Results from Young-of-the-Year Rockfish Surveys in the southern Salish Sea

2015 - 2024

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Summary

Rockfishes (*Sebastes* spp.) in the inland waters of Washington State and British Columbia, Canada, collectively known as the Salish Sea, have been exploited for millennia. In recent decades this exploitation has resulted in substantial loss of abundance and biomass, as well as truncation of the size/age-distribution for numerous species. Three species, for which impacts were especially severe, were listed under the federal Endangered Species Act in 2010: canary and yelloweye rockfish as threatened and bocaccio as endangered with canary subsequently removed following genetic testing (81 FR 43979). In addition, natural resource management agencies in the region have implemented policies and procedures that: recognize and codify numerous rockfishes as imperiled species in need of active management; acknowledge and reduce fishery impacts and other population stressors; and chart a course toward recovery. Tracking the initial stages of recovery requires a working knowledge of rockfish recruitment dynamics and habitat utilization by recently settled rockfishes. Until 2015, no survey effort sought the spatial and temporal data necessary to provide such information in the southern Salish Sea. To address this need, NMFS collaborated with state and federal agencies, non-profit groups, and academic institutions to develop a citizen science SCUBA survey program directed at young-of-the-year (YOY) rockfishes. In this program, volunteer and professional divers perform timed roving surveys in discrete habitat types while recording data on rockfish abundance, in four morphological classes, as well as qualitative attributes of the habitat. Consistent, focused outreach effort has led to increased survey participation over time, while better coordination and agency support has allowed for more frequent professional surveys. Here, general trends in YOY encounter across basins, habitat types, and seasons are explored. Effort has sufficiently increased over time to tease out spatial and temporal recruitment trends. Two boom recruitment events occurred in elongate body/dorsal spot species (2021 and 2024) and increasing numbers of yelloweye recruits are being found from the San Juan Islands through the northern stretches of Central Puget Sound. Applications of these data are growing as partner participation increases and additional years of data better define a baseline of YOY recruitment in Puget Sound and connected waters. After ten years, the program continues to grow and inform critical recovery actions outlined in the federal Rockfish Recovery Plan for Puget Sound/Georgia Basin yelloweye rockfish and bocaccio and the Washington State Wildlife Action Plan, with potential to contribute to the Canadian Management Plan for the yelloweye rockfish in coming years.

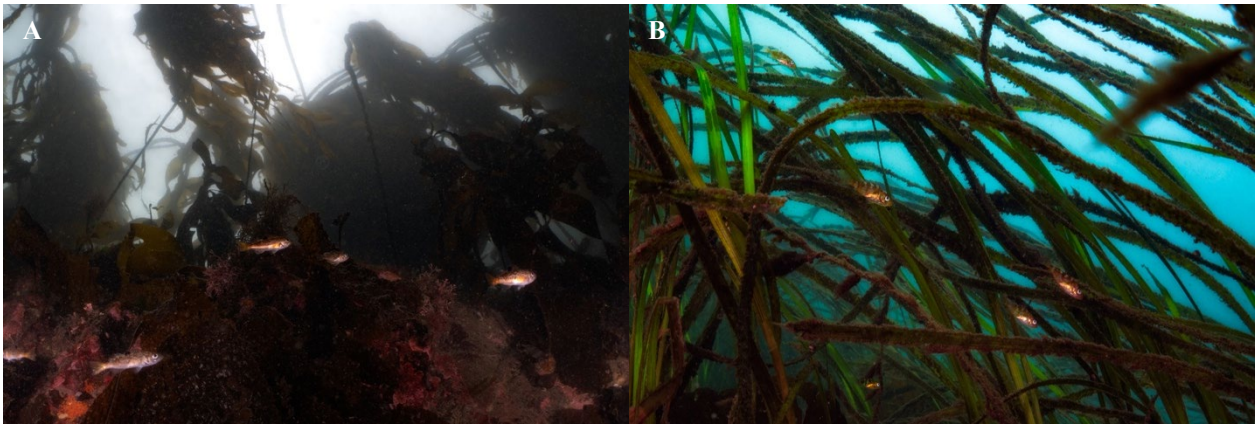
Introduction

Basis for Study

Rockfish comprise a suite of viviparous species within the genus *Sebastes* that function as mid-level predators in nearshore marine habitats. While they are found throughout the waters of the west coast of North America, populations in the southern Salish Sea (aka Puget Sound) have decreased in the past century, primarily as a result of overfishing and reductions in habitat quality (Palsson et al. 2009; Williams et al. 2010). These declines were especially sharp from the late 1970s through the early 1990s, but demographic impacts of the declines are expected to last for decades to come. Fishery effects were not evenly distributed, with larger-bodied, deep-water species with high abundance adjacent to human population centers hit especially hard. As a result, NOAA's National Marine Fisheries Service (NMFS) listed the distinct population segments (DPSs) of canary rockfish (*Sebastes pinniger*), yelloweye rockfish (*S. ruberrimus*), and bocaccio (*S. paucispinis)* occurring in the Puget Sound/Georgia Basin under the Endangered Species Act in 2010 (75 FR 22276), but canary rockfish were subsequently delisted based on new genetic evidence (81 FR 43979; Andrews et al. 2018). A final recovery plan for the yelloweye rockfish and bocaccio DPSs was released in October of 2017 (NMFS 2017) and a periodic five-year review and recovery progress assessment was released in February of 2024 (Lowry et al. 2024). An

important ongoing action identified in the recovery plan (and state plan is to better understand listed rockfish population abundance and habitat associations across the entirety of their life cycle. Included under this action are annual surveys of young-of-the-year (YOY) rockfish (though both Washington state and Canadian policy; WDFW 2015; DFO 2021) throughout the DPSs, though NMFS lacks jurisdiction to compel such surveys in Canadian waters. Because listed YOY rockfish are particularly rare (YOY bocaccio have yet to be documented in the Puget Sound) a comprehensive effort to document *Sebastes* YOY abundance and habitat association in the region would explicate recruitment dynamics in association with climatic, oceanic, and habitat variables and help shape various management efforts.

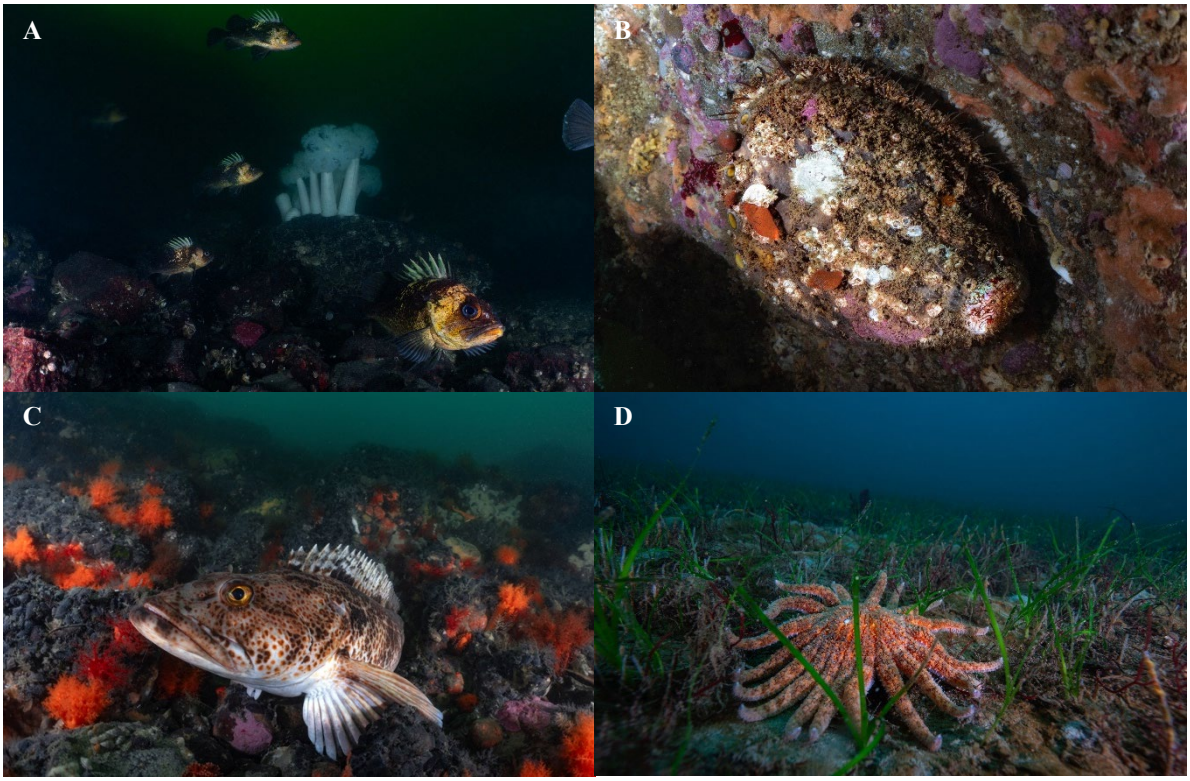
After spending several months incubating within their mother, rockfish begin their free-swimming life cycle as planktonic larvae that drift throughout pelagic habitat. After three to six months, they settle into nearshore or benthic habitats. YOY are known to aggregate in areas of high rugosity or submerged aquatic vegetation, such as kelp and seagrass (Love et al. 1991; Buckley 1997). Reefs and vegetated areas with low densities of adult and subadult rockfishes have been shown to hold higher densities of YOY (Matthews 1990; West et al. 1994). As rockfish typically parturate in the spring, YOY are often found in nearshore habitats in the summer and fall (Doty et al. 1995), though interannual and spatial variation in abundance is high (Sakuma et al. 2006; Ralston et al. 2013; LeClair et al. 2018). Using this baseline information as a starting point, a robust, long-term sampling program that quantifies recruitment strength was developed to support population models assessments and habitat management in the Salish Sea.



