WG = western GOA, EG = eastern GOA), year (2011 and 2013) and survey leg (01 = spring, 02 = summer, 03 = fall).

2 SiteCode: TB = Torch Bay, GH = Graves Harbor, IB = Islas Bay, SL = St. Lazaria, SS = Salisbury Sound, WB = Whale Bay; KB = Kiliuda Bay, IZ = Izhut Bay, BI = Barren Islands, PD = Port Dick, AB = Aialik Bay.

Appendix D

Data Corrections Applied to Summer 2011 and Fall 2011 Nearshore Echosounder Data

Introduction

After the conclusion of the 2011 summer acoustic surveys, wear on the transducer cable in the area where the cable enters the tow body was discovered. Inspection of data from this and previous cruises indicated that for the observations made in spring and summer 2011, the 38 kHz backscatter appeared weak relative to the 120 kHz backscatter. After the problem was identified, the cables were replaced, and discussions with several colleagues revealed that the cables are vulnerable to cable fatigue and that similar damage has gone undetected in several instances. In an effort to identify and characterize biases introduced by this damage to the cable, an analysis of measurements of the bottom echosounder made during repeated visits to the study site with the same equipment was undertaken to characterize the impacts of damage to the tow body's wiring on the acoustic measurements.

The premise of this analysis is that during the fall 2011 cruise, after the cable damage was identified, the cables were replaced, and the echosounder system was carefully monitored (calibrated on six occasions). The data are known to be free of errors introduced by damage to the cable. The bottom echo is known to provide a consistent acoustic signal, and using the bottom echo as a reference has proved useful in establishing instrument performance in previous studies (e.g., Dalen and Løvik, 1981; De Robertis and Hjellvik, 2007, Shabangu et al. 2014). Given that the same transects were revisited during the spring and summer and fall cruises, the echosounder performance was characterized by comparing the bottom echo observed in a given location with that observed during fall 2011, when instrument performance was free of biases introduced by damage to the cable.

Analysis of Acoustic Data

The echosounder data were post-processed using Myriax Echoview software (version 5.3). The mean values (averaged in linear units) of integration gain from all available calibrations were applied to each frequency, and the manufacturer-supplied measurements of equivalent beam angle were used in post-processing. A bottom zone integrating the first return from the seabed echo was defined as a vertical layer extending from 0.5 m above the sounder-detected bottom to 25 m below bottom and manually altering this line as needed so that it encompassed the first bottom echo. The data from the first 0-2 m in range, which are dominated by the echosounder's transmit pulse (Lars Anderson, Simrad, Pers. Comm.) were also exported. Geo-referenced acoustic data from these two features were exported at a 100 m along-track horizontal resolution using a -70 dB re 1 m^{-1} S_v integration threshold (see MacLennan et al. 2002 for definitions of acoustic units used in this document). Surveys were conducted in summer 2010 in the EGOA (hereafter referred to as pass 0), and in spring, summer, and fall of 2011 in both the CGOA and EGOA (hereafter referred to as passes 1-3).

Initial inspection of the water column data and examination of the bottom scattering strength in repeat passes suggested that damage to the transducer cable resulted in substantial under-estimates of 38 kHz backscatter. The 38 kHz backscatter from the seafloor during survey pass 2 and parts of pass 1 was substantially lower than during passes 0 and 3 (i.e., compare the adjacent boxplots in Fig. D-1: the black and red box plots tend to be lower than the blue and green ones). However, the 120 kHz did not exhibit this behavior: no consistent differences in backscatter from the seafloor echo are evident among passes (Fig. D-2).

Statistical Analysis of Bottom Echo

To align the observations made during repeat passes in space, a 200 m grid at was defined in each bay, and the measurements of bottom backscatter at each location and cruise $\mathrm{s}_{\mathrm{A},i,j}$ (i.e., location *i*, and cruise *j*) falling within ±100 m of each gridpoint were averaged. The measurements from the seafloor echo are defined as

$$\mathrm{s}_{\mathrm{A},i,j} \quad i = 1,..n, \qquad \text{(D-1)}$$

where $\mathrm{s}_{\mathrm{A},i,j}$ is the s_A from the first bottom echo (nautical area scattering coefficient, $\mathrm{m}^2/\mathrm{nmi}^2$) recorded at location *i* during pass *j* (2010 summer = 0, 2011 spring = 1, 2011 summer = 2, 2011 fall = 3) . We are interested in the ratio

$$R = s_{A,i,j} \,/\, s_{A,i,j=3} \ , \qquad \text{(D-2)}$$

which can be computed from the difference in the log-transformed observations of s_A from the seafloor in repeat passes of a given bay

$$d_i = \ln(\mathrm{s}_{\mathrm{A},i,j}) - \ln(\mathrm{s}_{\mathrm{A},i,j=3}) + e_i \, , \qquad \text{(D-3)}$$

where $e_i = \ln(\varepsilon_{i,j}) - \ln(\varepsilon_{i,j=3})$ is normally distributed random noise, and $\hat{R} = \exp(\bar{d})$, where $\bar{d} = n^{-1}\sum_{i=1}^{n} d_i$, is an unbiased estimate of *R* (Kieser et al. 1987).

Calculation of d_i for the data set showed a bimodal distribution for 38 kHz bottom echoes (Fig. D-3a), but a unimodal distribution in the case of 120 kHz (Fig. D-4). This suggests that the performance of the 120 kHz was consistent over the survey period but that the 38 kHz produced consistently different backscatter from the bottom during the survey passes. The bimodal histogram of d_i can be decomposed into two unimodal histograms with a mean d_i of approximately 0 (i.e., *R* of ~ 1) at the beginning of the study (Fig. D-3b) and another state later in the study with a mean d_i of ~2 (i.e., *R* of ~ 7, Fig. D-3c).

