NATURAL RESOURCES CONSULTANTS, INC.

4039 21st Ave West, STE. 404
SEATTLE, WASHINGTON 98199-1252, U.S.A.
TELEPHONE: (206) 285-3480
TELEFAX: (206) 283-8263
E-Mail: jjune@nrccorp.com (corporate)
kantonelis@nrccorp.com

Spatial Distribution and Magnitude of Derelict Shrimp Pots and their Potential Impacts to Rockfish in the Puget Sound

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Abstract

Derelict fishing gear has been identified as a potential stressor to rockfish populations in the Puget Sound, WA, including three species currently listed under federal protection by the Endangered Species Act. While derelict nets from the salmon fisheries and crab pots from the Dungeness crab fisheries have received the most attention over the past decade, little has been done to quantify the extent or impacts of derelict shrimp pots. In the Puget Sound and British Columbia, rockfish bycatch in active shrimp pots has been documented and both dead and live rockfish have been found in derelict shrimp pots encountered during the Northwest Straits Initiative's (NWSI) derelict fishing gear removal operations. Using data from questionnaires targeting commercial and recreational fishers, statistical data from Washington Department of Fish and Wildlife (WDFW) and information from resource managers, this study estimates 326 to 651 shrimp pots lost each year throughout the Puget Sound and Hood Canal. Based on WDFW rockfish bycatch rates in baited test fishery pots, lost shrimp pots could catch from 3,796 to 7,580 rockfish per year. However, research shows baited pots catch more rockfish than un-baited pots and certainly some rockfish will escape the shrimp pots before they die. However, our observations of dead rockfish in recovered derelict shrimp pots indicate some mortality from rockfish bycatch is likely to occur.

Through analysis of shrimp pot fishing effort, rockfish encounter documentation and areas of known rockfish habitat, locations for sidescan sonar surveys targeting derelict shrimp pots were identified and conducted. A total of 165 shrimp pot targets were found in 0.85 square nautical miles of area covered. The pot density was expanded throughout the fishing grounds of the three marine reporting areas where the surveys were conducted to estimate the number of derelict pots present. Extrapolated estimates from sidescan sonar surveys were significantly higher (40 times higher) than of the number of derelict shrimp pots expected based on pot loss rates derived from questionnaires and pot fishing effort data. This discrepancy may be caused by (1) non-homogeneous pot effort throughout marine area (2) derelict crab pots interspersed with shrimp pots and (3) an underestimate of pot loss rates derived from questionnaires and statistical data. Research shows that rockfish bycatch in baited shrimp pots is relatively low, and we assume they are less attracted to unbaited derelict pots, indicating that derelict shrimp pots may not pose a significant threat to overall rockfish populations, but may affect localized, isolated populations where pot effort and loss rates are high. A population-level assessment is warranted, considering the depleted status of many rockfish species in the Puget Sound. Further research is needed to distinguish between crab pots and shrimp pots among surveyed targets and to fully understand the operational lifespan of shrimp pots when derelict. Based on findings from this research we recommend the consideration of initiating an education program for recreational fishers to help minimize shrimp pot loss, and that fishers be encouraged to release live caught rockfish at depth to minimize barotrauma induced mortality.

Introduction

Lost and abandoned fishing gear, known as derelict fishing gear, is a phenomenon that occurs in all parts of the world where fisheries occur. In the Washington state waters of the Salish Sea, referred to in this document as Puget Sound, derelict fishing gear has been addressed through research, surveys and removals since 2002 through the Northwest Straits Marine Conservation Initiative (NWSI). Specific survey and removal methods have been established for the different types of gear encountered and priorities have been set for those gear types which have exhibited the greatest amount of impacts to the marine environment, human safety and economically valuable species; as well as the feasibility of removal efforts. Derelict gillnets and other types of fishing nets from the commercial salmon fisheries have taken the highest priority due to their ability to mortally entangle all types of marine life, while degrading habitat and posing hazards to navigation and other human activities. Derelict crab pots from the Dungeness crab fishery have also warranted attention, as yearly "ghost fishing" rates can account for the loss of hundreds of thousands of dollars worth of the coveted Dungeness crab per year (Antonelis et al. 2011).

Shrimp pots from the commercial and recreational spot prawn (*Pandalus platyceros*) fisheries have not appeared on the list of derelict gear types prioritized for removal for a couple of reasons. First and foremost, nearly all shrimp pot effort in the Puget Sound occurs in water depths beyond maximum allowable diver depth (BMDD) of 105 feet (32 m), significantly increasing the costs of survey and removal. Additionally, until recently, impacts to marine life and habitat associated with derelict shrimp pots have been considered minimal in comparison with other gear types. Throughout the course of derelict gear removal efforts in Puget Sound, a relatively small number of derelict shrimp pots have been incidentally identified and removed, and while the total number and variety of entrapped animals in these pots were low, multiple rockfish individuals (*Sebastes spp.*) were encountered, some of which were dead. At the time, this did not raise much of an alarm. However, upon the 2009 listing of the yelloweye rockfish (*Sebastes ruberrimus*), canary rockfish (*Sebastes pinniger*), and bocaccio rockfish (*Sebastes paucispinis*) for federal protection in Puget Sound under the US Endangered Species Act (ESA), all derelict gear data impacting rockfish was re-visited for further analysis and derelict shrimp pot gear were found to be a potentially significant threat to rockfish. Additionally, accounts of juvenile rockfish bycatch in shrimp pots had been documented by fishers and resource managers both in Washington and British Columbia (Favaro et al. 2010), (Mark O'Toole, WDFW, personal communication),(June and Antonelis, NRC, personal communication).

In this study we used data gathered through multiple methods to better understand the magnitude of shrimp pot loss in commercial and recreational fisheries and the potential impacts of derelict shrimp pots on rockfish populations in the Puget Sound. Information on pot fishing effort, pot loss and rockfish bycatch was collected from Washington Department of Fish and Wildlife statistical reports, creel surveys, telephone, online and in-person interviews with fishers and resource managers. Analysis of data provided pot loss rates per unit of fishing effort for each sector of the shrimp pot fishery, along with the associated estimated number of lost pots, which were then displayed geographically using ArcGIS®. Effort and loss estimates were correlated with documentation of locations of ESA listed rockfish species throughout the Puget Sound and sidescan sonar surveys were conducted to enumerate the number of derelict shrimp pots present in areas of "likely rockfish habitat." With evaluation of the geographic distribution of pot loss estimates, rockfish bycatch, likely rockfish habitat and identified survey targets, we offer preliminary

estimates of the geographic distribution of derelict shrimp pot accumulation, and the associated potential rockfish impacts.

Background

Project personnel met with WDFW shellfish biologists and shrimp fishery experts initially in January 2012, followed by continued correspondence and coordination over the course of the project term. During these meetings WDFW representatives provided statistical summaries of catch and effort from both the state commercial and recreational shrimp pot fisheries, along with access to commercial logbooks and recreational creel survey data forms. Additionally, a description and summary of the Puget Sound regional shrimp pot test fishery, including rockfish bycatch observations, was provided as well as expert opinion and suggestions towards achieving project goals. Early deliberations determined, based on a variety of factors such as overall effort, effort density, gear employed and timing of fishery openings, that the vast majority of shrimp pot loss in the Puget Sound would likely be generated by the recreational fishery. Therefore the bulk of the research involved in pot loss estimates focused on the state recreational fishery.

Description of the Fishery

The Puget Sound spot prawn pot fishery (referred to in this document as the shrimp fishery) consists of three sectors; recreational, non-Treaty commercial and Treaty commercial/subsistence. Yearly harvest quotas are split 50-50 between the state and the Treaty fisheries. Within the non-Treaty fisheries, in 2012 the recreational sector was allocated approximately 50% of the total quota, and the remaining 50% went to the commercial sector. Table 1 shows catch allocations for the ten-year period between 2002 and 2011. Management regions and catch reporting areas (CRA) are used to geographically divide catch and quota (Figure 1). Additionally, like many recreational fisheries in the Puget Sound, the shrimp fishing is managed by Marine Areas (MA) (Figure 2).

Table 1. Summary of spot shrimp pot catch throughout Puget Sound from 2002 to 2011 (source: WDFW)

Puget Sound Spot Shrimp Catch (lbs), 2002-2011							
Year	**Recreational Catch**	**Non-Treaty Commercial Catch**	**State Total**	**% Rec**	**% Comm**	**Treaty Total Catch**	**Grand Total**
2002	104,552	67,769	172,321	61%	39%	157,814	330,135
2003	109,267	77,187	186,454	59%	41%	167,758	354,212
2004	108,237	78,599	186,836	58%	42%	168,197	355,033
2005	109,395	83,567	192,962	57%	43%	193,322	386,284
2006	106,357	84,133	190,490	56%	44%	178,583	369,073
2007	119,768	86,930	206,698	58%	42%	221,826	428,524
2008	119,863	88,643	208,506	57%	43%	173,200	381,706
2009	125,467	92,562	218,029	58%	42%	189,683	407,712
2010	124,047	95,979	220,026	56%	44%	205,691	425,717
2011	120,076	106,372	226,448	53%	47%	249,555	476,003

The non-Treaty commercial fishery is limited to 18 license holders, and takes place during the months of June through September. Each fisher is limited to a weekly harvest of 600 lbs, and is required to report daily harvest information, along with logbook recordings of all fishing effort. The common style of pots used is truncated cone shape surrounded by nylon mesh, and weigh approximately 5 to 7 pounds. Entrance rings are 3-inch diameter and aligned with the bait cup, usually containing pellet type bait. Commercial fishers employ "strings" of 15 to 25 shrimp pots at a time, targeting the 200 to 400 feet depth range. The multiple pots are spaced 30 to 100 feet apart, and attached to a heavy groundline with a bridle and stainless steel snap. Each end of the groundline is attached to an anchor, often weighing up to 80 lbs, holding the string of pots in place. Also attached to the anchors are approximately 500 feet of line connected a polyform buoy on the terminal end. Soak times range from 2 to 48 hours, and are typically either 2 to 4 hours, or 24 hours.

The Treaty fishery usually employs similar gear to the non-Treaty commercial fleet. The actual number of participants is not publicly available but WDFW reports that in 2010 approximately 150 Treaty fishers made shrimp landings, and the current number may be slightly higher. The fishery occurs over a relatively short period of time each year compared to the non-Treaty commercial fleet.

The recreational fishery occurs on specific days in the month of May, and the number of days varies between management regions. The maximum pot limit is two pots per licensed fisher, and no more than four pots per vessel, and daily harvest is limited to 80 individual spot prawn per licensee. A portion of the recreational fleet uses similar web mesh pot designs as the commercial fleet, but with added weight, and most use square shaped, wire mesh pots with two to four entry ramps leading to a bait container often filled with a cat food type bait concoction. Each pot is fished separately, attached to a single buoy line and buoy. The wire mesh pots used by recreational fishers typically weigh much less than the web mesh style pots and, if not augmented with additional weight, can be prone to drag or drift during heavy tidal exchange periods, common during the month of May. Soak times vary depending on the location and timing of the effort and, in the derby style openings, usually last 45 minutes to 3 hours. Fishers generally target 200 to 400 ft water depths. All fishers employing pot gear in the Puget Sound are required to use degradable escape cord on each pot, which when released disengages the fishing capabilities of the pot by opening a door or section of the pot large enough for the entrapped animals to escape. Entrance tunnels are not equipped with "triggers" or "gates", and most entrapped animals are known to exit a shrimp pot once the bait is gone (M. O'Toole, WDFW, personal communication).

Recreational fishing effort varies by management areas but generally is greatest in Hood Canal where fishing effort increased significantly in the early 1990s. A similar increase in shrimp fishing effort took place in the central Puget Sound during the early 2000s.

Methodology

Pot Loss Estimates

Two initial actions were taken to gain further insight into rate of loss in the recreational fishery. First, a request was proposed and accepted for WDFW to add two columns to their creel survey forms for the recreational fishing season in 2012 and beyond, to include the questions: "*Did you lose any pots? Y or N*", and "*If yes, how many?*" And second, with input from WDFW personnel and an interested recreational

fisher who also sits on the Puget Sound Rockfish Workgroup, an online questionnaire on fishing effort and pot loss was generated through Survey Monkey® targeting recreational shrimp fishers.

Recreational pot loss rates were estimated from data collected during WDFW creel surveys of recreational shrimp fishers over a six-year span from 2007 through 2012, as well as the stand-alone estimate from data collected in 2012. Prior to the 2012 fishing season, WDFW creel survey forms did not include questions regarding pot loss, leaving only the "*Landmark*" or "*Comments*" column available for the possible volunteering of information regarding such an event. Because pot loss data was not relevant to the statistical goals of managing the recreational shrimp fishery, while pot loss may have been noted on the hard copy of the survey form it was not necessarily transferred to the electronic creel survey dataset. Therefore, all paper copies of creel surveys from 2007 to 2011 were visually cross-referenced with the electronic dataset and if pot loss information was found on the paper copies, it was added in an additional column to the corresponding data entry in the electronic version. Once the pot loss information was updated, creel survey results provided estimates of number of shrimp pots lost in each Marine Area (MA) per year and were compared to WDFW estimates of the number of pots fished per day to obtain rates per "pot day" – a standard metric used to describe effort in the recreational fishery, and the one decided to be most appropriate for pot loss estimates. The Puget Sound wide yearly pot loss rate was calculated by dividing the sum of all reported lost pots from the creel surveys from 2007 to 2012 by the sum of all pot days accounted for in the creel surveys, and the same was done for 2012 data independently. The projected number of lost pots per year was simply estimated by multiplying the pot loss rate by the average total number of pot days per year provided by WDFW statistical summaries.