The utilization of relatively shallow and nearshore habitats by YOY rockfish makes surveys on SCUBA possible. A visual census on SCUBA allows for direct observation of fishes in vegetated, high relief, and/or shallow habitats that may be challenging for other sampling approaches. However, SCUBA surveys at this scale are resource-intensive, which may pose a challenge for any lone stakeholder interested in monitoring juvenile rockfish throughout Puget Sound. Engaging with volunteer citizen divers provides an opportunity to collect sufficient data to answer the project's core questions and engage with a valuable stakeholder group for rockfish recovery. There are numerous examples of recreational divers effectively collecting scientific data on biodiversity (Goffredo et al. 2010), elasmobranchs (Ward-Paige and Lotze 2011), and fish abundance (Bodilis et al. 2014). In addition, the Seattle area has an active dive community that readily supports such an effort. Given the biology of rockfish, demonstrated effectiveness of citizen dive surveys, and pool of available divers, NMFS initiated a program in 2014 to monitor YOY rockfish abundance throughout Puget Sound, and recently expanded these surveys into Canadian waters through collaboration with the Marine Life Sanctuaries Society.

History of the Program

The sampling methodology developed for this program was drafted with input from multiple regional experts, including staff from the Washington Department of Fish and Wildlife (WDFW), The Northwest Straits Initiative, the Seattle Aquarium, The SeaDoc Society, NOAA's Northwest Fisheries Science Center (NWFSC), and the Reef Environmental Education Foundation (REEF) (Obaza and Tonnes 2017). Project leaders began the program with the goal of maximizing accurate data collection from across Puget Sound and not achieving a set requirement of citizen diver participation. That guiding principle has allowed for plasticity in program development, to go where the interested divers are and build a collaborative relationship. Therefore, the program does not exist as a pure citizen science (hereafter "partner driven") venture; diver experience levels range from highly capable recreational divers to field biologists with decades of experience. All participants collect data using the same methodology. This spectrum of expertise not only allows citizen divers the assurance and gratification of their contributions being on equal footing as professionals but also presents unique data comparison opportunities as the database grows.



The same survey methodology used for YOY rockfishes has also been applied to document adult rockfishes (A), pinto abalone (B) (*Haliotis kamtschatkana*), lingcod (C) (*Ophiodon elongatus*), and sunflower sea stars (D) (*Pycnopodia helianthoides*)

The expansion of the program over time is intrinsically edifying (see Appendix 1 for full list of partners). Each of the five foundational non-professional partners showed a positive relationship between outreach effort and data collection, with all groups exhibiting a two-year lag until substantial contributions (Obaza et al. 2024). Program creation required strong startup resources on the part of the project leads, but consistent buy-in was evident across groups and possible synergy (more rapid escalation of data collection output) was documented. Surveying rockfishes in Puget Sound with a partner driven approach not only provides lessons on rockfish life history necessary for species recovery but also informs the outreach and engagement blueprint of an effective collaborative conservation science program.

Data accumulation presents additional management and synthesis challenges. A workshop was convened in September 2017 with a diverse complement of institutions to clarify a path forward on these topics. The result was a rockfish monitoring plan authored by PMRG, NOAA and Natural Resources Consultants (Obaza et al. 2023). Of principal benefit in this document is a flexible, state-space hierarchical statistical model that can incorporate data collected with myriad methodologies to create an annual recruitment index. This quantitative approach is an integral step in accounting for the high variability in both recruitment and survey methodologies. The results from this index are not presented in this document but are noted nonetheless due to their long-term benefits to assessing recruitment.

With increasing survey infrastructure and partnerships through the years, the survey protocol has proved to be well suited to additional species of management and scientific interest throughout the Salish Sea. Over the past five years, adult rockfishes, pinto abalone (*Haliotis kamtschatkana*), lingcod (*Ophiodon elongatus*), and sunflower sea star (*Pycnopodia helianthoides*) have been recorded using the same survey methodology as YOY rockfishes. Partners can record these species as well and this approach provides an avenue to create additional partners with different primary research interests.

Report Scope

This report documents notable results from ten years of YOY rockfish surveys in the Salish Sea. It is not a comprehensive analysis of every application for these data, nor does it make a statement on long-term trends in recruitment. Instead, specific areas of interest are highlighted that include the state of our knowledge on yelloweye recruitment, habitat and depth trends, documentation of two jackpot recruitment events for yellowtail (*S. flavidus*) and black (*S. melanops*) rockfishes, spatial trends in recruitment, and applications of this methodology to other species.

Yelloweye YOY (*S. ruberrimus*) sheltering in a glass sponge (*Aphrocallistes vastus)*

Methods

Site Selection

Survey sites in greater Puget Sound were initially chosen for presence of suitable YOY habitat, ease of access, and popularity as regularly visited dive sites. To the degree practicable, they were also aligned with historical observations of YOY by WDFW and NMFS staff (e.g., Patten 1973; Matthews 1987; Doty et al. 1995; West et al. 1994; Buckley et al. 1997), though many previously surveyed locations were accessible only by boat and/or were relatively remote. This approach was adopted to encourage divers to consistently survey the same sites throughout the year, improving temporal coverage at these *de facto* index sites. Over time, as both citizen and professional diver survey effort and project commitment increased, additional sites were added within each of seven sub-basins of greater Puget Sound (Central Sound, South Sound, Whidbey, San Juan Islands, Admiralty Inlet, the Strait of Juan de Fuca, and Hood Canal; see **Appendix 2** for map) and Howe Sound in the Strait of Georgia. The purpose of adding sites was twofold: 1) to increase spatial coverage and capture regional trends in recruitment and, potentially, inter-basin dynamics; and 2) to expand the number of habitat types within each region for which data could be used to describe YOY association patterns, including kelp forests, eelgrass beds, rocky and artificial reefs, and other geological features (e.g., rugose soft bottom). Not all sites and habitats are equally used by rockfish, oftentimes for reasons that are not fully understood. However, it was determined that inclusion of these sites was warranted to facilitate evaluation of broadscale settlement patterns and longer-term survival of YOY in the event of a major recruitment event, or changes in species distribution. **Figure 1** identifies all sites within the southern Salish Sea surveyed from 2015 to 2024, with point size corresponding to annual effort and color to years surveyed.

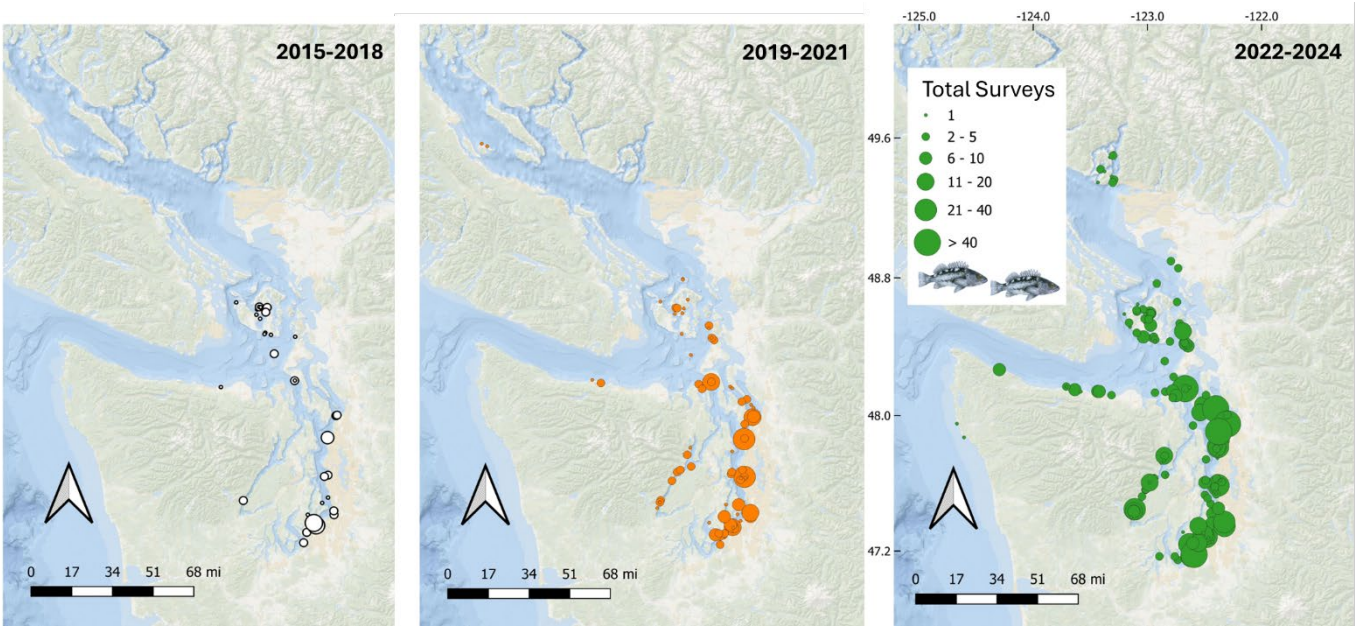


Figure 1. Young-of-year rockfish survey locations in Puget Sound and the San Juan Islands in Washington from 2015-2020. Point size indicates annual effort.