These first few samples in the echosounder data (often referred to as ’ringdown’), include information from the transmit pulse, and for a given set of settings, the ringdown is highly consistent in a properly performing echosounder. For example, deviations in the transmit pulse have been used to detect and accurately compute corrections for a ± 0.5 dB dither deliberately introduced in a variant of the EK60 echosounder developed for the fishing industry (Ryan and Kloser, 2004). This transmit pulse S_v (defined as the S_v observed at a range of 0-2 m) is correlated with the discrepancy in the 38 kHz bottom echo compared to that observed during fall

2011, and the trend between the transmit pulse S_v and the observed mean discrepancy in the bottom echo is approximately linear (Fig. D-5). There is substantial variation about this mean value, but this is to be expected as individual comparisons of the bottom echo on repeat visits are noisy estimators of R (e.g., Figs. D-3a, 4).

Adjustment of Acoustic Backscatter to the Bottom Echo

As an alternate form of calibration, the backscatter measurements made during survey passes 1-2 were scaled to the bottom echo observed during pass 3 in order to control for differences in echosounder sensitivity that are manifested in the bottom echo. The rationale for this approach is that if: (1) the bottom echo is measured accurately, and (2) the vessels passed over bottoms with similar average characteristics, echosounders adjusted to give the same bottom echo will produce similar echo intensity from targets in the water column.

The correction was applied on a ping-by-ping basis (i.e., on the raw 38 kHz data) by removing the change in sensitivity estimated from the change in the bottom echo compared to that observed during fall 2011 at that location from the data based on the observed state of the transmit pulse (Fig. D-5):

$$S_{v,corr} = S_{v,obs} - (-8.13 \cdot S_{v,transmit} - 109.83) \qquad \text{(D-4)}$$

This is analogous to calibrating the echosounder such that it will report the same average bottom backscatter strength on all passes. This has the effect of removing the trend in the bottom echo discrepancy (i.e., $\bar{d} = 0$, and R = 1) compared to fall 2011 (Fig. D-6) , and the corrected data do not show the severe bimodality of the corrected data (compare Fig. D-3c and Fig. D-6). Furthermore, the variability in the corrected 38 kHz data set is similar to what is observed in the 120 kHz (compare Figs. D-4 and D-6).

Residual Uncertainty in the Corrected Data Set

Any error in this correction will translate directly into an unaccounted bias in the corrected 38 kHz data set, and it is important to evaluate the level of confidence the corrected data to understand the potential impacts of inaccuracies remaining after correction on subsequent uses of the data. Two approaches were taken to estimate the confidence in the correction applied to the data set. The first was to compute confidence intervals based on the d_i, and the second was to examine the frequency response of the bottom echo (i.e., the ratio in bottom echo at 38 and 120 kHz) to test whether a similar relationship with the integrated transmit pulse was observed. In addition, we examined the sensitivity of the dual-frequency classification method used in GOAIERP to uncertainty in the correction applied to the data.

Assuming no autocorrelation in d_i, the 95% confidence interval for R is $\exp\left(\bar{d} \pm t_{n-1,0.025} s_d n^{-1/2}\right)$ where $t_{n-1,0.025}$ is the 2.5% quantile of the t-distribution with n-1 degrees of freedom (Kieser et al. 1987; Hjellvik and De Robertis, 2007). At the 200 m alongtrack horizontal resolution, d_i are highly autocorrelated, and we therefore aggregated the s_A in ESDUs (elementary sampling distance units) of 50 km (i.e., 250 200 m EDSU's), at which point, the data are no longer strongly autocorrelated (Fig. D-7).

A mean *R* and 95 % confidence intervals were calculated for the data sets listed in Table D-1. In the case of the initial 38 kHz data, and all the 120 kHz data, the mean seafloor backscatter estimates are within 20% of 1, and the 95% confidence intervals are close to 1. The confidence intervals should be viewed as approximate, as they account for sampling variance only, and do not include methodological biases such as calibration or changes in the orientation of the transducer relative to the seafloor (Hjellvik and De Robertis, 2007). By comparison, this suggests that the uncorrected 38 kHz data during the later period (i.e., Fig. D-3c) are substantially different than the expectation of an R of 1 (the mean value corresponds to 15% of the seafloor backscatter observed compared to that on pass 3), and the 95% confidence intervals are well outside of 1. Repeating the calculations on the corrected 38 kHz data produces a mean *R* close to 1 and a 95% confidence interval of ~ ± 13%, or ~ ± 0.5 dB in S_v units.