*(#pots lost / #pot days interviewed) * (total #pot days / year) = #pots lost / year*

To document temporal variability of pot loss per fishing season the yearly weighted average of pot loss rates by MA for all years from 2007 to 2012 was calculated by dividing the yearly sums of all documented pot loss by the yearly sums of all pot days recorded in creel surveys. The number of lost pots for each year was estimated by multiplying total pot days by the loss rate associated with each year. Average pot loss rates per year were also estimated for each MA, to account for the spatial variability of fishing effort within the recreational fishery. This was achieved by dividing the sum of all documented pots lost within each MA by the sum of pot days documented in creel surveys over the six-year period (2007-2012). These numbers were multiplied by the six-year average of total pot days per MA to estimate number of pots lost per MA. No effort estimates were recorded for MA 6 during the 2007 and 2008 fishing seasons, due to insufficient recreational shrimp fishing effort outside of Discovery Bay., therefore, the four years from 2009 to 2012 were used.

Responses from the online survey targeting recreational shrimp fishers provided information used to calculate overall pot fishing effort and a three-year average (2009 to 2011) pot days of effort, with associated pot loss. The overall pot loss rate was calculated by dividing the total number of pots lost by the total number of pot days fished, and the same method for the three year loss rate.

Non-Treaty commercial shrimp pot loss rate was estimated from data collected in WDFW logbooks, and augmented by inquiries regarding pot loss through personal communication by WDFW shrimp fishery managers. All paper copies of logbook entries from 2007 to 2011 were inspected for notes or documentation of pot loss. The yearly commercial pot loss rate was calculated as the sum of all pot drops per fishing season divided by the total number of lost pots reported over the 2007 to 2011 period. These

estimates were augmented with information from inquiries regarding pot loss through personal communication by WDFW shrimp fishery managers via email. The specific questions are as follows:

1. *How many years have you been commercial shrimp pot fishing in the Puget Sound?*
2. *Have you ever lost shrimp pots while participating in the Puget Sound commercial shrimp pot fishery?*
3. *If so, (a) how many have you lost over all the years you've been fishing? (b) How many pots have you lost in the last three years? (c) Where have these pots been lost (landmarks or catch areas)? And (d) do you have any idea why the pots were lost (strong current, theft, etc.)?*

Although similar fishing effort and pot loss information was not available for the Treaty fishery, catch per unit effort (CPUE) and pot loss rates per pound of shrimp caught were assumed equal in the Treaty fishery as in the non-Treaty commercial fishery. Landings in pounds were available for both fisheries. Pot loss rate per unit of catch was calculated in the non-Treaty commercial shrimp fishery and divided into the total annual catch weight in the Treaty commercial shrimp fishery to estimate Treaty pot loss over the period 2007 to 2011.

Spatial Distribution and Analysis

Shrimp Pot Loss Distribution

Yearly pot effort summaries provided by WDFW include number of pot days fished, pounds (lbs) caught, and catch per unit effort (CPUE) associated with each MA for the recreational fishery. The commercial fishery summaries include number of pot drops, pounds caught and CPUE associated with commercial shrimp management regions, as well as higher resolution CRA. Standard techniques utilizing ArcGIS were performed to geographically display shrimp pot fishing effort distribution by joining effort data to previously existing MA (recreational) and CRA (commercial) GIS shapefiles provided by WDFW. For the recreational fishery, each MA was displayed using graduated colors classified by the four-year (2008-2011) average of pot day totals and commercial effort was displayed similarly by CRA. Treaty landings from 2011 were displayed by CRA.

While recreational data is not summarized in detail by CRA, creel surveys include documentation of the CRA in which fishing effort took place per boat interview, as well as a "*Nearest Landmark*" or "*Comments*" column that often provides geographical description of where pot effort was focused. Using the CRA data, spatial distribution of documented pot loss was displayed by joining the cumulative number of lost pots from 2007 to 2012 documented in creel surveys per CRA with the CRA GIS shapefile. In Hood Canal, CRA creel data is divided into sub-areas, providing the ability to display pot loss documentation using the same methods described above, but with much finer resolution. In addition, the "*Landmark*" entries associated with each pot loss record in the creel surveys were extracted and assigned latitude/longitude coordinates and displayed in ArcGIS with graduated symbol sizes representing count of pot loss associated with each landmark. Similarly, descriptions of fishing effort locations reported by online survey respondents who lost shrimp pots were spatially displayed.

To estimate potential impacts to rockfish from derelict shrimp pots, a few sources were investigated. First, the WA State Derelict Fishing Gear Database (DGDB) was queried for all derelict shrimp pots removed during the NWSI derelict fishing gear program. The estimated number of derelict shrimp pots containing rockfish was estimated by dividing the total number of removed pots containing rockfish by

the total number of shrimp pots removed. Because the number of shrimp pots removed during NWSI derelict fishing gear removals is relatively small (n=41), further inquiries were made with recreational fishers in the online survey asking if they had experienced any bycatch while shrimp pot fishing along with their best description of the bycatch species. Rockfish bycatch reports were counted and the pot days associated with these respondents were calculated through analysis of answers on days per year and pots per day in order to make an estimate of how much of the total effort those respondents represented. Additionally, summaries of rockfish bycatch by location from annual WDFW shrimp pot test fisheries throughout the Puget Sound were provided by WDFW for catch rates to be incorporated into the assessment of potential rockfish impacts.

Charts showing WDFW buoy count and aerial survey data from multiple years were provided by shrimp fishery managers in *.pdf and *.jpg format to give a general view of the heavy-effort fishing grounds throughout the central Puget Sound region. These charts were later geo-referenced into ArcGIS and a new polygon shapefile delineating locations of heavy shrimp pot fishing effort was made. A Puget Sound bathymetry raster dataset was then overlain by these polygons, as well as multiple shapefiles provided by NOAA, WDFW and UW displaying specific locations of bocaccio, canary and yelloweye rockfish encounters from ROV, diver and trawl surveys reported over the last several years – some as recent as 2008. Additionally, a shapefile, provided by NOAA, consisting of high rugosity polygons within 30 – 110 meters (approx: 98 – 361 feet) depth was displayed to elucidate potential rockfish habitat. Visually analyzing the spatial relationship between these data layers along with preliminary results of the pot loss and rockfish bycatch estimates, by using cartographic displays with GIS was integral to the decision making and planning of sidescan sonar surveys for derelict shrimp pots.

Sidescan Sonar Surveys

The initial step in survey planning was to increase the understanding of the spatial distribution of the shrimp pot fisheries in the Puget Sound, while identifying heavy fishing effort locations that coincide with known rockfish habitat and documented locations of ESA listed rockfish species encounters. Common depths of the three ESA listed rockfish species in the Puget Sound range from 160 to 820 feet (50 to 250 meters) (NMFS 2012a, b, c), and the optimum depth for effective shrimp pot fishing is approximately 250 to 350 feet (M. O'Toole, WDFW, personal communication). Through an analysis of the geographical display of the datasets described above, project personnel in coordination with NOAA, identified four potential sidescan sonar survey areas at Mukilteo, Edmonds, Piper's Creek (North Seattle), and Point Monroe (North Bainbridge Island). It should also be noted that along with the above stated factors, proximity to the survey vessel's base of operations (Everett, WA) was also taken into account during survey planning, in order to maximize survey area covered while minimizing transit time.

Fenn Enterprises conducted three days of sidescan sonar surveys on the 40-foot research vessel R/V *Surveyor II* to locate derelict shrimp pots in three of the four potential survey areas. Surveys were conducted along the shoreline, between the 100 and 350-foot contour, in the Mukilteo, Edmonds and Piper's Creek areas. Surveys were conducted using a Marine Sonics® 600 kHz transducer, mounted in a heavy stainless-steel tow fish. The survey track lines were geo-referenced with a Trimble® differential global positioning system antennae (DGPS) mounted on a davit over the stern of the vessel and integrated into the survey records generated by the Marine Sonics sidescan system. An inertial motion tracking system and an ultra-short baseline (USBL) acoustic tracking system were utilized to account for the

variance in tow fish position from the vessel. Nobeltec®, a marine navigation software system was also used to track the progress of the survey vessel during operations.

After the tow fish was deployed from the stern of the vessel, a hydraulic winch with cable controlled the altitude of the tow fish. The survey image was displayed on a video monitor onboard the vessel and recorded onto a computer hard drive for post-survey data processing. Average survey speed was 1.74 knots (3.22 km/hr), and all surveys were conducted using both port and starboard channels each sending a signal covering 164 feet (50 meters), generating a swath width of 328 feet (100 meters). Targeted survey depths ranged from 100 feet (32 meters) to 350 feet (107 meters), with specific focus in the 150 – 300 foot depth range to target optimal depths of shrimp pot fishing – and potential lost pots.

The sidescan sonar images were examined in detail during post-survey processing and counts of precise locations of derelict shrimp pot targets were recorded. The products from the sidescan sonar survey included a track line file of the area surveyed, calculation of the amount of the seabed area covered and the positions (latitude and longitude) of likely derelict shrimp pot targets found.

Geographic displays of WDFW buoy count locations were used to approximate the bounds of the commonly fished grounds within the MA's where sidescan sonar surveys were conducted. Using ArcGIS, the polygons delineating these bounds were limited to the 100 to 350 foot depth range. Derelict pot density derived from sidescan sonar surveys were calculated, and those numbers were extrapolated through the estimated commonly fished grounds of the three MAs where surveys took place, in order to estimate the number of derelict shrimp pots present.

Results

Pot Loss Estimates

Recreational: Yearly Loss Rates

In 2012, a total of 1,897 recreational boats were interviewed during creels surveys, with a corresponding effort of 6,611 pot days. Of all boats interviewed, 109 (5.75%) boats reported a total of 133 pots lost. This equates to 2.01% of pots fished lost throughout Puget Sound for the 2012 season. The total pots days fished during 2012 was 30,217 and when multiplied by the pots lost per pot day ratio provides the overall estimate of 608 pots lost in the recreational fishery during the 2012 season (Table 2).

In order to evaluate the difference in recreational pot loss per year, particularly between 2012 when the creel survey included a specific question on pot loss and all prior years when fishers would have had to volunteer this information, pot loss rates and projected number of pots were calculated individually for all six years included in the study. The yearly weighted average of pot loss by MA provides an annual average of 0.93% of pots fished. The minimum loss rate during the six-year period was 0.29% of pots fished in 2009 and, as expected, the maximum loss rate was exhibited in 2012 with 2.01% of pots fished (Table 2). The difference in pot loss rates between 2012 and prior years probably indicates that without a specific question about pot loss, actual pot loss prior to 2012 was underestimated by the creel surveys. When applying the 2012 loss rate estimate to the 2007 to 2012 dataset, an average of 596 pots lost per year.

Table 2. Results, by year, of temporal variance in annual recreational shrimp pot loss estimates

Period	Area	Number of Boats Surveyed (creel)	Number of Boats with Documented Pot Loss (creel)	Number of Surveyed Pots Days (creel)	Number of Surveyed Pots Lost (creel)	Percent of Surveyed Pots Lost	Total Pot Days Fished	Projected Number of Pots Lost
2007	All PS	1,621	29	7,323	47	0.64%	29,639	190
2008	All PS	2,135	44	7,300	54	0.74%	30,301	224
2009	All PS	1,950	15	6,850	20	0.29%	29,061	85
2010	All PS	1,907	26	6,550	39	0.60%	30,167	180
2011	All PS	1,947	70	6,588	84	1.28%	28,365	362
2012	**All PS**	**1,897**	**109**	**6,661**	**133**	**2.01%**	**30,217**	**608**

A total of 11,457 recreational boats were interviewed during creel surveys from 2007 to 2012 with a corresponding effort of 41,222 pot days. Of all boats interviewed during these years, 293 (2.6%) boats reported a total of 377 pots lost. This equates to an overall six-year, Puget Sound wide average of 0.91% of pots fished lost each year. The six year average (2007 to 2012) of total pots fished per year is 29,625 and when multiplied by the pot lost/pot day fished ratio provides the overall estimate of 1,626 pots lost or 271 pots per year Puget Sound-wide between 2007 and 2012. When applying the 2012 loss rate estimate to the 2007 to 2012 dataset, an average of 596 pots lost per year (Table 3).