Surveys

Surveyors collect data using a timed roving dive approach in discrete habitat and depth bins (Obaza et al. 2017; 2019; 2021). Tasks may be divided among a buddy pair, where one member records fish and the other tracks habitat, depth, and survey time, or completed entirely by a single diver. The diver recording fish documents all visible YOY (individuals < 10 cm) within 1 m on either side of their swimming path and ≤1 m above the substrate. This survey is timed and lasts as long as a single habitat and depth bin is being searched. During 2015, the swimming path was a five minute transect (i.e., a single heading) while in 2016-24 divers conducted transects of any length if novel habitat was still being searched. If habitat is patchy (i.e., areas of one habitat type are disjointed), sampling within each distinct patch of any given habitat type is counted as a separate survey. If macroalgae or eelgrass are being surveyed, the diver lightly disturbs the vegetation to better expose individuals. If rocky substrate is present, the surveyor uses a flashlight to illuminate potential hiding places. YOY rockfish do not need to be recorded to species. Instead, they are classified into one of four morphological categories based on NOAA's YOY survey guide (**Appendix 3**): 1) deep body with dorsal spot; 2) deep body without dorsal spot; 3) elongate body with dorsal spot; and 4) elongate body without dorsal spot. If the diver cannot classify the individual to one of those groups, "YOY" is simply noted. Both ESA-listed bocaccio and yelloweye rockfish fall into the elongate body/no dorsal spot category with the comparatively more common Puget Sound rockfish (*S. emphaeus*), though yelloweye are typically reported at the species level given their unique red/orange coloration and conspicuous racing stripes. In the event surveyors are comfortable recording adult and juvenile rockfishes, they are identified to species and grouped into juvenile or adult size classes. Juveniles are individuals 10-20 cm and adults are >20 cm for all species besides Puget Sound rockfish (6-12 cm juveniles and >12 cm adults). Lingcod, abalone, and sunflower sea star may also be counted and measured to the nearest cm (total length is recorded for Lingcod and abalone, whereas radial width is measured for sunflower sea stars). Video or still images may also be taken to improve morphological category assignment and size determination, as well as to allow species identification/validation when rare species are encountered.

As each survey is completed in an area dominated by a single habitat type, the sampler may record several categorical metrics to further describe the habitat (**Table 1**). These metrics are general and may be completed following the dive, particularly if discussion between a buddy pair may clarify assignment. Video or still images may also be taken to improve evaluation of habitat type metrics. Survey depths are recorded and reported within one of three bins: shallow (<7m), intermediate (7-18m), and deep (>18m). Therefore, each survey has an associated habitat type and depth bin, regardless of whether fish are encountered or not.

Table 1. Habitat type, feature, and metrics used to characterize habitat for rockfish transects.

Habitat Type	Habitat Feature	Metrics
Rocky Reef	Relief (height in meters above seafloor)	Low (<0.1), Medium (0.1-1), High (>1)
	Benthic macroalgae abundance	Common, Sparse, Rare to Non-Existent
Eelgrass	Density (# turions / m^2)	High (>10); Medium (1-9); Low (<1)
	Blade length (meters)	Approximate (no measuring device)
Kelp Forest	Density (# stipes encountered / transect)	High (>100); Medium (20-100); Low (<20)
	Canopy height (meters above seafloor)	Approximate (no measuring device)
Soft Bottom	Sediment type	Sand or silt
	Detrital algae abundance	Common, Occasional, Rare

Both volunteer citizen divers and professional scientific divers collected YOY and habitat data throughout the survey area during all months of the year from 2015-24. For the purposes of this report, data from these two surveyor categories were treated uniformly as the methodology was designed for divers of various scientific backgrounds. While no formal training was provided to citizen divers, each participant in the program was vetted for fish and habitat identification competence by an experienced surveyor. This process involved a survey dive where participants would locate and accurately identify YOY to the more experienced surveyor as well as show methodological proficiency. Training materials are also available online for review (https://www.pauamarineresearch.com/resources-publications) and project leads deliver regular presentations to interested participants, both to engage new surveyors and update active participants about protocol changes, analytical findings, and additional survey opportunities.

Effort

The large expanse of the Salish Sea and temporal variability of rockfish recruitment necessitate heavy survey demands to separate trends from noise. This issue is ubiquitous in ecology and spatial monitoring of populations, and this program was created with full knowledge that engagement of many partners would be necessary to maximize data utility. Fish population assessment parameters are often not discussed in terms of required sample sizes for estimation, rather improved precision with higher data inputs (Kritzer et al. 2001). That is, no endpoint or optimum survey effort exists to create a utopian dataset. Expanding survey area may give the impression of worse performance because of increased variability associated with the broader geographic and/or temporal scope.

The rockfish survey program has increased sampling effort across all basins (**Figure 1**), in collaboration with partners (see **Appendix 1**; **Figure 2**), while progressively evening data collection across basins (**Figure 3**). Distributing effort more evenly over time is equally important to increasing annual survey time, with regard to increasing statistical rigor and understanding of spatiotemporal recruitment patterns. The Salish Sea is incredibly diverse across basins in physical and chemical aspects (Sutherland et al. 2011) and fish assemblages (Pietsch and Orr 2015; Blaine et al. 2020; Lowry et al. 2022). Heightened

effort in only a single basin would likely reduce variability in recruitment success estimates but increase bias when attempting to make inferences to the entire Salish Sea.

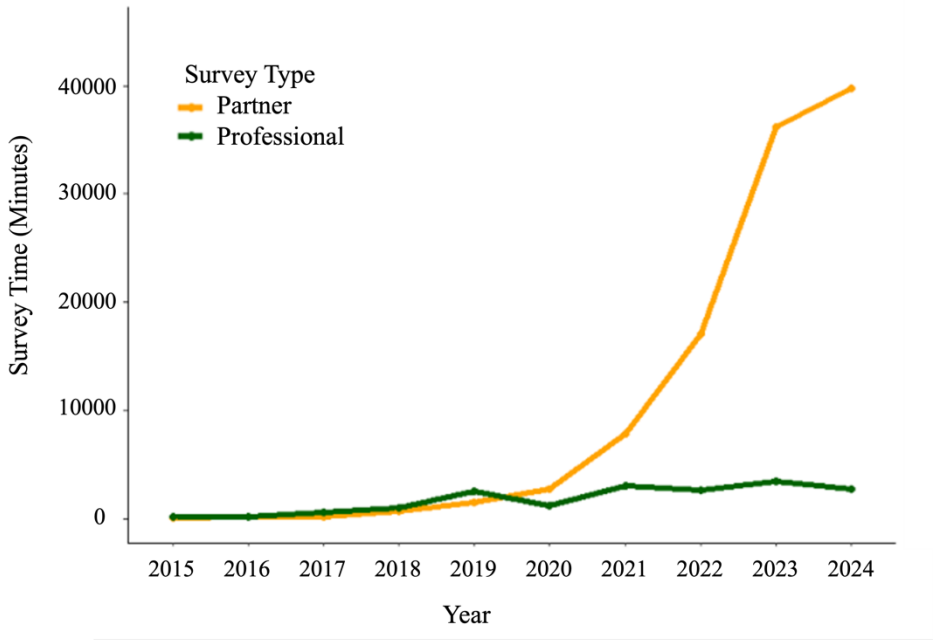


Figure 2. Survey effort over time by partner organizations and project leads

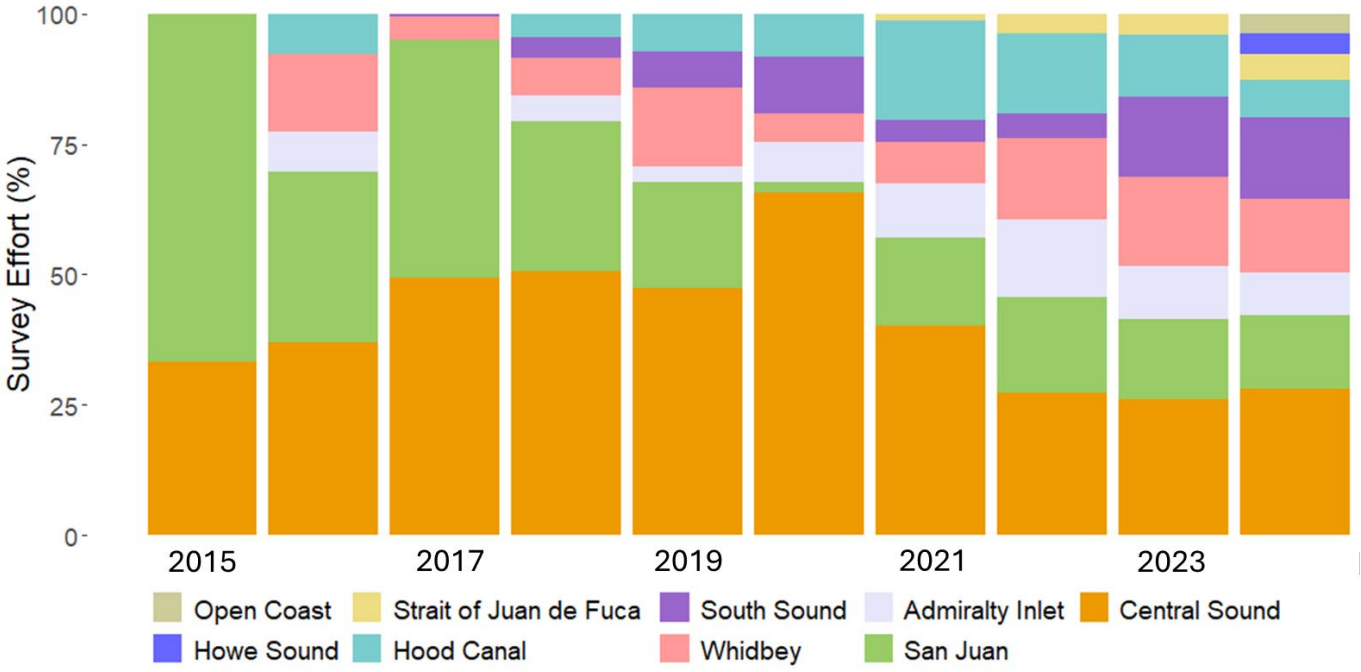


Figure 3. Relative survey effort across basins over time

General Spatiotemporal Results

Since program inception, a total of 26,875 YOY rockfish have been recorded across the study area. Approximately 33.1% of these YOY were deep body/no spot, 37.8% were elongate/dorsal spot, 28.5% were elongate body/no dorsal spot, and only a small handful (0.6%) were deep body/dorsal spot. Not explicitly accounting for variation in sampling effort, but looking at relative occurrence of morphological categories, rockfish assemblages vary substantially across basins within the Salish Sea (**Figure 4**). South Sound, Central Sound, and Hood Canal are dominated by deep body/no dorsal spot YOY, while the Admiralty Inlet and San Juan basins are more likely to contain elongate/dorsal spot and elongate/no dorsal spot YOY.