As a ‘reality check' on the premise that the transmit pulse is a reasonable basis for correction, we examined the ratio in bottom backscatter observed at the same time and place (i.e., $10 \cdot \log_{10}(s_{A,38kHz/}\ s_{A,38kHz})$), and observed a strong decrease in the ratio across frequencies as the transmit pulse increased (Fig. D-8). The slope of the linear regression implies a 7 dB decrease in 38 kHz sensitivity per dB change in the transmit pulse S_v (Fig. D-8), which is similar in magnitude to the slope of ~ 8 dB observed for the analysis of bottom echoes during passes 1 and 2 relative to pass 3, which is unaffected by the error (Fig. D-5). Assuming that 1) the mean frequency difference in the bottom echo in an unaffected system should be independent of the transmit pulse S_v (this is the case for example in the 120 kHz data set), and 2) the 120 kHz was free of major bias (c.f. Fig. D-4), the trend in Fig. D-8 should largely reflect changes in the performance of the biased 38 kHz echosounder. Over the range of transmit pulse S_v observed (~1.3 dB), the corrections these two methods would differ by up to 1.5 dB at the highest levels of correction. The analysis based on the repeated visits to the same location is thought to be more reliable as it offers a clear prediction for the mean ratio (i.e., $R = 1$) which does not depend on which data are included in the analysis, while the analysis of frequency response depends strongly on the bottom composition of areas included in the analysis and the angle of the transducer relative to the seafloor (as beamwidths differ between frequencies). Overall, once can conclude that this alternate analysis is similar to that derived based on repeated visits to the same site (compare Figs. D-5 and D-8), and lends support to the use of the transmit pulse integration as a basis for applying a correction. Additionally, the frequency response of the bottom does not incorporate the data from fall 2011 but yields similar results as the analysis based on repeat visits. This suggests that the correction based on the comparison of bottom echoes during repeated visits is not strongly influenced by measurement biases occurring in fall 2011 (for example, consistent changes in the orientation of the transducer, which can bias the bottom echo, Hjellvik and De Robertis, 2007).

Impacts of Residual Errors

Although the residual error remaining after correction remains difficult to characterize, the distribution of the 38 kHz d_i after correction resemble those of the 120 kHz, which is free of major error. The 95% confidence interval of *R* after correction is ~ 0.5 dB (~12% in linear terms). Calibration on the bottom echo has proven to be close to calibrations derived on the standard sphere method (Hjellvik and De Robertis, 2007), with 95% confidence intervals of < 20% in linear terms (e.g., Hjellvik and De Robertis, 2007; De Robertis and Cokelet, 2012). However, it would be desirable for the correction to be robust to larger biases. In the case of analyses based on 38 kHz backscattering strength, the effect of any residual error is 1:1, meaning that a 1 dB error in the correction will result in a 1 dB (26%) bias in the S_v at 38 kHz and any abundance estimates derived from these data.

Residual errors in the 38 kHz data will also affect the performance of backscatter classification based on frequency response. In the case of this study, we used a frequency difference $Sv_{,38\ \mathrm{kHz}}$-$Sv_{120\ \mathrm{kHz}}$ of -10 to 8 dB to identify backscatter consistent with fish and 8 to 30 dB to identify backscatter consistent with macro-zooplankton based on the observations of De Robertis et al. (2010). In order to quantify the sensitivity of this classification technique to residual errors in the 38 kHz data, we examined the classification success of walleye pollock (all sizes combined) and euphausiids as a function of bias in the frequency response (Fig. D-9). Over the ±3 dB range examined (a factor of two in linear terms), the classification success remained high (Fig. D-3b), suggesting that the dual-frequency classifier used in GOAIERP is insensitive to residual error in classification, which as discussed above, is thought to be on the order of < 2 dB.

Given that the 120 kHz data appear to be free of bias, and that the use of multiple acoustic frequencies can be used to aid in species identification, it may be advantageous to, where possible, use the corrected 38 kHz backscatter to compute frequency response for the purpose of classifying fish and zooplankton and the 120 kHz data for echo integration. The advantage to this approach is that it is relatively robust to errors, as the 38 kHz data are only used to make a binary categorization of backscatter with a frequency response consistent with that of ‘fish’ or ‘zooplankton’. Any errors remaining after correction will affect only the classification probability which is relatively robust to residual errors of < 3 dB, but not the backscatter measurements. Stated another way, using this method, the remaining biases in the corrected 38 kHz data will have only a minor effect on whether a given measurement is classified as fish or zooplankton, but these biases will not influence the backscatter measurement from which abundance is derived.

Conclusions

A first-order correction for the spring and summer 2011 38 kHz data was implemented as it is clear that equipment damage affected the results during spring and summer 2011 surveys. The approximate 95% confidence intervals on this correction were estimated as ± 0.5 dB (± 12% in linear terms), which is consistent with other applications of this method, although it is possible that the errors at any given point in time have been underestimated by this method. For many applications of the data, uncertainties of this magnitude may ultimately be a relatively small fraction of the total uncertainty (e.g., uncertainties in the identity of the acoustic targets, which are poorly known in many cases). Residual errors remaining after correction are unlikely to markedly affect the dual-frequency technique used to classify backscatter as consistent with ‘fish’ and ‘zooplankton’, which is robust to errors of < ± 3dB. Consequently, use of the corrected 38 kHz data for the purpose of backscatter classification and the uncompromised 120 kHz data for the purpose of echo integration will be the most robust use of the corrected data, which will be largely free from effects of the errors introduced by the damage to the transducer cable.