Table 3. Results of annual recreational shrimp pot loss estimates for the all Puget Sound from 2007 to 2012

Area	Percent of Surveyed Pots Lost: 2007-2012	Percent of Surveyed Pots Lost: 2012	Total Pot Days Fished	Projected Number of Pots Lost per year: 2007-2012 estimate	Projected Number of Pots Lost per year: 2012 estimate
All PS	**0.91%**	**2.01%**	177,750	**271**	**596**

Recreational: Loss Rate per Marine Area

To gain an understanding of the spatial distribution of derelict pots, a pot loss rate was calculated for each MA for 2012 (Table 4) and over the six-year period separately (Table 5). In 2012, the highest rate of loss occurred in MA 11 at 9.55% of pots fished, and the lowest occurs in MA 12 at 1.10% of pots fished (Table 4). For the six-year average, the highest rate of loss occurred in MA 11 at 3.75% of pots fished, and the lowest loss rate occurs in MA 8 at 0.62% of pots fished. The greatest variance in yearly loss rates appears in MA 11, with a minimum of 0.00% in 2008 and a maximum of 9.55% of pots fished in 2012. Because little to no recreational shrimp fishing has occurred in MA 13 during the 2007 to 2012 period, it was not included in these results.

Table 4. Results of shrimp pot loss rates (% of pots fished) and projected number of lost pots per MA, 2012 only.

Period	Area	Number of Surveyed Pots Days (creel)	Number of Surveyed Pots Lost (creel)	Percent of Surveyed Pots Lost	Total Pot Days Fished	Projected Number of Pots Lost (2012)
2012	MA 6	235	6	2.55%	2,469	63
2012	MA 7	717	27	3.77%	3,015	114
2012	MA 8	853	13	1.52%	2,599	40
2012	MA 9	496	8	1.61%	1,332	21
2012	MA 10	1,018	26	2.55%	1,419	36
2012	MA 11	199	19	9.55%	398	38
2012	MA 12	3,093	34	1.10%	18,985	209
Sum of Projected Pot Loss by MA (2012 only)						**521**

Table 5. Results of shrimp pot loss rates (% of pots fished) and projected number of lost pots per MA, 2007 to 2012.

Period	Area	Number of Surveyed Pots Days (creel)	Number of Surveyed Pots Lost (creel)	Percent of Surveyed Pots Lost	Projected Number of Pots Lost (6 yr)	Projected Annual Number of Pots Lost
2009-2012	MA 6	972	11	1.13%	70	17
2007-2012	MA 7	3,780	34	0.90%	187	31
2007-2012	MA 8	6,339	39	0.62%	95	16
2007-2012	MA 9	2,658	21	0.79%	52	9
2007-2012	MA 10	5,034	49	0.97%	80	13
2007-2012	MA 11	1,120	42	3.75%	99	17
2007-2012	MA 12	21,304	181	0.85%	1,002	167
Sum of Projected Pot Loss by MA (six-year average)						**270**

Recreational: Online Survey

The online survey questionnaire included 13 total questions regarding shrimp pot effort, pot loss and bycatch (Appendix A). The online survey was created on February 16, 2012, and advertised to recreational fishers through association meetings, email, word of mouth and Internet websites. Survey responses were downloaded on May 4, 2012, one day prior to opening day of shrimp season, to ensure the data collected was from seasons prior to 2012.

Out of 320 total respondents, 268 provided enough information to calculate total number of pot days fished overall and number of pot days fished over the last three years (2009 to 2011). With effort metrics, and responses to questions regarding pot loss, rates of pots lost were calculated for the recreational fishery overall, and for the last three years. In total, respondents reported 338 lost pots over their entire time participating in the fishery. The associated total number of pot days was estimated at 36,103. The number of lost pots reported over the 2009 to 2011 time period was 141 and the number of pot days fished was 11,192. The overall loss rate over all years fished calculated from the online survey respondents is 0.93% of pots fished, and the average loss rate over the last three years (2009 to 2011) was 1.26% of pots fished. If applied to the average yearly number of pot days fished, the estimated number of pots lost per year is 276 over all the years fished and 368 pots per year for the period 2009 to 2011. These

estimates coincide well with six-year average estimate made using the creel survey data, and are reasonably lower than the estimate based on 2012 data alone.

Commercial: non-Treaty

Analysis of WDFW non-treaty commercial logbook data from 2007 to 2011 provided information related to four strings of potentially lost pots. In 2007, one fisher noted "Did not pull – TIDE" on a string of 15 pots in CRA 23A-S. In 2010, one fisher reported two strings, one of 20 pots and the other of 18 pots as "LOST" in CRA 26A. These two strings of pots along with the full complement of anchors, buoys and line, were verified as stolen as reported by citizens who witnessed the theft from a nearby beach. Therefore, these 38 pots were not included in the lost pot calculations. Also in 2010, in CRA 23D a string of 20 pots was noted as "GONE". WDFW shrimp fishery managers report that most gear that is lost by commercial fishers are eventually recovered, usually by grapple which is a proven method used to hook the groundline connecting the string of pots. Therefore, it is quite possible that the pots reported as 'lost', 'gone' or 'did not pull' were recovered at a later date by their owners or were possibly stolen. Of the potentially lost gear described above, the 15 pots in 2007 and 20 pots in 2010 were included in the overall lost pot estimates. Responses to the set of questions emailed to all non-treaty commercial shrimp pot fishers by WDFW shrimp fishery managers were limited to only two of the 18 participants (11%). Of these respondents, one reported only losing 'just a few' shrimp pots since 2001, and not having lost any in the last five years. The second responding fisher reported losing "about 4 to 6" pots per year; and also losing a string of 25 pots in CRA 23C in 2009. A total of 125,694 pot drops were recorded in the non-Treaty commercial fishery throughout the five-year period of 2007 through 2011. A total of 35 pots were reported as "not pulled" or "gone" in the logbooks, and another 25 reported lost from email responses, plus an additional 25 to account for the 4 to 6 pots lost per year response. This equates to an estimated 85 lost pots over the five-year period or an average of 17 lost pots per year from the non-treaty commercial fishery at rate of 0.068% of pots fished (Table 6).

Table 6. Results of annual commercial shrimp pot loss estimates based on logbook entries for the all Puget Sound from 2007-2011

Period	Area	Number of Fishers	Number of Fishers with Documented Pot Loss	Number of Total Pot Drops	Number of Documented Pots Lost	Percent of Surveyed Pots Lost	Projected Annual Number of Pots Lost
2007-2011	All PS	18	3	125,694	85	**0.068%**	**17**

Commercial: Treaty

To estimate pot loss within the Treaty fishery we assumed the same loss rate and CPUE as the non-Treaty commercial fleet. From 2007 to 2011, non-treaty commercial fisheries landed 470,486 lbs of shrimp with an associated estimated loss of 85 pots. This equates to one pot lost for every 5,535 lbs of shrimp landed. The average pounds landed from 2007 to 2011 in the Treaty shrimp pot fishery was 207,991. Using this ratio, we estimate 38 pots lost per year in the Treaty commercial shrimp pot fishery.

Spatial Distribution and Analysis

The spatial distribution of fishing effort by MA was displayed for the recreational shrimp pot fishery (Figure 3), with values representing the average number of pot days per year. As seen clearly in Figure 2, from 2008 to 2011 the majority (66%) of recreational shrimp pot effort occurred in MA 12, Hood Canal. Twenty percent of the remaining effort occurred in MA 7 the San Juan Islands and MA 8, Saratoga Passage/Port Susan/Possession Sound. Marine Area 10, Seattle/Bremerton, had 5% of the fishing effort, while both MA 6, East Juan de Fuca, and MA 9, Admiralty Inlet, each account for roughly 3.5% of total recreational shrimp fishing effort each year. Marine Area 11, Tacoma/Vashon, represents 1.5% of annual fishing effort and basically no effort has taken place in MA 13, South Puget Sound.

The non-treaty commercial fishing effort from 2008 to 2011 represented by CRA is shown in Figure 4. This shows that the greatest amount of effort occurs in the Region 1A, western San Juan Islands, and in eastern portion of Region 3, Straits of Juan de Fuca. The highest yearly effort occurs in CRA 1A-22A and CRA 25A, while the remainder of the effort is dispersed unevenly throughout the Puget Sound region with many CRAs having no effort at all. Distribution of Treaty fishery shrimp pot effort was displayed by catch effort rather than pot drops, by CRA for the year 2011 only (Figure 5). In 2011, 40% of the Treaty catch occurred in Region 5, Hood Canal, and 15% took place in Region 1A, western San Juan Islands, with the remaining effort focused in the region between Seattle and the San Juan Islands. Since the recreational fishery was established as the prime contributor to derelict shrimp pots, no further analysis of the commercial fisheries was conducted.

Cumulative recreational pot loss documentation from creel surveys by CRA is displayed in Figure 6, and provides finer scale resolution to the areas and counts of pot loss within MAs. This shows that the greatest number of lost pots reported per CRA was in Hood Canal. Outside of Hood Canal, the greatest numbers of reported pots lost was in the Tacoma-Vashon region, and other notable numbers of lost pots are seen in the Seattle area, central Puget Sound, Possession Sound and south Lopez Island. Figure 7 provides a breakdown of the CRAs by sub-area in Hood Canal with associated pot loss and while no immediate pattern presents itself, this information may be useful for future studies. Additionally, landmarks associated with pot loss records in creel surveys are presented in Figure 8, and locations associated with effort of those respondents reporting pot loss in the online survey are displayed in Figure 9. Because Hood Canal creel sheets include a "*Comments*" column rather than a "*Landmark*" column, no Hood Canal data was available to include in Figure 8. The displayed landmarks in Figures 8 and 9 should not be considered the actual coordinates of where pots are lost, rather an overview of the general areas where documented pot loss has occurred.

Sidescan Sonar Surveys

Three days of sidescan sonar surveys were conducted during the period of April 8, 2012 to April 13, 2012. One half day was used for transit to and from the study sites from Everett, and another half day was used for post-survey data processing. Survey track lines totaled 21.17 linear nautical miles (nm), covering 0.85 nm^2 of popular shrimp pot fishing grounds and likely rockfish habitat (Figure 10). A total of 165 derelict shrimp pot targets were identified during post-survey processing, as well as sonar imaging of likely rockfish habitat (Appendix B).

Surveys in the Mukilteo area ranged in depth from 45 – 353 feet, and covered 0.25 nm^2 , detecting 107 derelict shrimp pot targets; resulting in an average pot density of 428 pots/nm^2. The Edmonds survey area

was the largest in size, covering 0.40 nm^2 between the depths of 59 to 489 feet; however, the number of shrimp pot targets identified was significantly less than that in the Mukilteo survey area. A total of 45 targets were detected in the Edmonds survey area or 113 pots/nm^2. Piper's Creek was the smallest of the three survey areas in both area and number of targets identified. A total of 13 derelict shrimp pot targets were found in an area covering 0.20 nm^2 in the depth range of 42 to 462 feet, for a projected derelict pot density of 65 pots/nm^2. The overall derelict pot density of the three survey areas combined is 194 pots/nm^2. Target depths range from 87 to 311 feet, and averaged of 194 feet (Table 7).

Table 7. Sidescan sonar survey target count and depth by area

Survey Area	Target Count	Survey Target Depths (feet)				
		Min	Max	Mean	Median	Mode
Mukilteo	107	87	311	194	202	219
Edmonds	45	113	269	192	195	249
Piper's Creek	19	106	240	145	128	128
Grand Total	165	87	311	190	194	219

All targets and associated information were entered into the WA State derelict fishing gear database with the disposition of BMDD.

In MA 8, the commonly fished grounds are estimated to cover approximately 7.98 nm^2 and with a density of 428 pots per square nautical mile, this equates to an extrapolation of 3,415 derelict shrimp pots at various decomposition levels present within the fishing grounds of MA 8. Marine Area 9 holds an estimated 1.92 nm^2 of commonly fished grounds, and when multiplied by the density of 113 pots per square nautical mile, projects 217 derelict shrimp pots present. Pot density in MA 10 was 65 pots per square nautical mile, and the estimated area of fishing grounds is 3.80 nm^2. Extrapolation of this density throughout the fishing grounds 247 derelict pots present.

Discussion

Pot Loss Estimates

Based on the results of the study, we believe relatively low rates of pot loss exist in both the commercial and recreational shrimp pot fisheries in the Puget Sound. Using pot loss rates derived from both the 2007 to 2012 period, and the stand-alone 2012 fishing season, we estimate that the total number of shrimp pots lost per year in all shrimp fisheries ranges from 326 to 651.

Due to the lack of WDFW creel survey questions regarding pot loss in the years prior to the 2012 fishing season, we assume that the pot loss rates derived from creel survey information from 2007 to 2011 are underestimates and may only represent about 1/3 of the actual pot loss totals (M. O'Toole, WDFW, personal communication). With the addition of the two pot loss questions, we assume a much higher level of confidence in shrimp pot loss estimates for 2012 and in the future. Although the estimate of pot loss from the creel survey data in 2012 probably provides the best estimate of pot loss in the recreational shrimp pot fishery, causes of pot loss vary greatly both spatially and temporally, therefore, the one year of relatively accurate pot loss reporting in 2012 does not necessarily represent a long-term pot loss estimate. For example, the pot loss rates reported for MA 8 and MA 12 in 2011 were greater than those reported in 2012. Nevertheless, the average pot loss rate per year for the period 2007 to 2011 is 0.70% of pots fished,

equaling only 35% of the 2012 pot loss rate. We believe that pot loss rates reported in future WDFW creel surveys will be closer to the 2012 loss rate than the six-year average from 2007 to 2012. Additionally, if pot loss data continues to be collected during creel surveys as it was in 2012, estimates made for future years can be used to better understand the yearly variability in recreational pot loss.