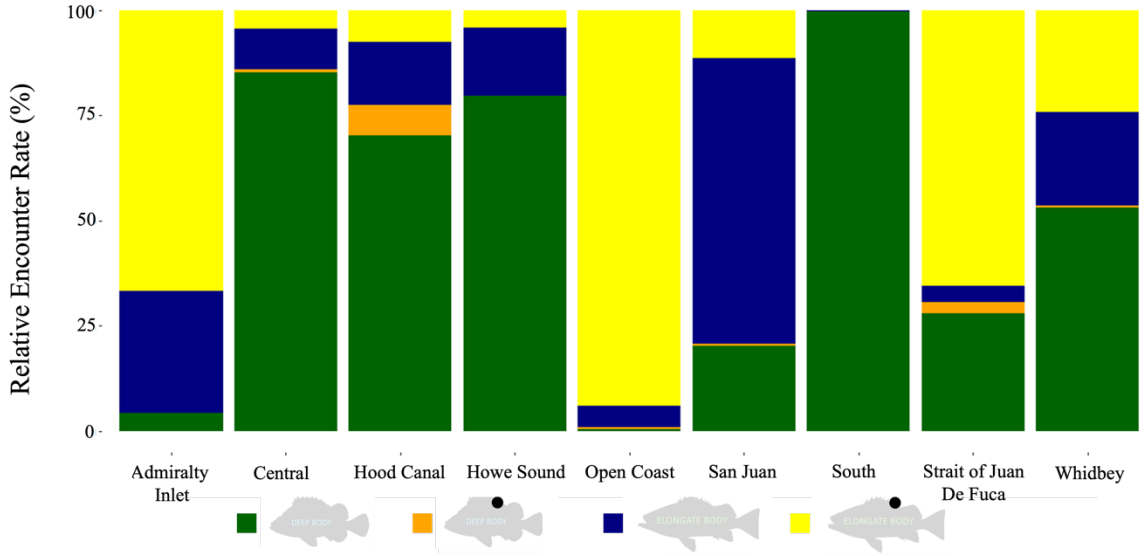
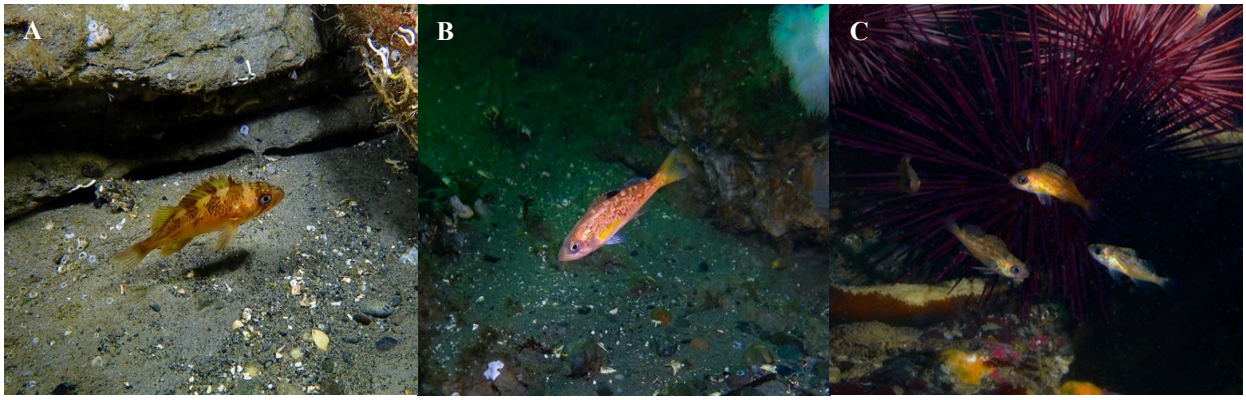


Figure 4. Relative encounter rate of each morphological type across all basins



South and Central Sound and Hood Canal are dominated by deep body/no dorsal spot YOY(A), while Admiralty Inlet and the San Juan basins are more likely to contain elongate/dorsal spot (B) and elongate no dorsal spot YOY (C)

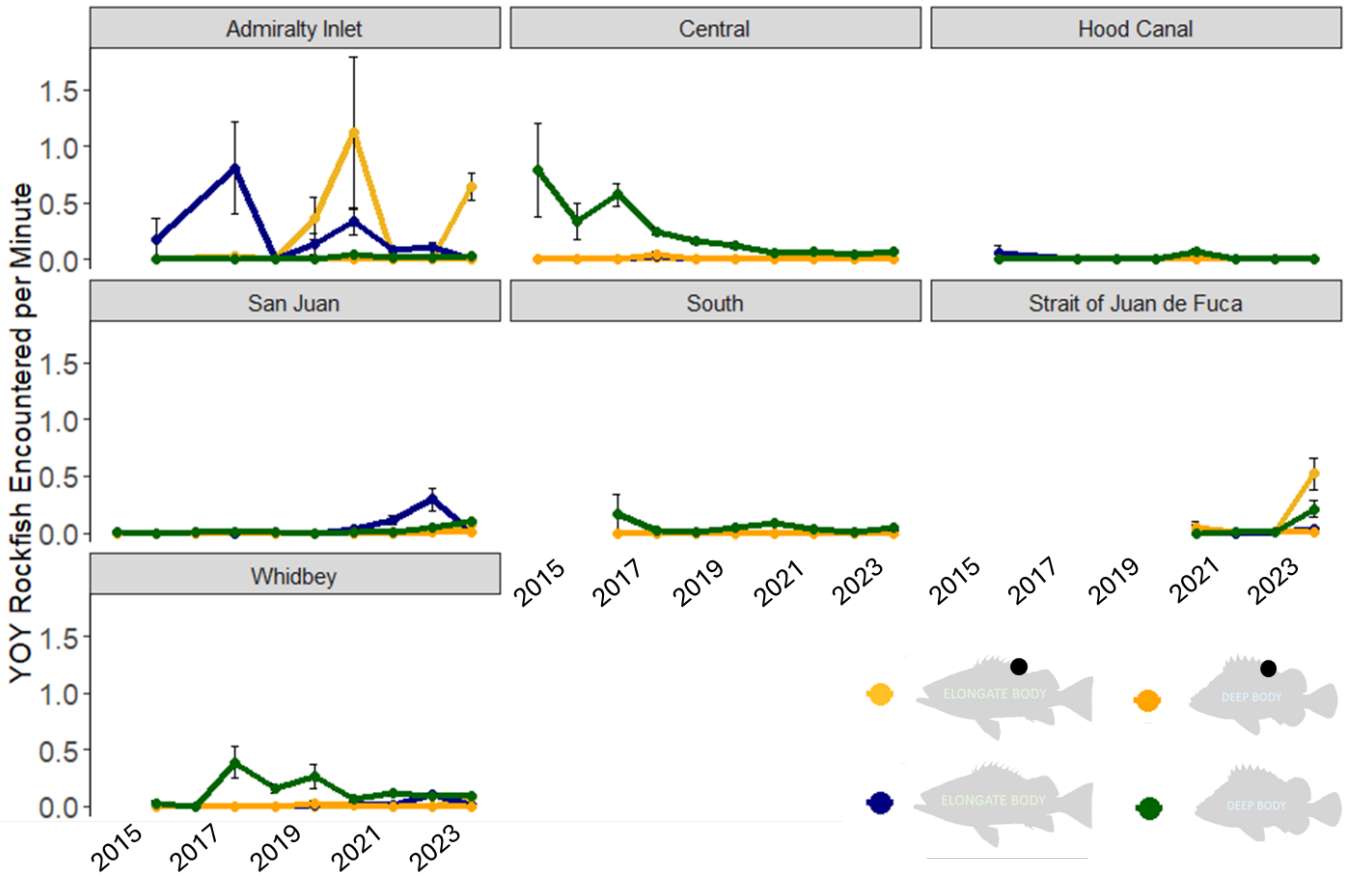


Figure 5. Encounter rate averaged annually across all sites by morphological group and basin

Survey effort began with a focus on Central Sound and the San Juan Islands and expanded into additional basins in subsequent years. One would expect YOY encounters to change along with the wider geographic scope. **Figure 5** depicts higher encounters of deep body/no dorsal spot in Central and Whidbey basins that decline in more recent years, while elongate/dorsal spot and elongate/no dorsal spot depict two peaks in 2021 and 2024 in Admiralty Inlet and the Strait of Juan de Fuca (and to a lesser extent in San Juan). Higher variability as illustrated by larger error bars occurs when encounter rates at either specific sites or portions of a year dramatically differ. The two most likely causes are either low effort or a short-term spike indicative of a jackpot recruitment event. Early deep body/no dorsal spot encounters in Central basin are likely from low effort, while elongate body/dorsal spot in 2021 in Admiralty Inlet is more likely a boom event. Elongate/no dorsal spot YOY appeared to have two relatively strong recruitment classes in 2022 and 2023. These results do not mean data from early years of the program are without value, they are still accurate site-specific records of recruitment. But the changes in effort along with survey results suggest a more powerful dataset over time.