Appendix D Citations

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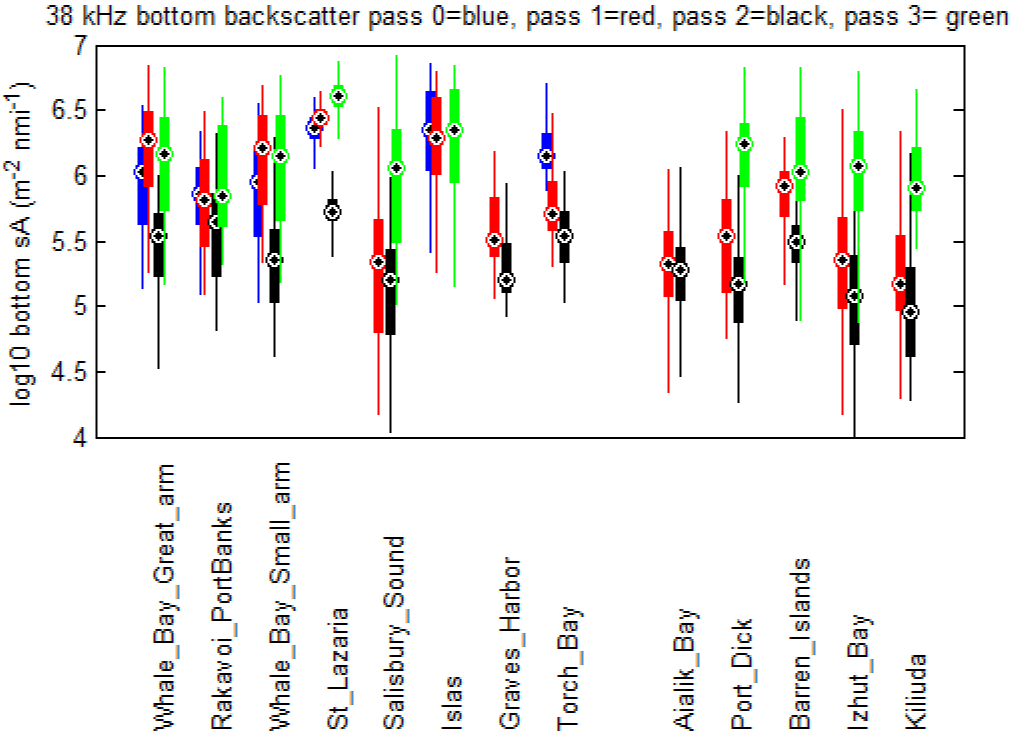
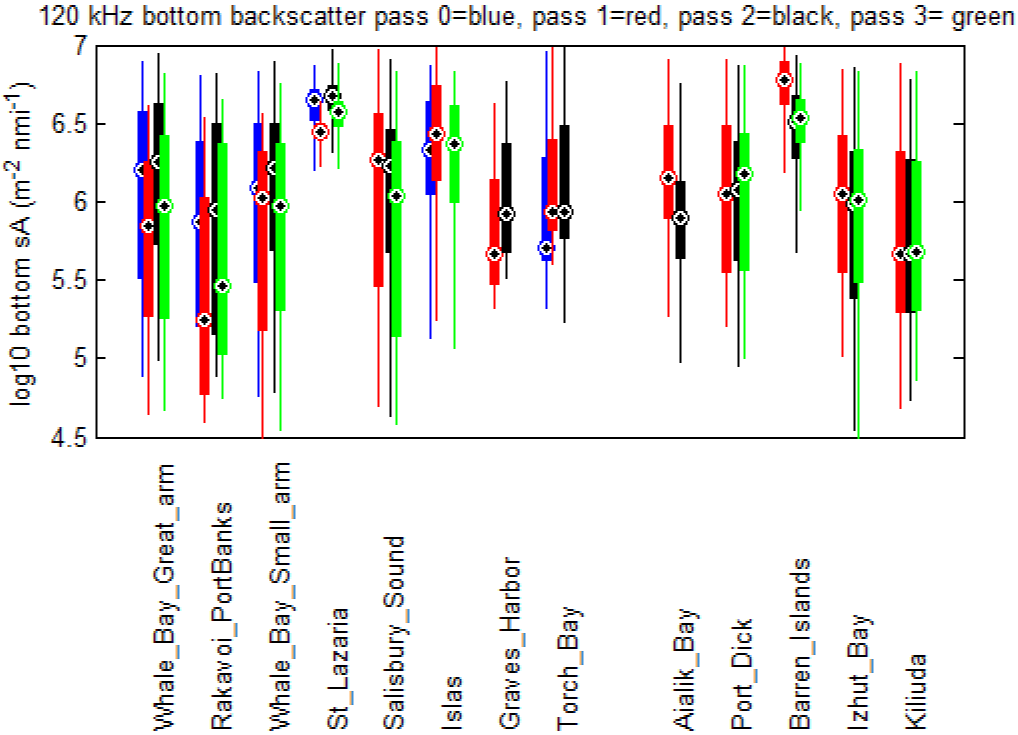
Appendix Table D-1. -- Estimates of mean *R* and 95% confidence intervals for the ratio of backscattering from the seafloor relative to that observed during fall 2011, when the echosounder cable is known to be free of damage. The early period corresponds to the time periods and observations shown in Fig. D-3b, and the late time period to those in Fig. D-3c. Calculations are for data aggregated in 50 km sections of trackline.