An initial assumption in the study was that the pot loss rates derived from the online survey would be much larger than those from creel surveys since the online survey would favor those fishers who had lost a pot. However, the difference in overall average pot loss rates between the two sampling methods for the period prior to 2012 was only 0.02%. This lack of difference can be interpreted in a few different ways. One is simply that while creel surveys did not solicit information regarding shrimp pot loss from respondents, an accurate account of lost pots was nevertheless recorded, which is unlikely. Another way to interpret this is to consider the manner in which the online survey was advertised to recreational fishers, as the avenues used to target participants were much the same as those used for promotion, outreach and education of derelict fishing gear issues in general. It would make sense that prior to 2012, recreational fishers that are aware of the derelict fishing gear program in the Puget Sound would report lost pots to creel surveyors without being asked the specific question, and it is possible that many of the 320 participants in the online survey were from this same group of people, and that the increase in pot loss reports beginning in 2012 in the WDFW creel survey may be connected to the less informed, and possibly less experienced portion of the recreational fleet.

Reasons for shrimp pots becoming derelict vary, but generally can be narrowed down to a few specific underlying causes. One question in the online survey asked, "*Do you know the reasons for your pots being lost? Check all that apply.*" Answer options and responses from 172 survey participants are reported in Table 8.

Table 8. Reasons for shrimp pot loss in recreational fishery. Source: 2012 online survey. *Other reasons were derived from written responses.

Do you know the reasons for your pots being lost? Check all that apply		
Answer Options	**Response %**	**Response Count**
Strong currents	53.5%	92
Entanglement with other gear	22.7%	39
Unexpected water depth	18.0%	31
High winds, rough sea conditions	16.9%	29
Buoy struck by vessel	14.0%	24
Believed my pots stolen	12.8%	22
*Other: Gear Handling Error	5.8%	10
*Other: Faulty Gear	1.7%	3
Observed my pots stolen	1.7%	3
*Other: Bull Kelp pulls pots under	0.6%	1
*Other: Entanglement with floating debris	0.6%	1
*Other: Sabotage	0.6%	1
*Other: Stuck on Bottom	0.6%	1
	Answered Question	172

Over 50% of responses attributed pot loss to strong currents, followed by entanglement with other gear, unexpected water depths and high winds and rough seas. Most pot loss incidents could surely be caused by any combination of these factors, as well as others that fall lower on the response ranking. While almost 13% of responses believed their pots were stolen, only 1.7% actually observed their pots being stolen. Many of these reasons for pot loss can vary in magnitude depending on geographic location, particularly those attributed to forces of nature, such as strong tidal currents, unexpected water depth, and high winds/rough sea conditions. This also can be related to a fisher's level of experience and familiarity with a given location and possible lack of familiarity with another location.

Only one response from the non-Treaty commercial fleet described reasons for lost pots. However, this response was very detailed. This fisher reported that at times individual pots on a string of pots will become caught on a snag and detach from the groundline while it is being hauled in. Also, a snagged groundline may part on various types of underwater obstructions, and pots will peel off each parted end of the line as it is being retrieved. Heavy currents do not affect the commercial fishing gear as they do the recreational gear by sinking buoys or causing them to drag along the bottom, however heavy currents can twist a pots bridle causing the snap to fail and become detached from the groundline. Operator error in a few different ways can also cause pot loss in commercial gear, similar to that in recreational gear.

WDFW Marine Enforcement personnel conduct scheduled sweeps of the fishing grounds within a few days after shrimp openings to remove buoyed gear remaining on the fishing grounds. In the online survey and elsewhere, recreational fishers have reported that they often return to recover pots that were unrecoverable during their fishing opener, or that their lost gear is returned by other fishers who found them. Therefore, we know the number of shrimp pots that are lost each year does not equate to the number of derelict shrimp pots existing on the seafloor, however currently, there is no available method to quantify this discrepancy.

Rockfish and shrimp pots

The structural integrity of derelict pots degrades over time. And while we currently do not have an estimate for the lifespan of a derelict shrimp pot, studies from Puget Sound and British Columbia report derelict Dungeness crab pots not equipped with escape cord lose their fishing capabilities after 2.2 years (Antonelis et al. 2011)(Breen 1987). Many of the shrimp pot types used in the Puget Sound are built with a thinner and lighter wire mesh than those used in the crab fishery. Therefore, we assume that the fishable lifespan of a derelict shrimp pot is less than that of a crab pot.

The WA State DGDB contains 81 total derelict shrimp pot gear items, 41 of which have been removed. Of those 41 removed pots, two contained a total of eight rockfish, six live and two dead. The removed derelict shrimp pots containing rockfish were un-baited and had been derelict for several months, providing speculation that juvenile rockfish were attracted to the pots as habitat. In one instance, a dead rockfish was partially decomposed, and being eaten by spot shrimp in the pot; evidence that the rockfish died in the pot while it was sedentary and not as a result of barotrauma from pot removal. It was also noted by the onboard biologist, that some of these rockfish were too large to fit either in or out of the pot doors, giving reason to believe that these animals were in the derelict pot long enough to grow too large to escape from the same portal it entered. This limited dataset provides speculative estimates suggesting that 4.88% of all derelict shrimp pots contain at least one rockfish, one quarter of which could be mortally entrapped.

In British Columbia, studies of fishery-independent shrimp pot survey catch history have quantified rockfish bycatch in shrimp pots. From 1999 to 2008 overall rockfish catch per shrimp pot was 0.015, and results showed that this rate increased after 2004, and in 2008 the rockfish bycatch rate was 0.039 (Favaro et al. 2010). No rockfish were reported as dead in the shrimp pots, however high mortality rates for rockfish bycatch are assumed due to effects of ruptured swim bladders and barotrauma. With data from pots deployed for a 24 hour soak time, this research does not provide insight into the potential for rockfish to "live" in shrimp pots, however affirms that juvenile rockfish are attracted to these pots.

WDFW also performs annual shrimp pot test fisheries throughout Puget Sound and Hood Canal using strings of baited pots similar to those used in the commercial fishery. Typically, a string of five pots spaced 100 feet apart are set parallel to the slope of the seafloor, covering approximately 100 feet of vertical change from 220 to 320 feet in depth. The pots are baited with commercial style pellet bait, and the targeted soak time is 24 hours. A summary of historical pre and post season shrimp pot test fishing bycatch of individual rockfish species was provided by WDFW. This was the cumulative data from 2003 through 2010, and covered all regions of the Puget Sound shrimp fishery, except Hood Canal. Separate test fisheries take place in Hood Canal. However, the rockfish bycatch summary data was not available for analysis at the time of the study. Table 9 shows the summarized data by test fishery location.

Table 9. Historical pre and post season shrimp pot test fishing bycatch of individual rockfish species 2003 - 2010 (Data source: WDFW)

Region	Pot Pulls	INDV Rockfish	Bycatch Rate (RF/pot pull)
Biz Point	15	0	0.00
Boundary Pass	195	1	0.005
Des Moines	236	21	0.089
Everett	105	6	0.057
Iceberg Pt.	160	0	0.00
Salmon Bank	35	1	0.029
San Juan Channel	95	1	0.011
Saratoga Pass	225	1	0.004
Vashon Island	249	11	0.044
Grand Total	**1,315**	**42**	**0.032**

Species composition of the individual rockfish caught in the WDFW shrimp pot fishery included; 12 unidentified rockfish, 10 quillback, one greenstriped rockfish, five Puget Sound rockfish and 14 copper rockfish. Rockfish, and other finfish, found in test fishing pots are often partially eaten by shrimp, making it difficult to identify rockfish to specific species (M. O'Toole, WDFW, personal communication). WDFW personnel providing this data reported that the large numbers of copper and quillback rockfish were mostly caught in MA 11 during the 2005 and 2006 fisheries; coinciding with a large year class for each of these two species. The main point taken from this data is the overall rate of individual rockfish catch per pot drop of 0.032 is close to the 2008 rockfish catch per pot rate in British Columbia.

If we assume that juvenile rockfish are attracted to shrimp pots for their potential habitat characteristics rather than the scent of bait, we can speculate the potential number of rockfish caught due to "ghost fishing" from derelict shrimp pots by using the bycatch rate from the WDFW test fisheries. The yearly

estimate is calculated by multiplying the catch rates per pot by the number of estimated lost pots per year, and assuming that a derelict shrimp pot maintains fishing viability for at least one year, we then multiply this number by 365 to account for the fact that the test fishery soak times are only 24 hours. In doing so, the potential number of rockfish caught over the course of one year, in one year's worth of derelict shrimp pots ranges from 3,796 to 7,580. How many of these rockfish may escape the shrimp pots before they die is unknown but our observations of dead rockfish in recovered derelict shrimp pots indicates some mortality is likely to occur.

Of the 320 total respondents of the online survey questionnaire, 280 (87.5%) responded to the question: "*Have you ever caught animals other than shrimp in our shrimp pots? (e.g., crab, rockfish, etc.)?*" Of those, 171 (61% of those responding) responded "yes" and 109 (39% of those responding) answered "no". Of the 171 respondents reporting bycatch of some sort, 43 (25%) reported rockfish bycatch and one report identified a canary rockfish as bycatch in Hood Canal. The 280 fishers responding to the bycatch question represented 3,993 pot days of fishing effort and the 43 respondents reporting rockfish bycatch had an estimated fishing effort of 716 pot days per year or 18% of the yearly pot effort exhibited by the 280 respondents to this question. Based on the results of the online survey about 15% of recreational fishers catch some species of rockfish as bycatch in their actively fishing pots, supporting test fishery data indicating that rockfish are attracted to shrimp pots. While the information provided by the online survey was not sufficient to calculate a rockfish bycatch estimate to compare to the WDFW test fisheries estimate, it supports the supposition that rockfish bycatch in shrimp pots occurs regularly enough to warrant investigation of potential mortality as it relates to rockfish populations. The complete list of species reported as shrimp pot bycatch from the recreational online survey respondents is provided in Appendix C.

Online survey respondents had the opportunity to remark on where ("*Location description*") their fishing effort takes place. While this question was not specifically related to where bycatch was encountered, it does describe the fishing grounds frequented by those who reported rockfish bycatch. These descriptions were assigned a set of coordinates, not to depict exact location of rockfish bycatch, rather to give a general vicinity of where these bycatch occurrences have taken place. Results, in Figure 11, show the heaviest concentration of these locations is in Hood Canal and in the area between Edmonds and the southern extent of Camano Island.

One Puget Sound commercial shrimp pot fisher reported that he has removed "countless" derelict recreational pots of all types, "and they are always empty." This anecdotal account does not support the evidence of rockfish attraction to shrimp pots as habitat. However more information regarding this is necessary to discount the evidence provided from the derelict shrimp pot removals.

Sidescan Sonar Surveys

Sidescan sonar surveys found derelict shrimp pot targets in areas defined as likely rockfish habitat and in proximity to documented locations with ESA listed rockfish species. Marine Areas cover the entire Puget Sound and more precise geographic areas within those MAs that are commonly fished have not been previously defined. Geographic displays of shrimp pot buoys from WDFW surveys were used to approximate the bounds of the commonly fished grounds in MA 8, 9 and 10, where sidescan sonar surveys were conducted. The estimated number of derelict pots calculated by extrapolating pot densities

derived from sidescan sonar surveys throughout the commonly fished grounds in each of these MAs is equivalent to several years of pot loss based on estimates from creel surveys.

A few key factors may be the cause of the discrepancy between the derelict pot loss estimates derived from creel surveys and the number of derelict pots present on the fishing grounds extrapolated from the sidescan sonar surveys. First, extrapolating the pot density throughout the fishing grounds assumes a homogeneous derelict pot density. Since sidescan surveys targeted locations where heavy shrimp pot fishing effort was known to occur, it is probable that the loss estimates may not be appropriate to extrapolate pot loss throughout the entire fishing grounds within an MA. Also, many of the shrimp fishing grounds either overlap or are adjacent to Dungeness crab fishing grounds and it is possible that a portion of these targets could be derelict crab pots interspersed amongst shrimp pots. This is likely considering that an estimated 12,000 crab pots become derelict every year in the Puget Sound and that they remain in fishable condition for over 2 years (Antonelis et al. 2011). It is also possible that the pot loss estimates based on creel surveys are low and the number of lost pots within all fishing sectors is larger than estimated from creel surveys and other inquiries.

Summary

Based on loss rate estimates provided in the study, we believe that the number of shrimp pots lost in the Puget Sound shrimp fishery is relatively low compared to the amount of effort expended. However, calculating the density of derelict shrimp pots using sidescan sonar surveys provides a significantly higher number of derelict pots estimated to be present than what would be assumed from the loss rates and the operational lifespan of a lost shrimp pot. This may be attributed to the presence of derelict crab pots dispersed throughout the shrimp fishing grounds, as many locations are popular places to target both spot prawns and Dungeness crab. It could also reflect an underestimate of loss rates within the shrimp pot fisheries from question and answer surveys, however, this cannot be determined until further investigation of the targets are conducted.