Coarse results may still provide useful information. Hood Canal and South Sound demonstrate consistently low recruitment, Admiralty Inlet and the Strait of Juan de Fuca are more variable, while Whidbey and Central Sound have greater amounts of deep body/no dorsal spot YOY, but less in other morphological groups. San Juan is unique in that encounter rate appears to be increasing over time for multiple morphological groups. The more commonly encountered deep body/no dorsal spot YOY have not exhibited the boom-and-bust recruitment cycles of other morphological groups. These data create fertile ground for assessing life history strategy and influence of oceanic factors in these differing

recruitment patterns. Basins closer to the Pacific Ocean appear to yield the former recruitment patterns while basins with more muted flow contain more deep body/no dorsal spot YOY that demonstrate steady recruitment patterns. Alternatively, deep body/no dorsal spot YOY may experience recruitment booms at longer time steps than have currently been reached by this program.

Yelloweye (*S. ruberrimus*) Recruitment

Recruitment data on ESA-listed bocaccio and yelloweye rockfish in the southern Salish Sea underpins the entire survey program. Encounters with these species are exceedingly rare, as would be expected following an ESA listing. Using other rockfish species found in the region as indicators of their recruitment is useful (Field et al. 2021), particularly because encounters of ESA listed species will lack power for robust analyses (NMFS 2017). The anatomy and physiology of early juvenile life phases of rockfishes are comparable across species, such that the impacts of biophysical recruitment drivers like wind intensity, prevailing wind direction, water temperature, pH, predation, and planktonic prey availability are assumed to be similar across all species in a given locality. Encounters of bocaccio and yelloweye rockfish should be carefully reviewed to adapt survey effort and inform recovery progress.

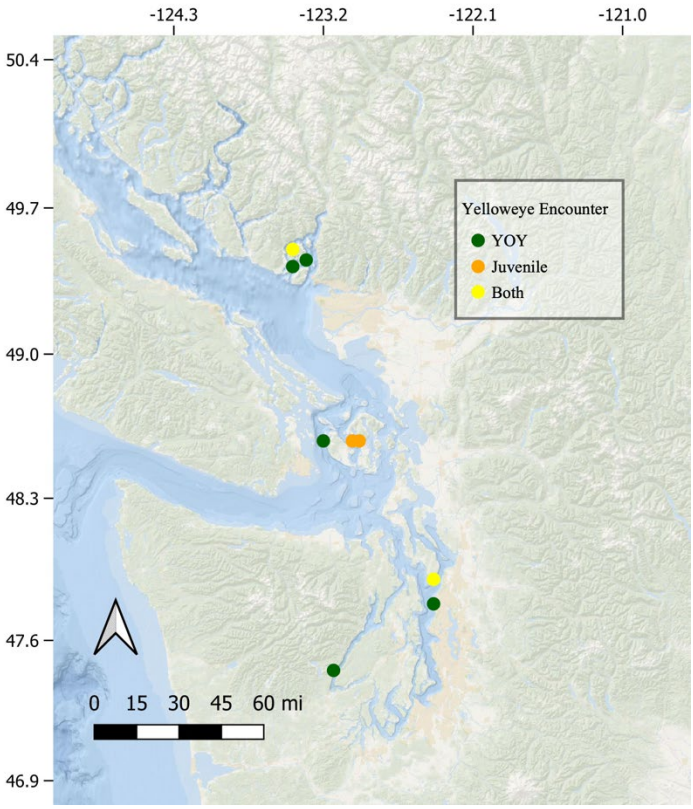


Figure 6. Map of yelloweye encounters. Note that Howe Sound points are randomly assigned across space to deter poaching

To the writing of this report, no YOY bocaccio have been recorded during the entirety of surveys in the Salish Sea. Twenty-five yelloweye rockfish have been recorded, where seven are juvenile, 18 are YOY, and none are adults. Yelloweye recruits often settle in deeper reef habitat that is near the limits of scientific and recreational diving (Yamanaka et al. 2006). Yelloweye have been documented at nine sites across five basins: one in Hood Canal, three in San Juan, one in Central, one in Whidbey, and three in Howe Sound (**Figure 6**). A single individual was found on an artificial reef, but the remainder were found either on natural reefs or in association with sponge garden. Seven YOY were found in intermediate depth bins, 11 YOY and all juveniles were in deep habitat. Encounters are increasing over time (**Figure 7**), but this trend is likely biased by spatiotemporal variation in sampling. These data do not include survey effort, though a simple review of **Figure 2** will indicate correlation between overall survey effort and yelloweye rockfish encounters. Several sites have supported yelloweye over multiple years. That coupled with encouraging samplers to be extra diligent when surveying those sites and it is almost certain that the totals reported above actually include repeat observations. Accounting for such repeat sampling, we estimate that 18 unique individuals have been identified at the nine sites in **Figure 6**. While effort increased in the San Juans, yelloweye were identified at two sites that have been surveyed for many years as part of this program. A charter vessel brought partner divers to the region in the summer of 2024 where dives were coincidentally conducted in

areas of regular effort. This result lends credence to value in multiple observers and consistent monitoring sites. Howe Sound was surveyed for the first time in 2024, and that basin is richer in yelloweye than any other sampled to date in the Salish Sea. The larger message from these findings is that while recent observations may not signal imminent recovery, they do denote additional sites for close monitoring that may provide data to evaluate temporal recruitment dynamics, the value of partner participation in finding these rare individuals and information on spatial coverage as well as habitat use.

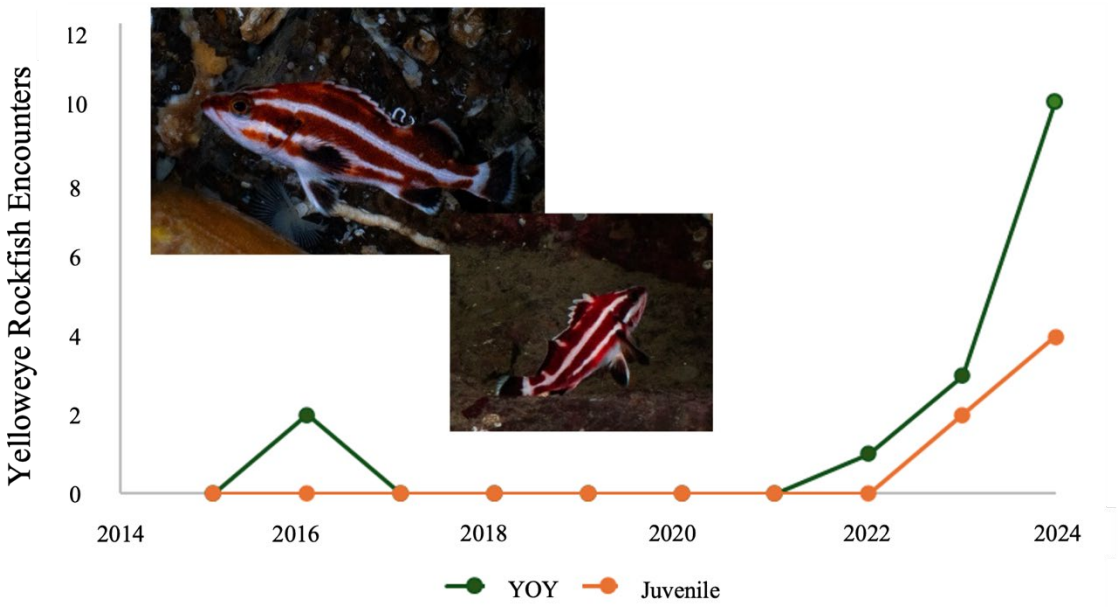


Figure 7. Yelloweye rockfish encounters by life stage over time throughout program

Habitat and Depth Trends

Previous sections of this report have documented the complicated relationship between rockfish recruitment, space, and time. Layering habitat and depth information on top of this introduces additional complexity and reduces strata-specific sample size, but broad trends are notable and applicable to management actions. A simple summary view of recruitment by habitat type across morphological groups is indicative of that tendency (**Figure 8**). Natural reef appears to be the most valuable recruitment habitat across all morphological groups, particularly for elongate body/no dorsal spot species (e.g., Puget Sound rockfish, yelloweye rockfish). If those few sites with exceedingly high encounters for that morphological group are briefly set aside, it appears kelp forests and artificial reefs are equally suitable to natural reefs, with eelgrass, soft bottom, and sponge gardens less so. That conclusion somewhat defies conventional wisdom and must be interpreted with caution. For example, sponge gardens are notorious for high levels of rockfish recruitment (Marliave et al. 2009) but are rare at depths reachable with SCUBA in the southern Salish Sea. This habitat has received far less survey effort than others, as it was only surveyed as part of this program for the first time in 2024, in Canadian waters. The small sample size is likely to skew results and additional years of effort will clarify the importance of this habitat type during rockfish early life stages. Eelgrass provides a more instructive example, as the literature is also replete with examples of YOY rockfish recruiting to these shallow, comparatively structurally complex habitats (e.g., Studebaker and Mulligan 2009; Markel et al. 2017). The majority of eelgrass sites in **Figure 8** had no YOY rockfish documented in them. Given that 4,322 minutes have been spent surveying these sites (far greater than the 50 minutes total in sponge gardens, but considerably less than the 45,069 minutes on natural reefs and 38,332 minutes on artificial reefs), these data are far more likely to accurately depict actual usage by YOY. A closer look at YOY rockfish relationship with time and eelgrass (**Figure 9**) shows that late

summer and fall are peak encounter time, mirroring peak eelgrass biomass (Thom and Albright 1990). Though not illustrated in this report, seasonal encounter rates are not as pronounced in natural and artificial reefs, which may be in part because cover is more consistently available in those habitats than eelgrass. One would expect kelp forests to illustrate a similar dynamic, except sampling in kelp forests during winter months is often impossible as they may completely disappear during low-growth months, making that comparison both more and less complicated. The recruitment relationship is less tight over space, as sites in five basins (San Juan, Central, South, Whidbey, and Strait of Juan de Fuca) have supported YOY rockfish. Synthesizing this information, eelgrass beds are likely to support rockfish recruitment during a narrow four-month window, at a minority of sites across a wide geographic range in the Salish Sea. Further research is encouraged to determine what traits are shared among these eelgrass beds that support recruitment. Habitat relationships and rockfish recruitment are complicated, but the sustained effort provided by this program is able to narrow in on specific trends that may be useful during management applications, such as the refinement of critical habitat designation criteria established in 2014 (79 FR 68042).