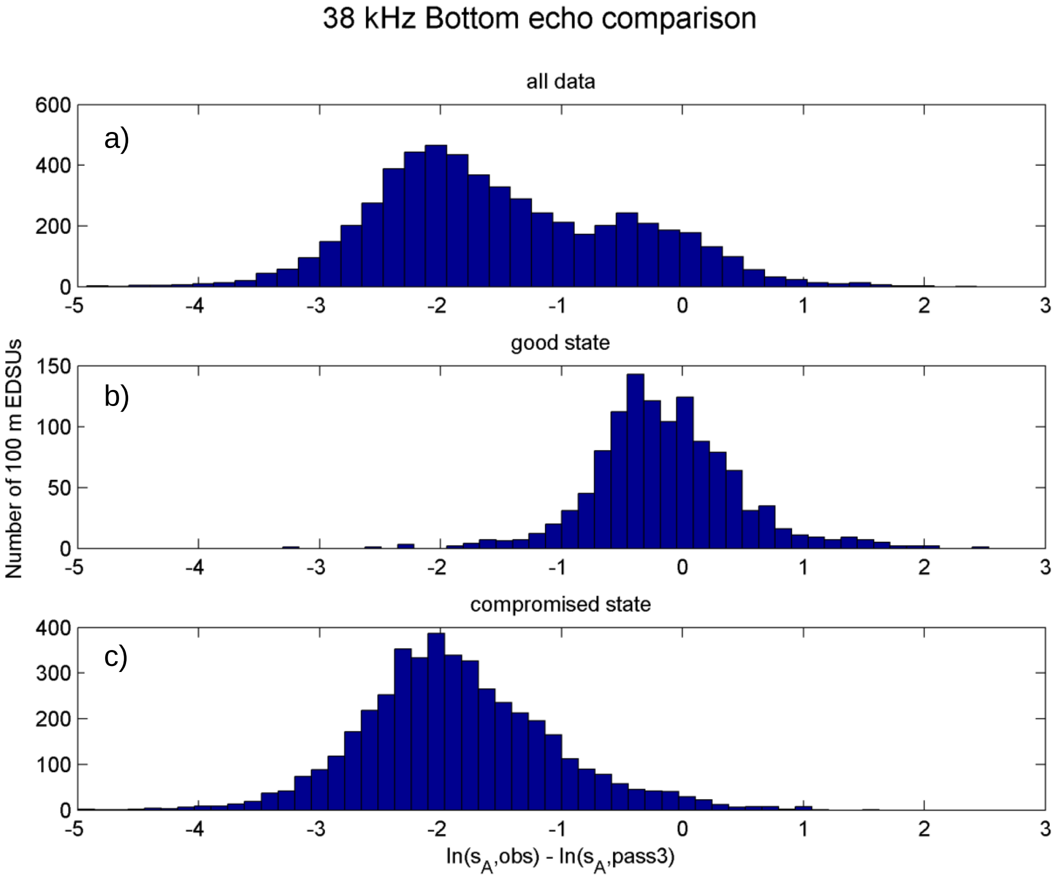
Frequency	Time period	n	**R ($s_{A,bot}/s_{Abot,pass3}$)** Mean, (95 % CI)
38 kHz	Early	4	0.86 (0.63,1.17)
38 kHz	Late	17	0.16 (0.13, 0.20)
38 kHz	All (bottom corrected)	21	0.99 (0.87-1.12)
120 kHz	Early	4	1.07 (0.72,1.59)
120 kHz	Late	17	1.20 (1.05, 1.36)
120 kHz	All	21	1.17 (1.05-1.31)



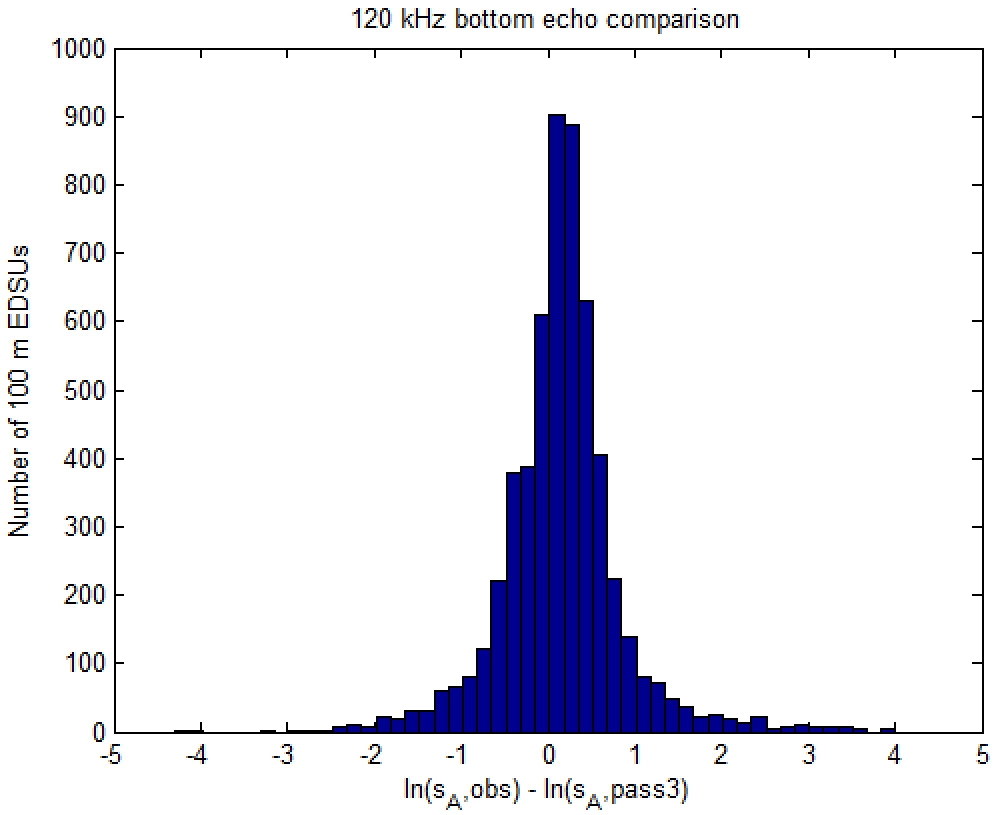
Appendix Fig. D-1. -- Boxplots of $\log_{10}$ transformed bottom 38 kHz backscatter observed in each bay during each cruise. Observations observed during survey pass 0 (pilot study) are shown in blue, survey pass 1 (spring 2010) in red, survey pass 2 (summer 2010) in black and survey pass 3 (fall 2010) in green. Not all areas were visited on a given survey.