Rockfish bycatch rates appear to be low in actively fishing baited pots, and they may be less attracted to unbaited derelict pots even though they have been observed during derelict fishing gear removal operations and may represent habitat for juvenile rockfish. The rockfish bycatch rates in actively-fished baited pots both in Puget Sound and British Columbia are relatively small and without a larger sample size of derelict pot information to support the observed level of bycatch (8 rockfish in 41 pots), we assume that the bycatch rates and mortality in unbaited derelict pots is smaller and, therefore, may not represent a significant threat to the overall rockfish populations in the Puget Sound. However, a population-level assessment is warranted in light of the depleted status of many rockfish species in the Puget Sound. Additionally, there is the potential for derelict shrimp pots to affect localized, isolated populations of rockfish in areas where effort and pot loss are high. Further investigation of WDFW test fishery data from Hood Canal, when available, may be helpful not only to augment the Puget Sound data, but also to see if there are any significant differences in bycatch rates between Hood Canal and other Puget Sound areas.

Recommendations

Based on the observations and results from the shrimp pot loss analysis and sidescan sonar surveys in the study, the following are recommendations for research priorities to further understand the potential impact to rockfish caused by derelict or active shrimp pots in the Puget Sound.

- Further explore rockfish bycatch rates in shrimp pots from WDFW Hood Canal test fishery data.
- Further explore rockfish bycatch by interviewing the WDFW Marine Enforcement officers who often recover lost and derelict shrimp pots
- Investigate sidescan sonar survey targets reported in the study to verify they are shrimp pots and not crab pots, record presence or absence of live and dead rockfish by species and estimate length of time pots have been derelict.
- Investigate the length of time shrimp pots remain viable when derelict in order to fully understand the potential impacts shrimp pots have on rockfish.

A full exploration of management options to reduce rockfish mortality in shrimp pots is beyond the scope of the study. However, the following are two recommendations for management action aimed at reducing shrimp pot loss and rockfish mortality in the recreational shrimp pot fishery.

- Consider initiating an education program for recreational fishers to help minimize shrimp pot loss.
- Fishers should be encouraged to release live caught rockfish at depth, similar to what is currently being proposed in the sport finfish fishery, in order to minimize mortality due to barotrauma.

Acknowledgements

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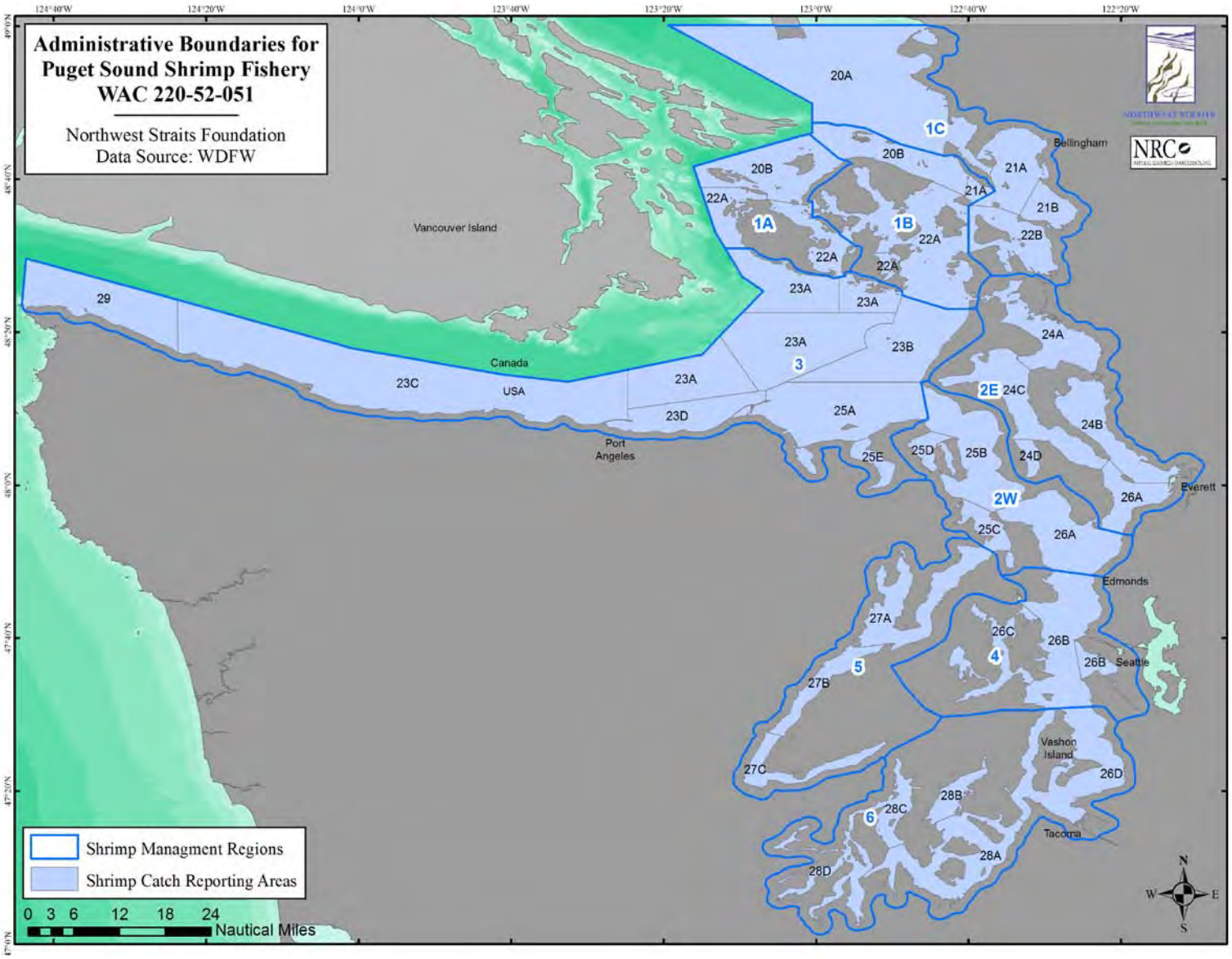


Figure 1. Puget Sound Shrimp Management Regions and Catch Reporting Areas

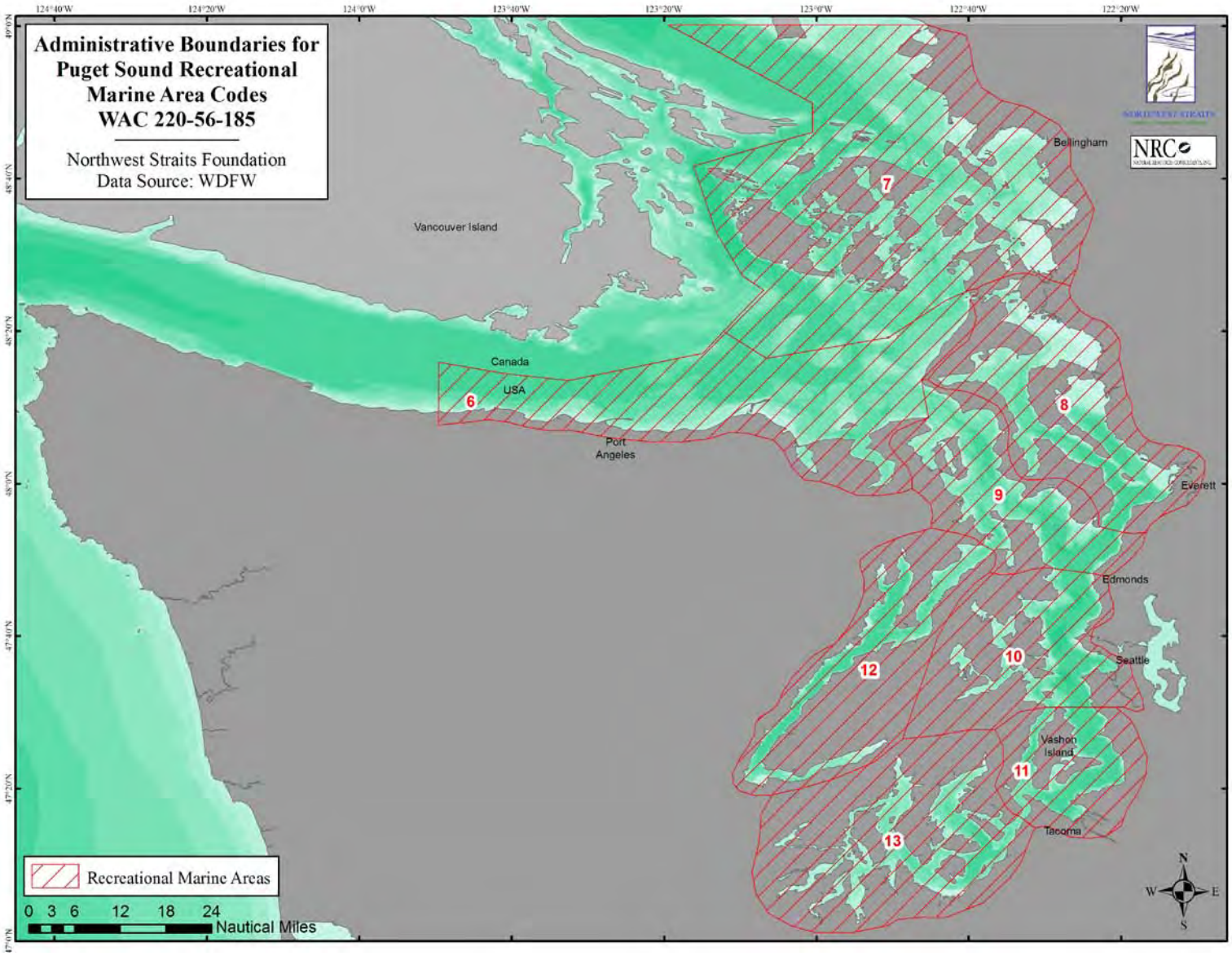


Figure 2. Puget Sound Recreational Marine Areas

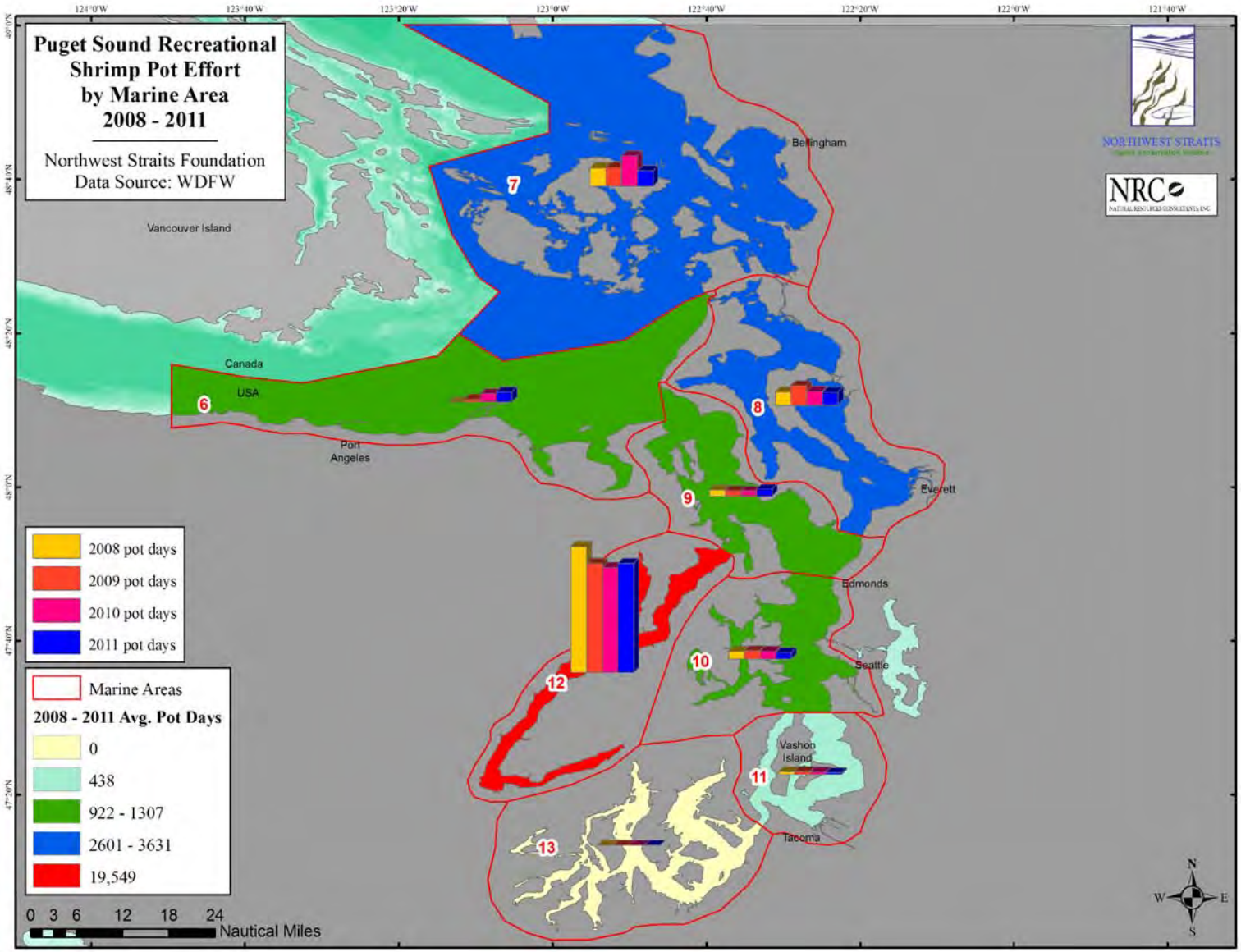


Figure 3. Puget Sound recreational shrimp pot effort (2008-2011)