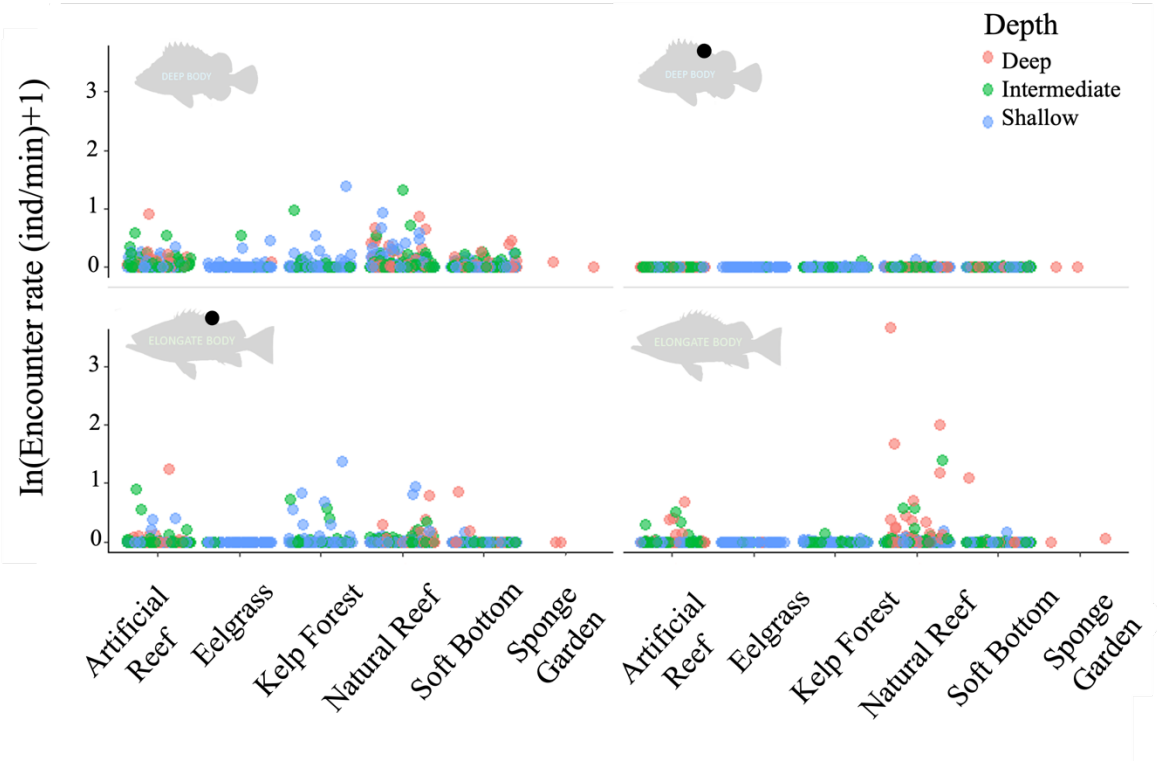


Figure 8. Log transformed rockfish encounter rate by habitat, depth bin and morphological group. Each point is the average encounter rate by depth and habitat type for each site from duration of program.

Videos documenting rockfishes from remotely operated vehicles maneuvering through dark environments may give the impression that encounters will increase the further one departs from the tide line. That may be true for some species, but those most commonly found in standard scientific dive depths do not exhibit that pattern (**Figure 8**). Most notably, elongate/dorsal spot (yellowtail and black) and deep body/no dorsal spot (copper, brown and quillback) illustrate a preference for shallow (< 21 feet)

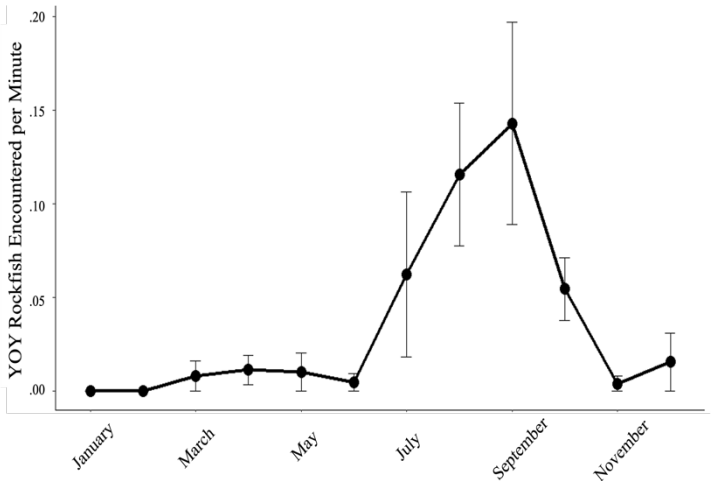


Figure 9. Total YOY rockfish encounter rate by month in eelgrass habitats across all survey years

habitats, and elongate/no dorsal spot (Puget Sound and yelloweye) for deeper (> 60 feet). The drivers for this trend may be multifaceted and possibly related to presence of macroalgae, competition, predator avoidance, etc. Assigning causation is beyond the scope of this report, but the existence of the trend is compelling. Rockfish recruitment often happens in shallow water (< 21 feet) and that finding has numerous implications for restoration activities and stressor avoidance.

Basin-specific Spatial Trends

That basins across the Salish Sea exhibit different rockfish recruitment dynamics is expected given numerous physical and biological factors that drive habitat suitability and larval drift patterns over such a large area (Andrews et al. 2021). Coarse differences in morphological group composition across basins supporting that notion are shown in **Figure 4** above, and the geographic influence on adults is discussed below. When overall YOY encounter rate is examined across years by basin several distinct patterns are apparent: encounter rates are highly variable in Admiralty Inlet and the Strait of Juan de Fuca; encounters in San Juan have been increasing; and encounters in Central, Hood Canal, and South have been relatively stable (**Figure 10**). The higher relative encounter rates of elongate/dorsal spot YOY in basins with wide encounter rate swings follows logically as those species appear to exhibit a near all or nothing recruitment (**Figure 5**). Of note is that in no basin, with the exception of Central Sound, was a declining trend in recruitment observed. High Central Sound encounter rates in early years of the program are likely from lower survey effort and subsequent small survey footprint; wide error bars reinforce that assessment (hence this basin is considered stable and not declining). That conclusion, however, may be a tautology, with any declines explained away as resulting from survey effort and not true declines. The takeaway from **Figure 11** should be superficial as the analysis was not robust to variable effort and other factors. Encounter rates were also near zero and, with little room to decline, in Hood Canal and South Sound. The across-basin encounter rates are variable,

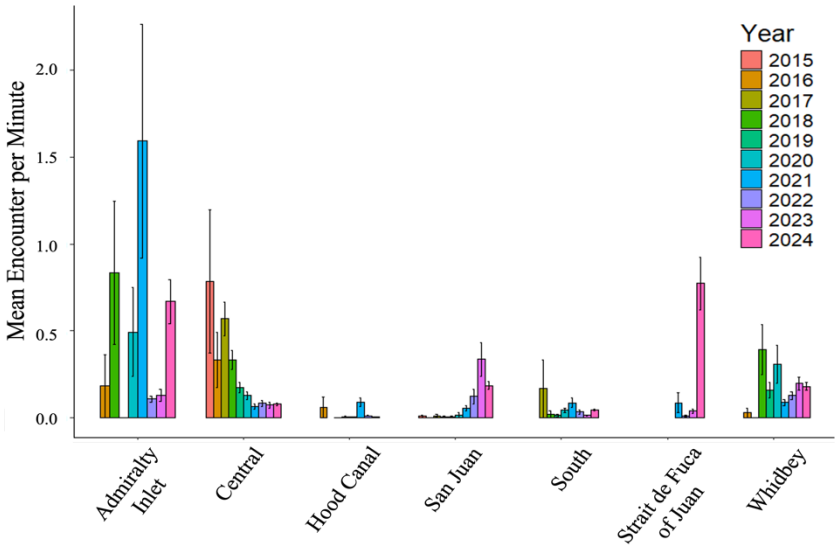


Figure 10. Mean annual encounter rate by basin for all morphological groups

likely affected by morphological group composition, and may present some positive news for rockfish recovery given episodic evidence of recruitment pulses across a wide geography.

Encounter rate does not appear to substantially differ over months across basins (**Figure 11)**. Several peaks with greater variability are evident in the regions, with more elongate body/dorsal spot encounters driven by single years with large recruitment events, but no obvious broad trends are visible. Taken along with **Figure 10**, these data suggest basins exhibit variable trends in encounter rate, but those differences are not manifested at any specific time of year. A closer look at the 2024 boom event for the elongate body/dorsal spot morphological group over space and time **(Figure 12)** compared with deep body/no dorsal spot (**Figure 13**) clarifies that point. Elongate body/dorsal spot YOY were not present for the first four months of the year and only became abundant in July. Their abundance was in closer proximity to the Strait of Juan de Fuca, Admiralty Inlet, and the San Juan Islands. Deep body/no dorsal spot species were present throughout the year, with less obvious spatial/temporal patterning, save for lower encounters in late spring. The story of rockfish recruitment in the Salish Sea is intricate: time and space *both* matter, but their influence is often mediated by species complex and short and long time steps.