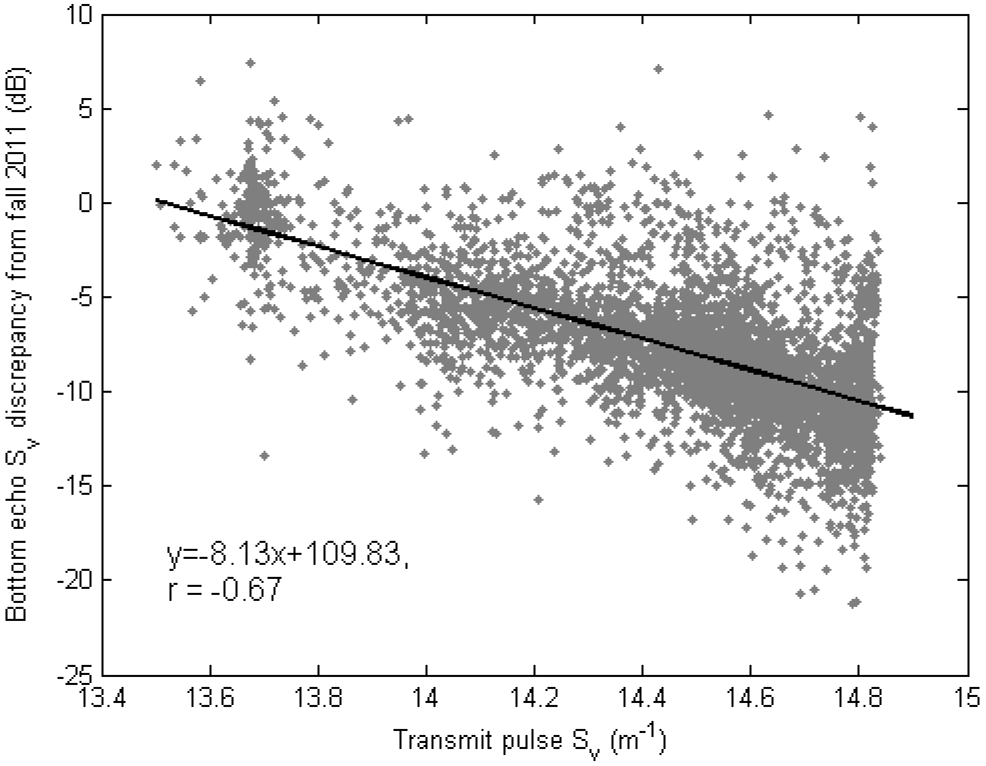
Appendix Fig. D-2. -- Boxplots of $\log_{10}$ transformed bottom 120 kHz backscatter observed in each bay during each cruise. Observations observed during pass 0 are shown in blue, pass 1 in red, pass 2 in black and pass 3 in green. Not all areas were visited on a given pass.



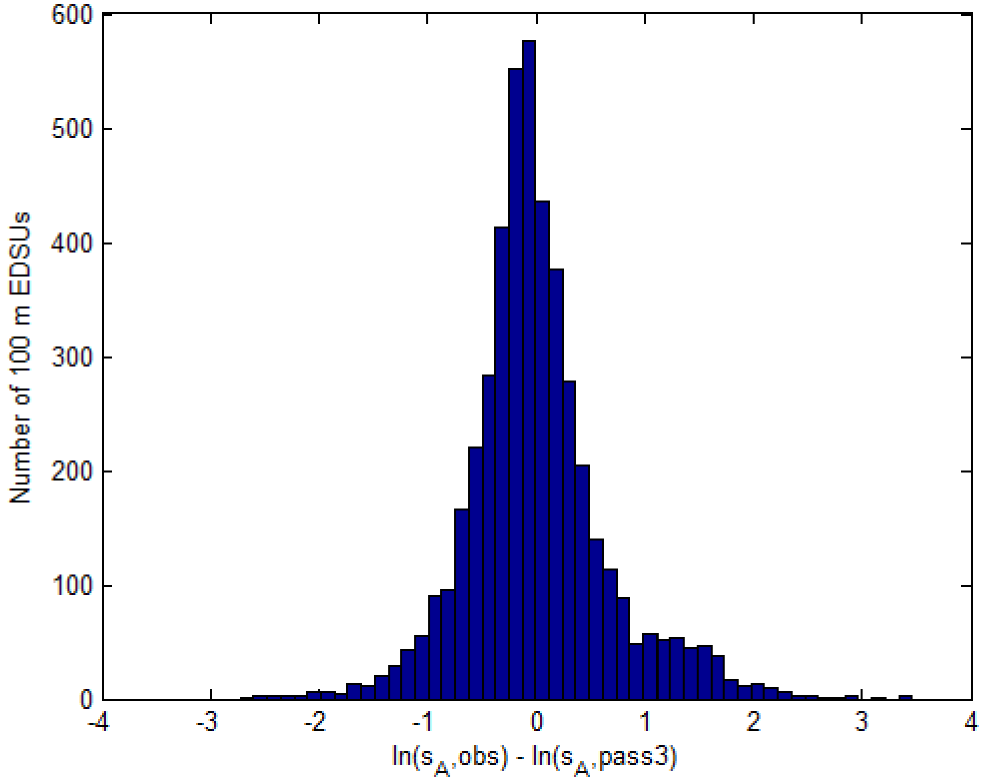
Appendix Fig. D-3. -- Histograms of 38 kHz d_i (see equation D-3), which is a logarithmic representation of the ratio of backscatter from the seafloor observed in a given location compared to that in the fall of 2011, when instrument performance was uncompromised. a) All observations showing bimodal histogram of bottom echo ratio compared to observations made on pass 3. b) Observations made prior to 21 April 2011, and 25 April to 7 May 2011, where no major changes in bottom echo were observed. c) Observations made 22-25 April 2011 and 8 May-16 August 2011 where a reduced bottom echo is observed in the 38 kHz data.