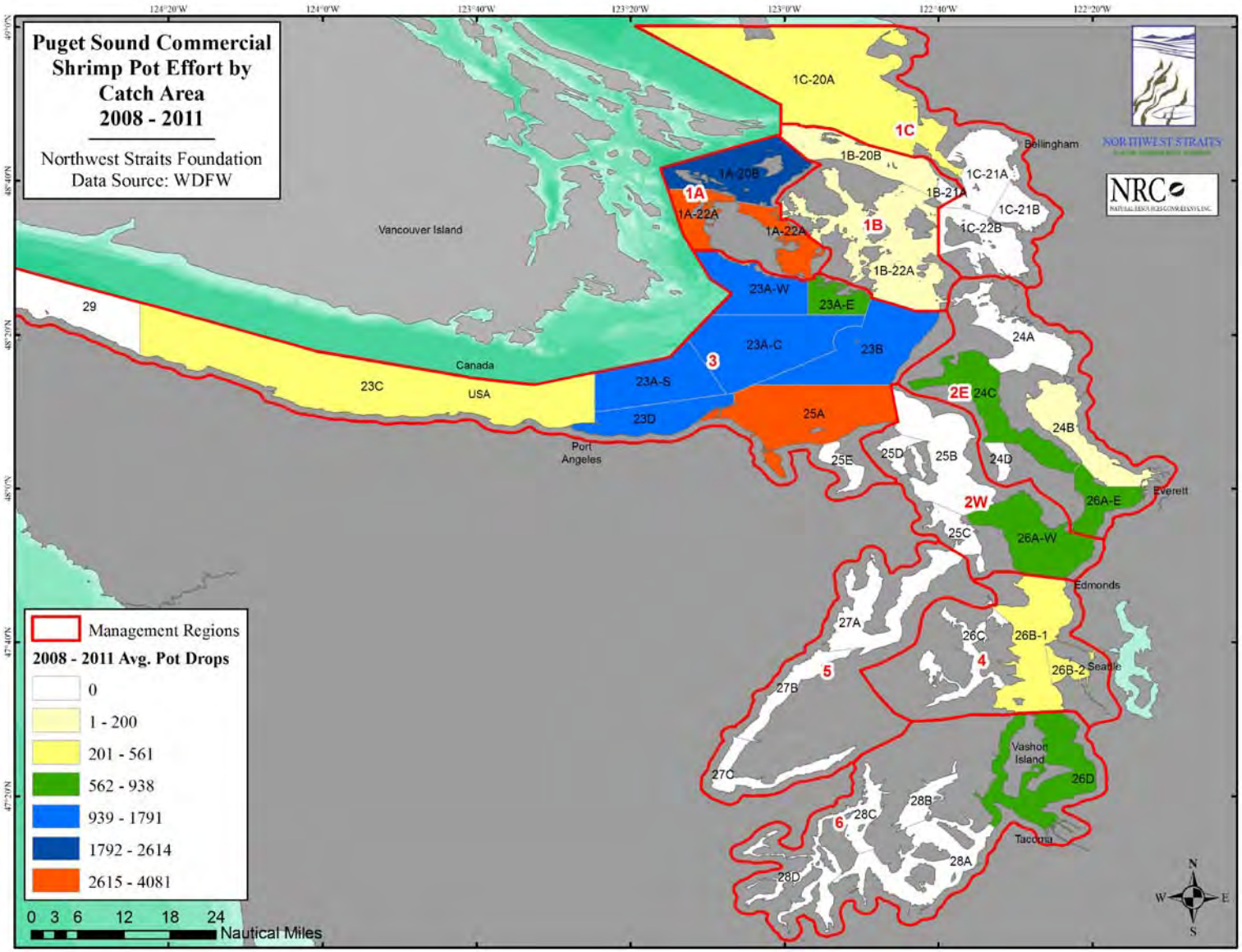


Figure 4. Puget Sound non-Treaty commercial shrimp pot effort (2008-2011)

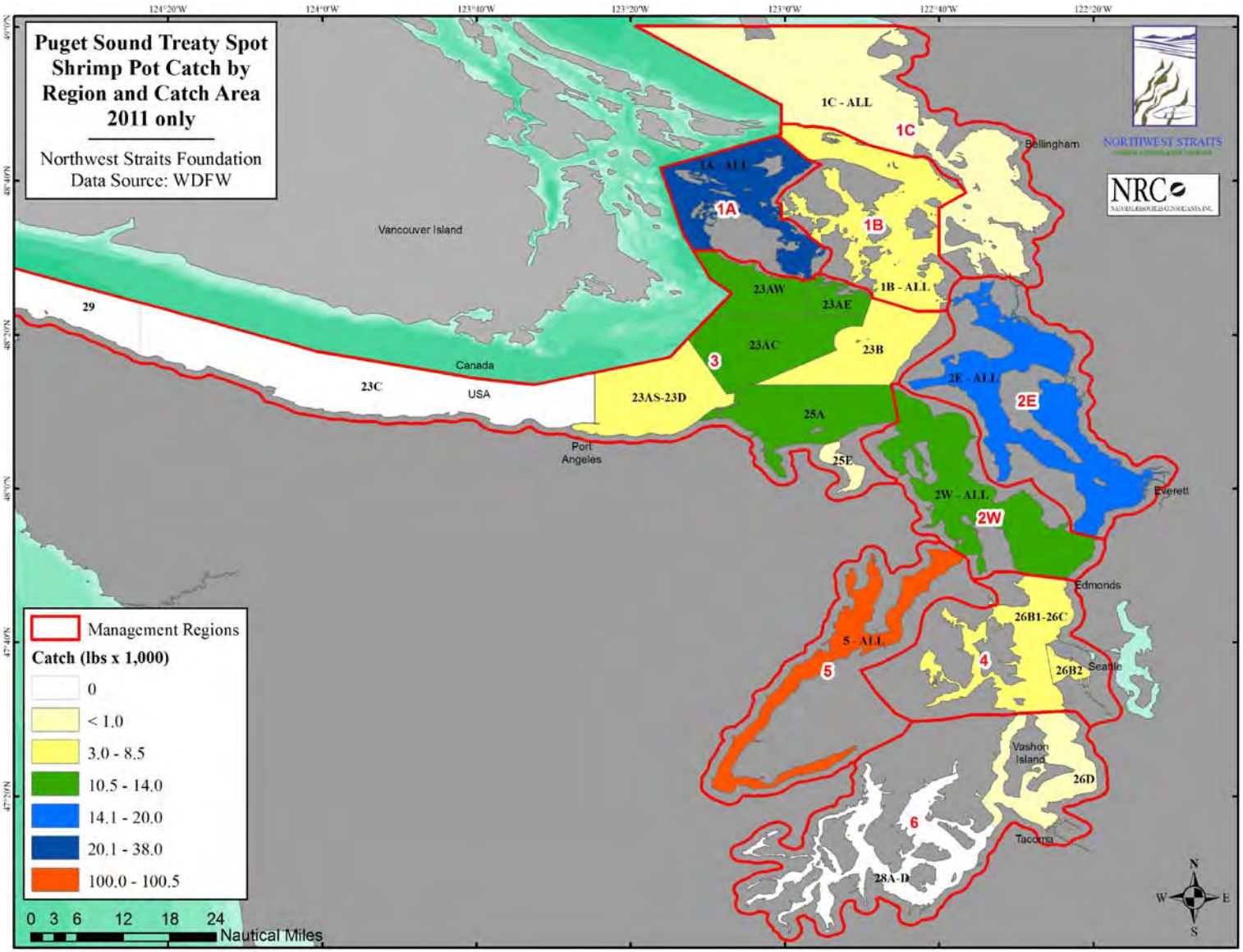


Figure 5. Puget Sound Treaty shrimp pot effort (2011)

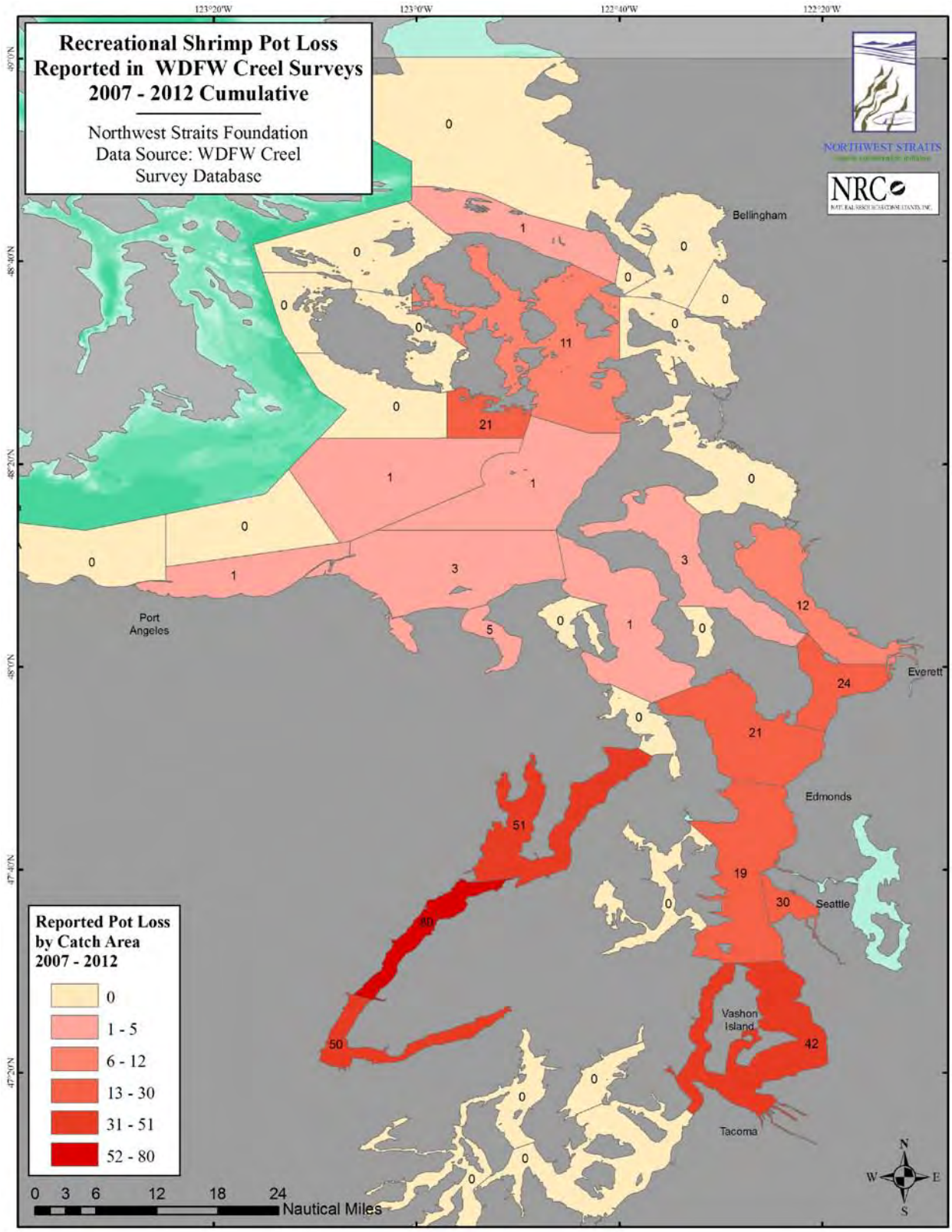


Figure 6. Cumulative recreational pot loss documentation from WDFW creel surveys (2007-2012)