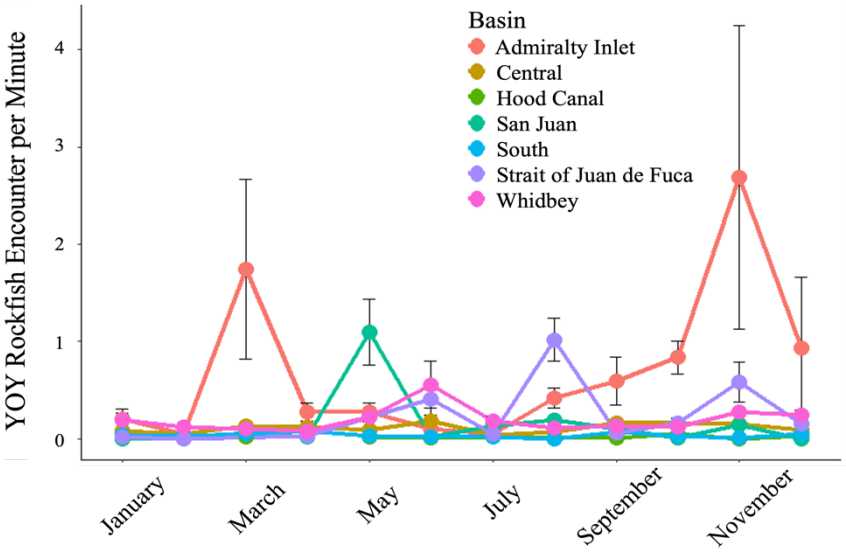


Figure 11. Mean monthly encounter rate across the entire study for all morphological groups

Elongate body/dorsal spot recruits and juveniles during a boom event

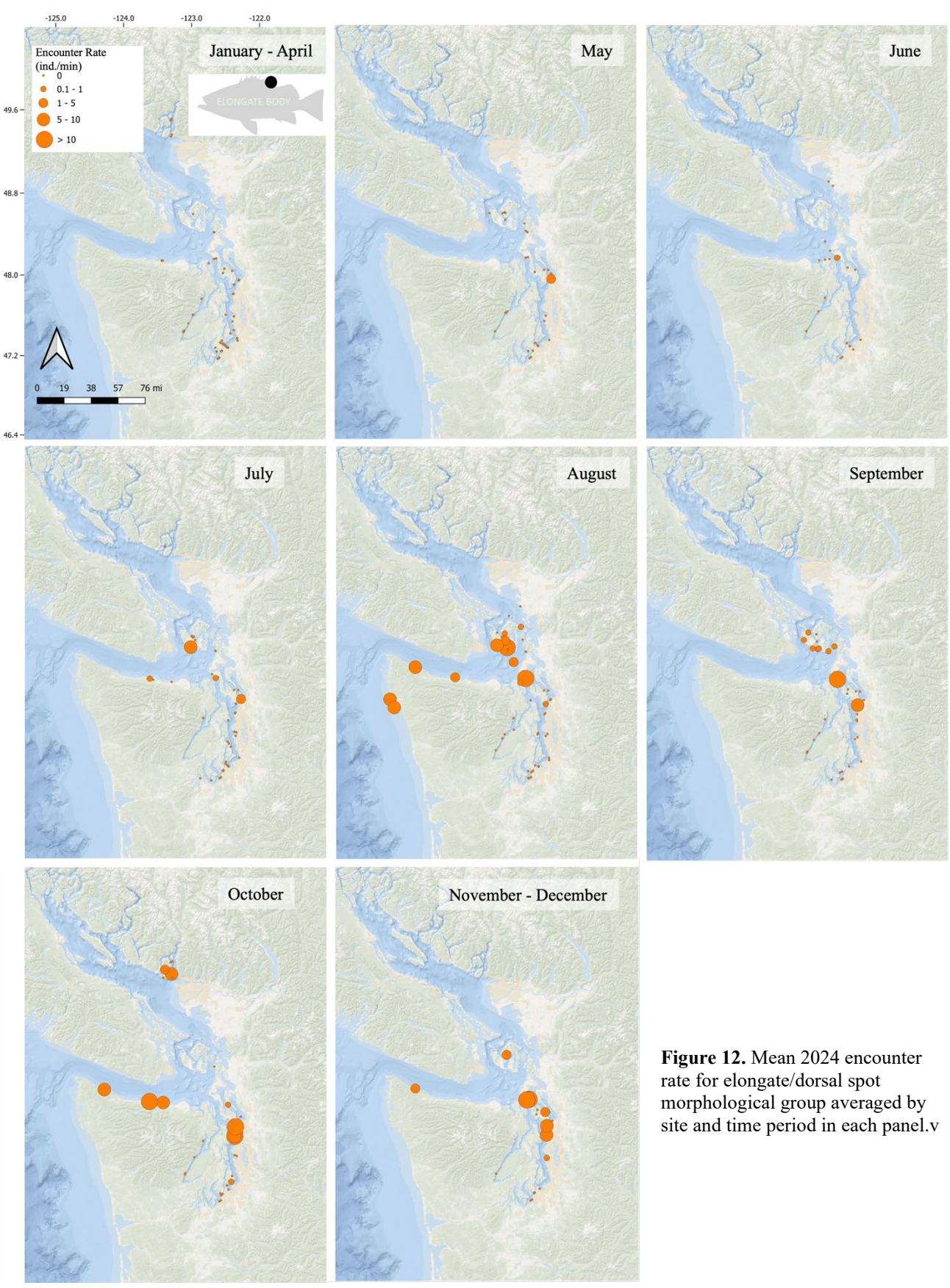


Figure 12. Mean 2024 encounter rate for elongate/dorsal spot morphological group averaged by site and time period in each panel.v

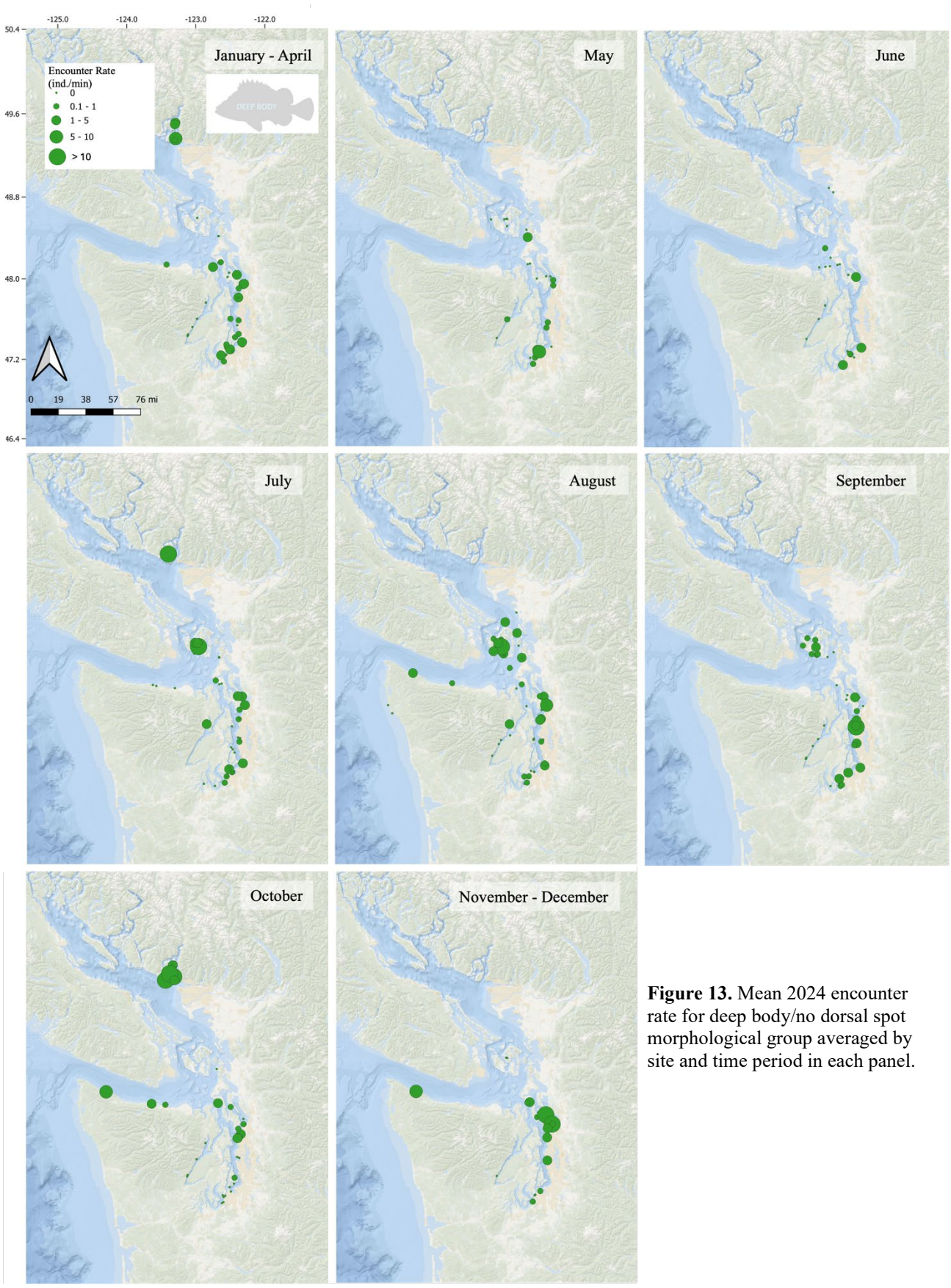


Figure 13. Mean 2024 encounter rate for deep body/no dorsal spot morphological group averaged by site and time period in each panel.

Diel Activity

Sampling fish distribution through time and space is complicated, and no method is free from bias that may skew results. In addition to appropriately caveating results, steps should be taken to quantify bias and correct for it where possible. Variable diel patterns, or the changes in likelihood of encountering a YOY rockfish during day or night periods, are one such source of potential bias. With generous support from The SeaDoc Society and partnership with Harbor WildWatch, visual surveys from 34 dives and 368 transects (184 for each diel period) were compared across the same habitat during day and night hours. In addition, 41 time lapse camera deployments were completed (stationary cameras took an image every 10 minutes over multiple days) over 275 days and twelve sites (**Figure 14**). These deployments resulted in over 40,000 images that were processed using an Access database to record presence and location of rockfishes relative to substrate across day and night periods. Cameras were generously loaned from the Washington Department of Fish and Wildlife.