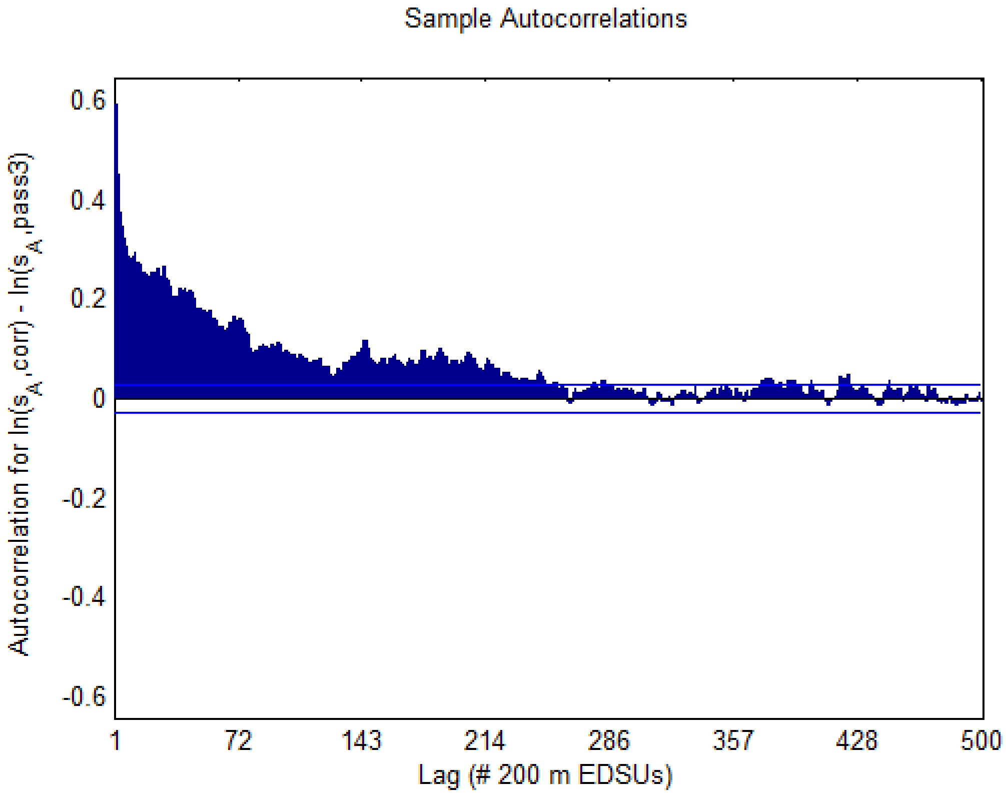
Appendix Fig. D-4. -- Histogram of 120 kHz d_i (see equation D-3) for the entire data set. The quantity d_i is a logarithmic representation of the backscatter ratio from the seafloor observed in a given location compared to that in the fall of 2011.



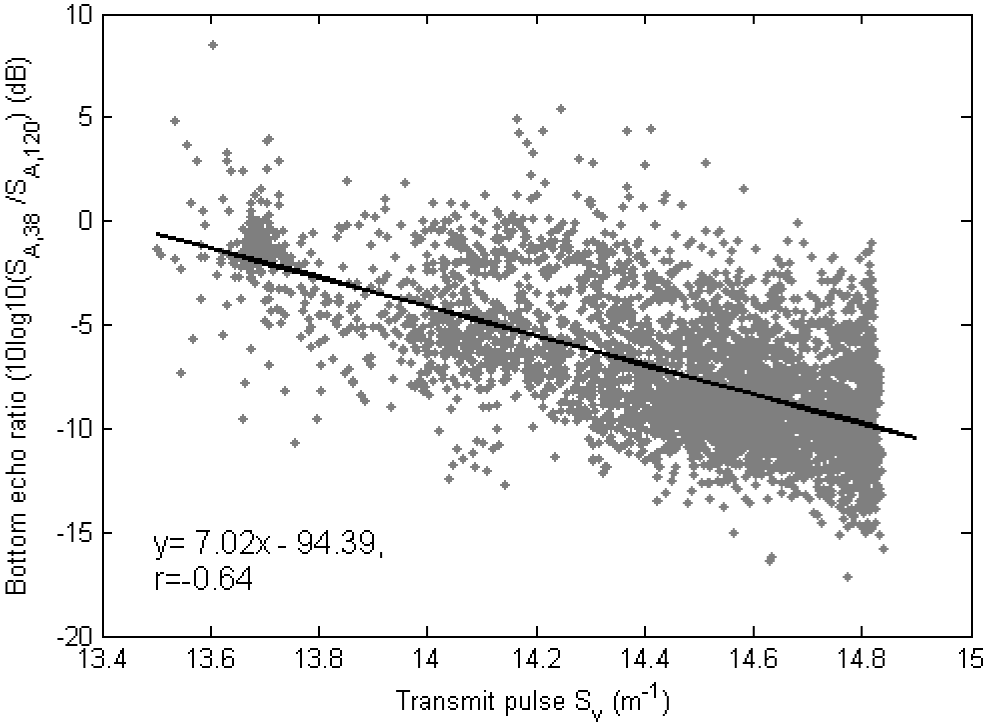
Appendix Fig. D-5. -- Discrepancy in 38 kHz bottom echo (S_v dB re 1 m^{-1}) at a given location compared to that observed during fall 2011as a function of the integrated transmit pulse. The results of a linear regression between the two variables is given on the figure.