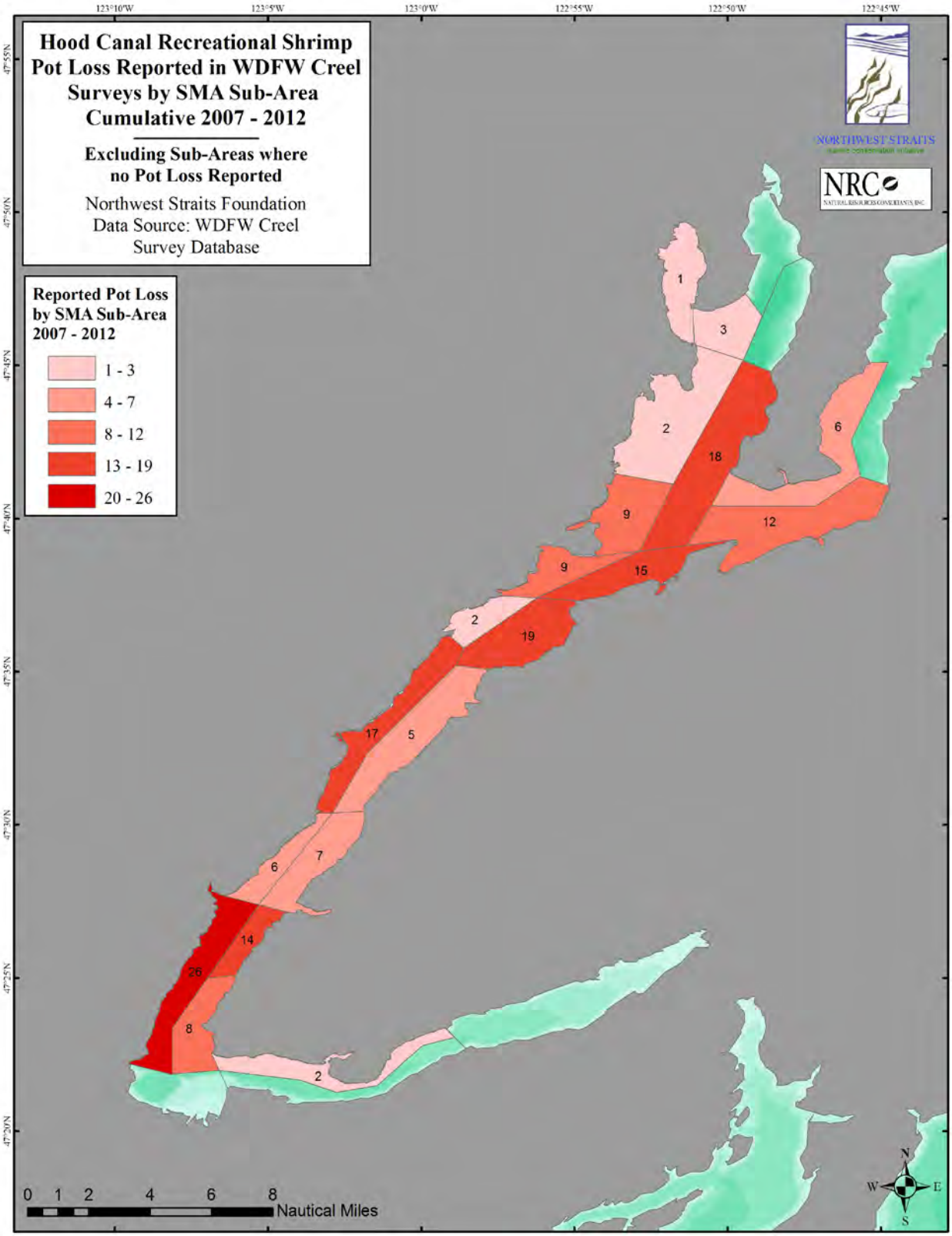


Figure 7. Pot loss documented by sub-area in Hood Canal (2007-2012)

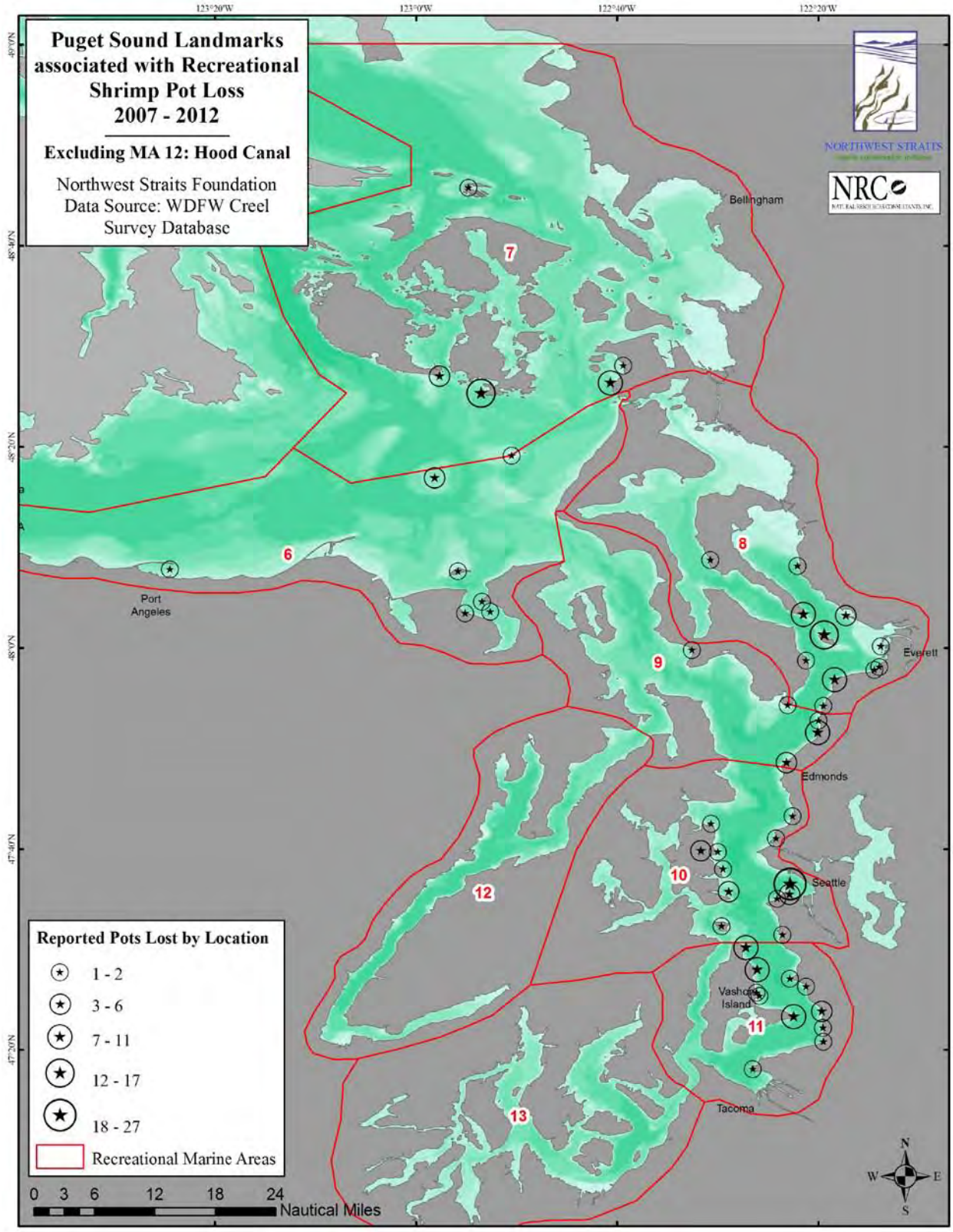


Figure 8. Landmarks associated with creel survey pot loss records

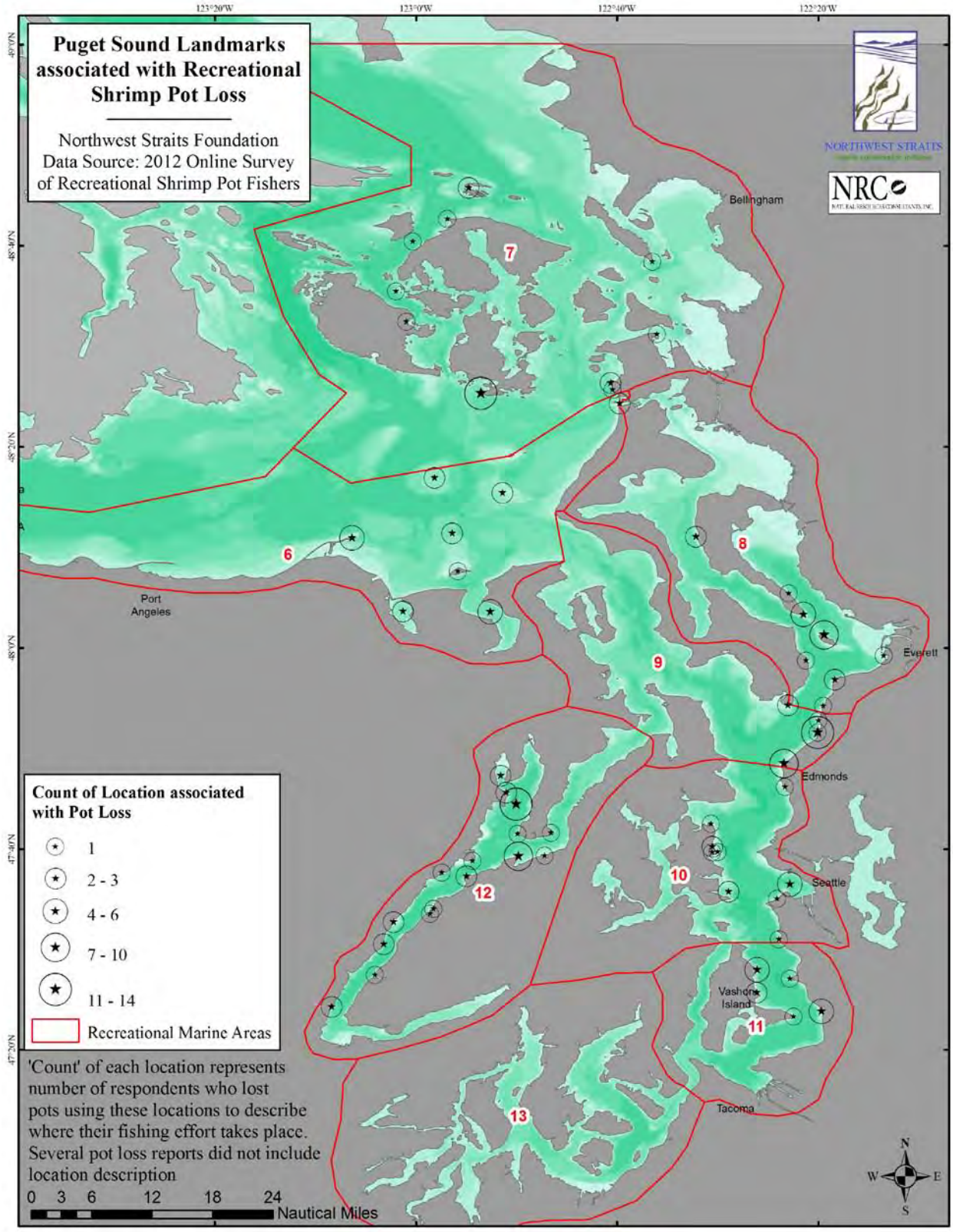


Figure 9. Landmarks associated with online survey pot loss effort

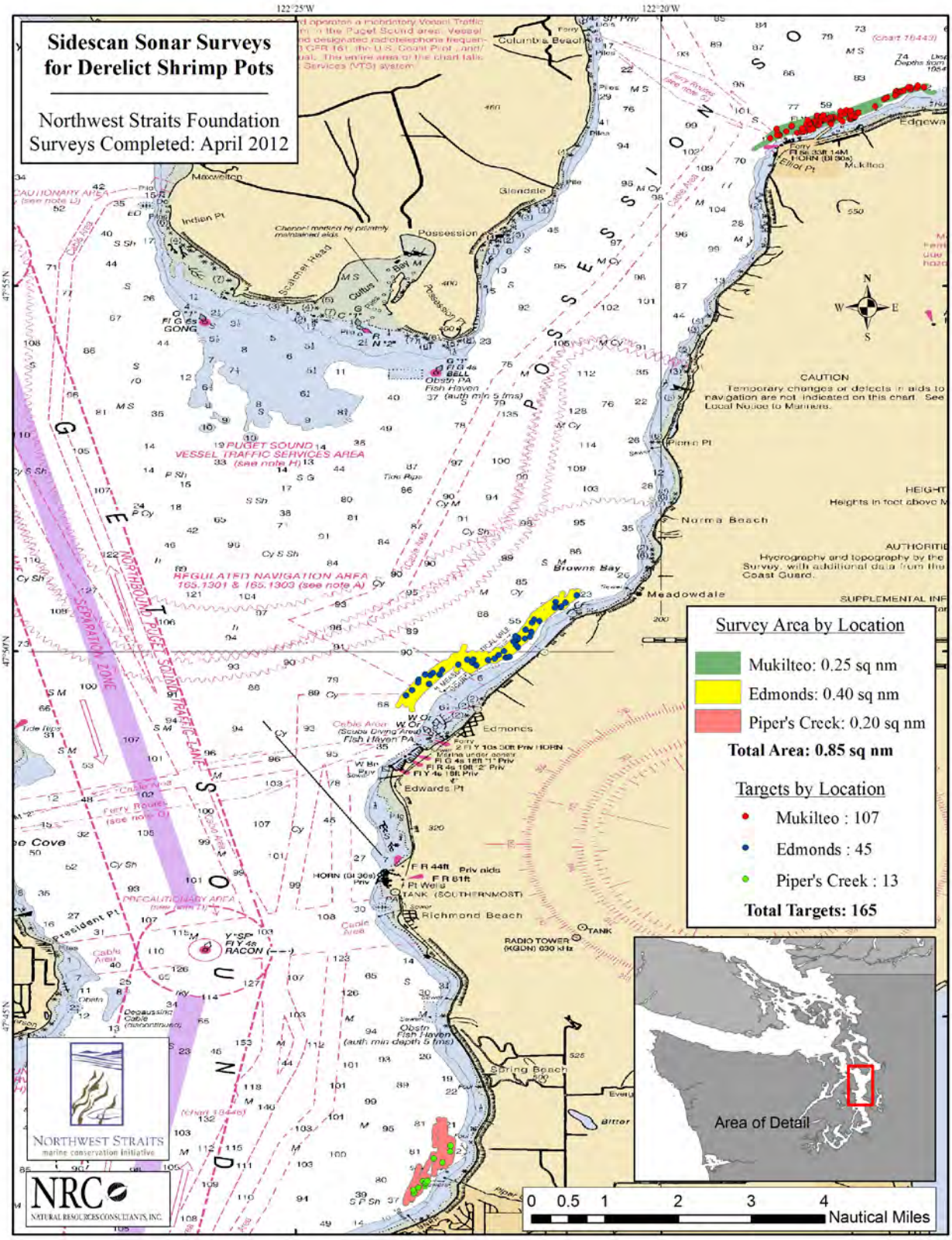


Figure 10. Sidescan sonar survey results

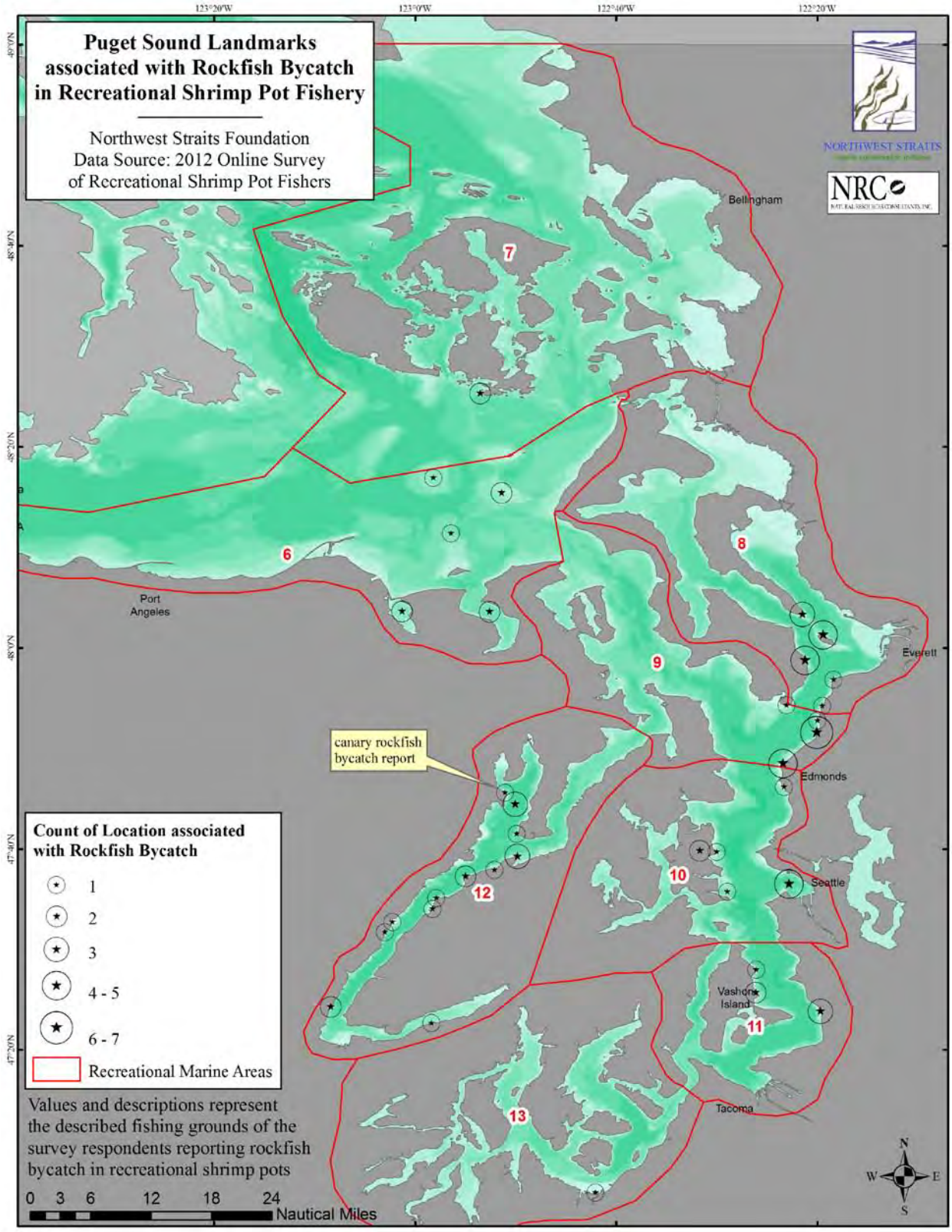


Figure 11. Landmarks associated with online survey rockfish bycatch effort

Appendices

Appendix A: Puget Sound Recreational Shrimp Pot Survey 2012 (Survey Monkey®). Page 1.

Puget Sound Recreational Shrimp Pot Survey 2012

Recreational Shrimp Pot Loss Questionarre

The purpose of this survey is to gain an understanding of the frequency and location of recreational shrimp pot loss in Puget Sound and Hood Canal. All responses are anonymous, and your participation is greatly appreciated.

1. Do you or have you participated in recreational shrimp pot fishing in Puget Sound and/or Hood Canal?

- ◯ Yes
- ◯ No

2. Where in the Puget Sound/Hood Canal do you participate in shrimp pot fishing? Check all that apply.

- ☐ Marine Area 6: East Juan de Fuca Strait
- ☐ Marine Area 7: San Juan Islands
- ☐ Marine Area 8-1: Deception Pass, Hope Island and Skagit Bay
- ☐ Marine Area 8-2: Port Susan and Port Gardner
- ☐ Marine Area 9: Admiralty Inlet
- ☐ Marine Area 10: Seattle - Bremerton Area
- ☐ Marine Area 11: Tacoma - Vashon Island Area
- ☐ Marine Area 12: Hood Canal
- ☐ Marine Area 13: South Puget Sound

Location description (e.g., Edmonds, Iceberg Point, Seabeck, etc.)

Puget Sound Recreational Shrimp Pot Survey 2012

3. How many years have you participated in the recreational shrimp pot fishery?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10

Other (please specify)

4. About how many days do you participate in shrimp pot fishing each year?

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10
- ◯ 11-20
- ◯ more than 20

Other (please specify)

Puget Sound Recreational Shrimp Pot Survey 2012

5. In a typical day of shrimp pot fishing, how many shrimp pots are on your vessel?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4

6. In a typical day of shrimp pot fishing, how many licensed fishers are on your vessel?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4

Other (please specify)

7. Has your fishing party ever lost a shrimp pot from the vessel you were fishing from?

- ◯ Yes
- ◯ No

Additional comments

8. In all the years you have been shrimp pot fishing, about how many shrimp pots have you lost in total?

9. About how many shrimp pots have you lost IN THE LAST THREE SEASONS?

- ◯ 0: I've not lost a shrimp pot in the last three seasons
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

If more than 5, how many?

Puget Sound Recreational Shrimp Pot Survey 2012

10. Do you know the reasons for your pots being lost? Check all that apply.

- ☐ High winds, rough sea conditions
- ☐ Strong currents
- ☐ Entanglement with other gear
- ☐ Unexpected water depth
- ☐ Buoy struck by vessel
- ☐ Observed my pots stolen
- ☐ Believed my pots stolen

Other (please specify)

11. About how many pounds did your lost pots weigh?

- ○ less than 5 lbs
- ○ 5-15 lbs
- ○ 15-25 lbs
- ○ 25-35 lbs
- ○ 35-45 lbs
- ○ more than 45 lbs

Comments

12. Which type of pots have you lost?

	None of my lost pots	Some of my lost pots	All of my lost pots
Wire mesh (square pots, McKay pots, etc.)	○	○	○
Flexible web mesh (Ladner pots, Stealth pots, etc)	○	○	○

Other (please specify)

Appendix A: Page 5

Puget Sound Recreational Shrimp Pot Survey 2012

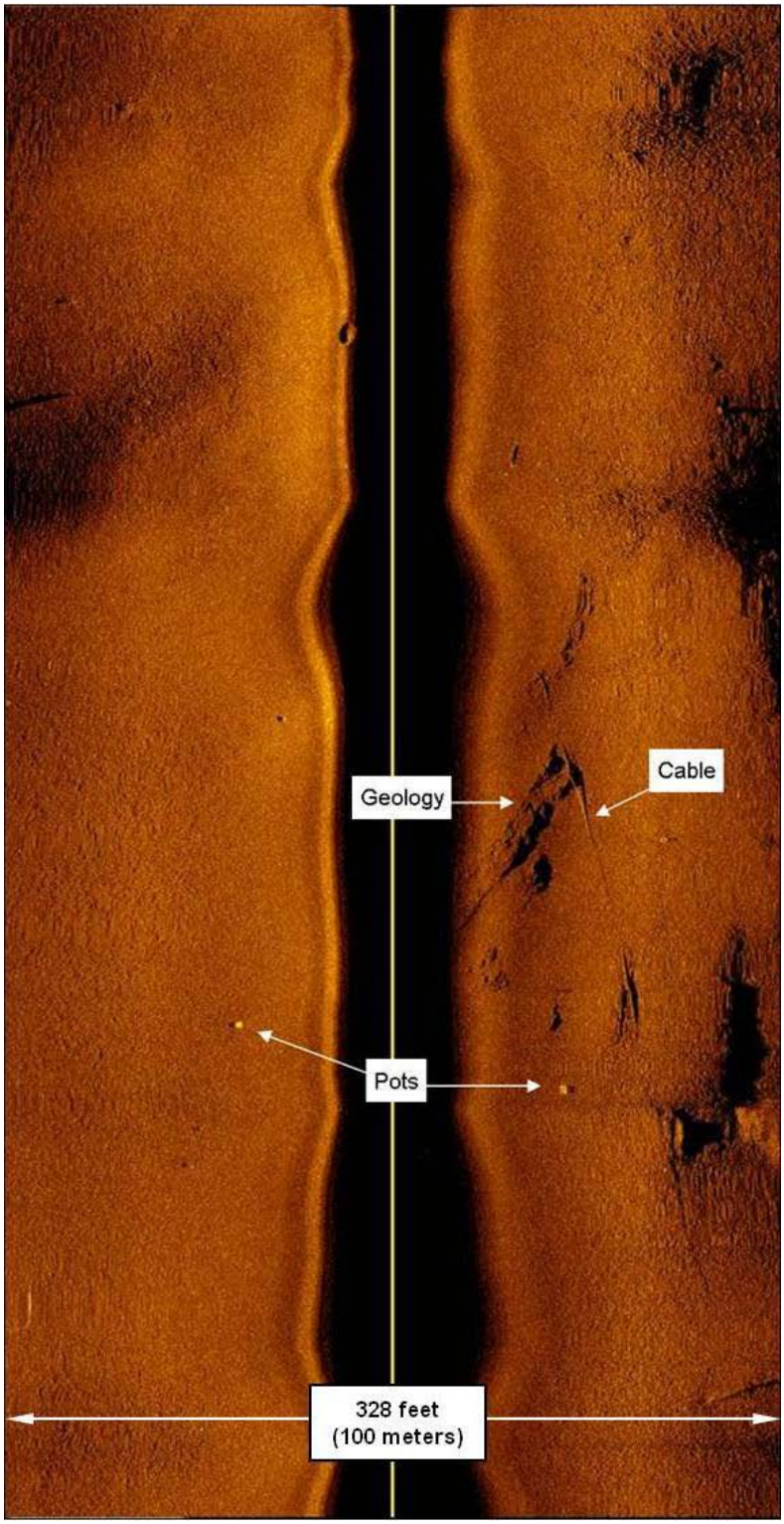
13. Have you ever caught animals other than shrimp in your shrimp pots? (e.g., crab, rockfish, etc)

- ◯ Yes
- ◯ No

Please explain

Thanks for your time! Your responses are extremely valuable.

Appendix B: Sidescan sonar image of derelict shrimp pot target and potential rockfish habitat. Image courtesy of Fenn Enterprises.



Appendix C: List of shrimp pot bycatch species encountered by recreational shrimp pot survey respondents.

Group	Species Description	Count of Occurrences in survey responses
Bird	sea birds	1
Fish	bottom fish	3
	bullhead	4
	cabezon	2
	cod	5
	dogfish	6
	eel like fish	1
	eels	2
	fish	12
	fish (not rockfish)	1
	flatfish	1
	flounder	16
	kelp greenling	1
	lingcod	1
	lingcod (juvenile)	2
	perch	1
	ratfish	3
	rockfish	35
	rockfish (juvenile)	3
	rockfish, canary	1
	rockfish, copper	3
	rockfish, quillback	1
	sand dab	3
	sculpin	10
	shark	2
	sole	5
	starry flounders	2
	tomcod	1
Invertebrate	crab	49
	Dungeness crab	3
	hermit crabs	6
	jellyfish	1
	octopus	59
	red rock crab	6
	scallop	12
	scallops, pectin	1
	scallops, pink	1
	scallops, swimming	1
	sea cucumbers	2
	sea urchins	1
	seastars	3
	short tailed crab	1
	Snails	1
	spider crabs	2
	squat lobster	9
	squid	2
	starfish	46
	sunstars	2