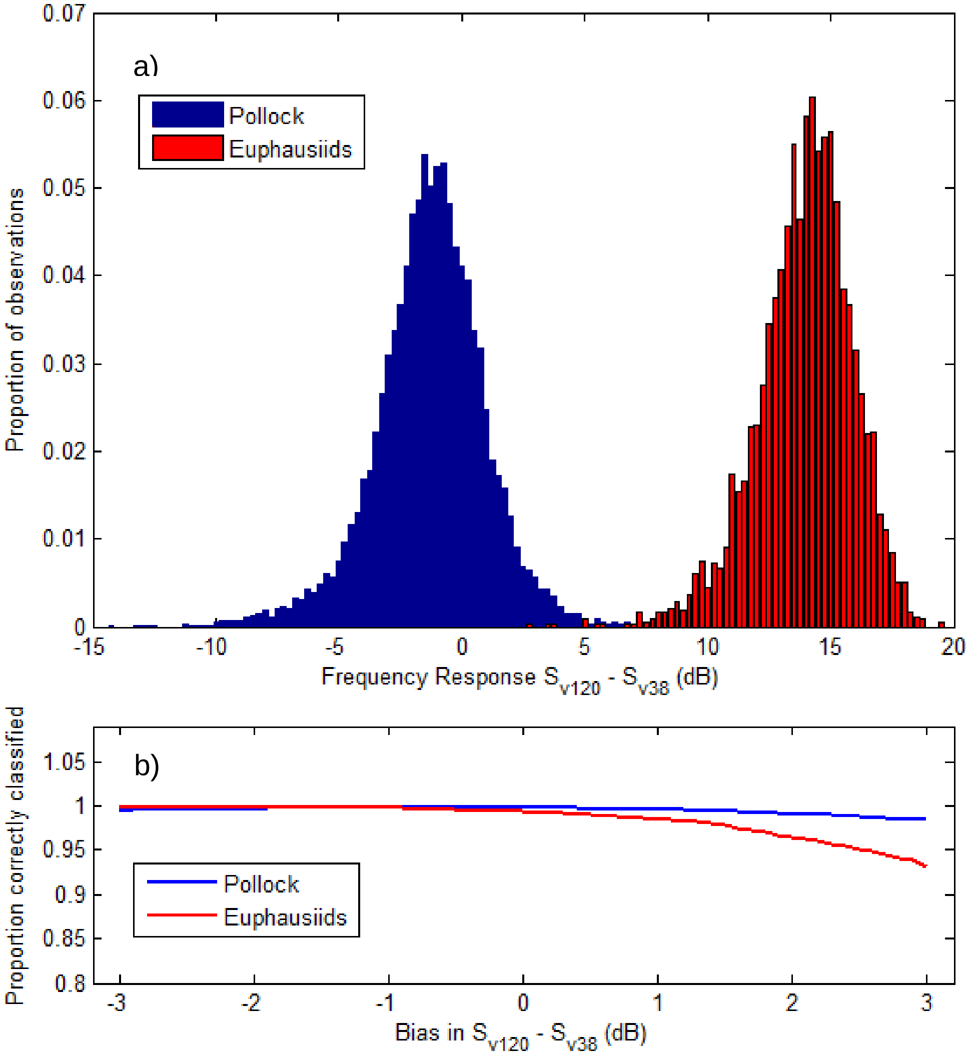
Appendix Fig. D-6. -- Histogram of 38 kHz d_i (see equation D-3) for the entire data set after correction for the discrepancy in the bottom echo shown in Fig. D-5. The quantity d_i is a logarithmic representation of the backscatter ratio from the seafloor observed in a given location compared to that in the fall of 2011.



Appendix Fig. D-7. -- Sample autocorrelation coefficients as a function of lag for bottom corrected d_i at 38 kHz (i.e., data shown in Fig. D-7). The horizontal blue bars show the rejection region bands for testing the null hypothesis that individual autocorrelations = 0.



Appendix Fig. D-8. -- Frequency difference in bottom echo kHz bottom frequency response ($S_{v,\ 38\ kHz}$- $S_{v,\ 38\ kHz}$) as a function of the integrated transmit pulse. Some data from the first cruise of spring 2011 were excluded because a different pulse length was used, which affects the measurement of the transmit pulse.



Appendix Fig. D-9. -- a). Frequency difference ($S_{v,120\ kHz}$-$S_{v,38\ kHz}$) for pollock (all sizes combined) and euphausiids from De Robertis et al. (2010). b). Classification success using the $S_{v,120\ kHz}$-$S_{v,38\ kHz}$ ranges used to discriminate pollock and euphausiid aggregations with the frequency response shown in panel a) using the frequency response parameters used to discriminate fish (8 to 30 dB) and zooplankton (-16 to 8 dB) in this study as a function of error in frequency response introduced by residual errors remaining after correction of the 38 kHz data as described in the text. The abscissa is in logarithmic units: 3 dB is a factor of 2. Classification success remains high in the ±3 dB range, suggesting that residual errors after correction of the 38 kHz data based on the bottom echo, which are expected to be < 1-2 dB (see text) will have little impact on classifications applied in this study.

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