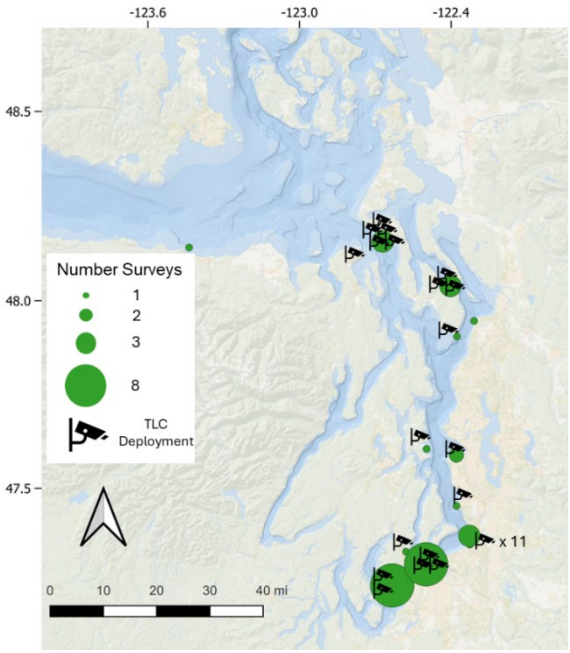


Figure 14. Map of diel survey dives and time lapse deployments during this study

Only deep body/no dorsal spot YOY exhibited significant difference across diel periods in SCUBA surveys (**Figure 15**). Mean daytime encounter rate was 0.14 individuals/minute, while nighttime was 0.29 individuals/minute, or almost double the encounter rate at night. Though elongate body/dorsal spot comprised the majority of YOY encountered during the study, resulting from the boom recruitment event in 2024, they were recorded during only two dives. As dive was the unit of replication for statistical testing, power of the test was limited. Anecdotal evidence suggested that elongate body/dorsal spot YOY shifted to shallower habitat at night. Time lapse imagery did not show a significant difference in YOY encounter rate for deep body/no dorsal spot, an interesting result given that it runs counter to SCUBA data. Elongate body/dorsal spot individuals were more frequently recorded during the daytime, with slightly lower encounters at dawn and dusk (defined as the hour on either side of sunrise and sunset, respectively. Assigned using the suncalc package in R), and nearly no encounters during the night. This result is consistent with anecdotal diver observation of YOY moving into shallower water at night. Results from this study will allow more accurate quantification of data from dives that occur at night, as may be the only option for partners during limited daytime hours during the winter.

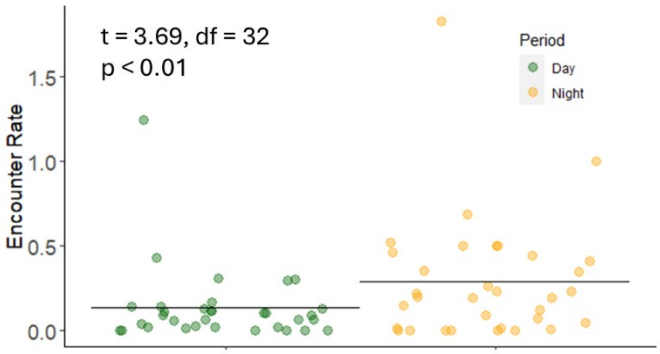


Figure 15. Comparison of deep body/no dorsal spot YOY encounter across day and night periods. Each point is the average across all transects for a single dive.

Sunflower Sea Star, Lingcod and Adult Rockfishes

Though this report documents substantial survey effort focused on rockfish recruitment, the same survey methods and pool of participants have been used to collect data on adult rockfish and other species as well. Occurrence data for the sunflower sea star, lingcod, and adult rockfish are briefly explored here to provide ecological context to the YOY patterns described above. Addition of these supplemental species to the survey program was not random. Adult rockfishes often inhabit similar habitats as recruits, for many rockfish species, and monitoring over time will add a critical demographic piece for recovery efforts. Lingcod are known to prey upon rockfish recruits, as well as adults of some species (e.g., Puget Sound rockfish). Sunflower sea star populations dropped dramatically in the mid-2010s following a wasting disease pandemic and are now proposed for ESA listing (Hewson et al. 2024; Gravem et al. 2021; Lowry et al. 2022; 88 FR 16212). Though this program has provided invaluable data on rockfish recruitment, it is adaptable to various species that can improve best available science for various management applications.

Sunflower sea star, as with all the additional documented species in this section, were only recorded on a subset of transects. Since their addition to the monitoring regime in 2022, 1,398 individuals were documented over 2,924 transects and 36,039.5 minutes of survey time. An overview of sunflower sea star encounter rate documents two primary trends regarding basin and habitat (**Figure 14**). The first is that sunflower sea star are rarely encountered outside of Hood Canal, Whidbey Basin, and the Strait of Juan de Fuca. Those basins are not contiguous, suggesting remaining sunflower stars are not holed up in a single suitable stronghold. Individuals are more frequently encountered in eelgrass and soft bottom habitats. That result is notable because while they are known to be habitat generalists (Gravem et al. 2021; Lowry et al. 2022), and much research has focused on impacts of their loss to rocky reef and/or kelp communities (Burt et al. 2018; McPherson et al. 2021; Galloway et al. 2023; Tolimieri et al. 2023). Our data show that there is a remaining population in the Salish Sea, and restoration efforts should be sure to incorporate eelgrass and soft bottom habitat.

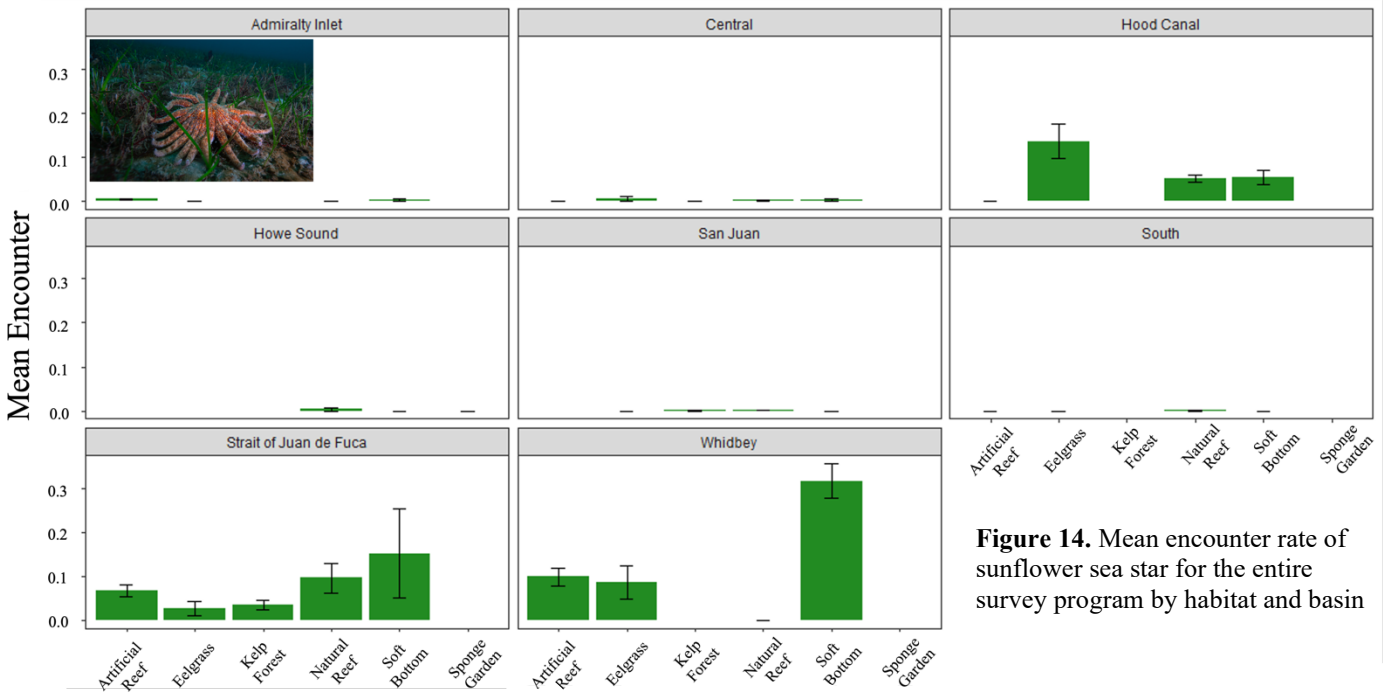


Figure 14. Mean encounter rate of sunflower sea star for the entire survey program by habitat and basin

Lingcod and adult rockfishes prey upon YOY rockfishes. Encounter data presented in **Figure 8** suggest a depth gradient for several morphological groups, and it is possible predation drives that relationship. Inclusion of lingcod and all adult rockfish encounter rate shows a possible inverse relationship for those predators and the elongate body/dorsal spot morphological group (**Figure 15**). Deep body/no dorsal spot YOY encounters do not appear to show a depth gradient, and elongate body/no dorsal spot exhibit the opposite trend, where their encounters are greater at depth. Because elongate body/no dorsal spot YOY showed the same depth gradient as predators, further investigation into temporal variability showed a weak temporal difference where YOY were more abundant in several springs, when adult rockfishes were less frequently encountered (**Figure 16**). Lingcod did not appear to change across seasons. These data are not sufficient to show causation: the encounter changes by depth gradients or month may be the result of predation, thermal tolerances of one or more species, linked with fishing pressure, or affected by a variety of other environmental and biological drivers. But that distinction may not be important for management purposes. Rockfish recruitment may vary by depth or time, and further investigation (particularly geographically) may refine relationships between recruits and predators. This exercise is only one application of adult and lingcod data, that have myriad other uses.

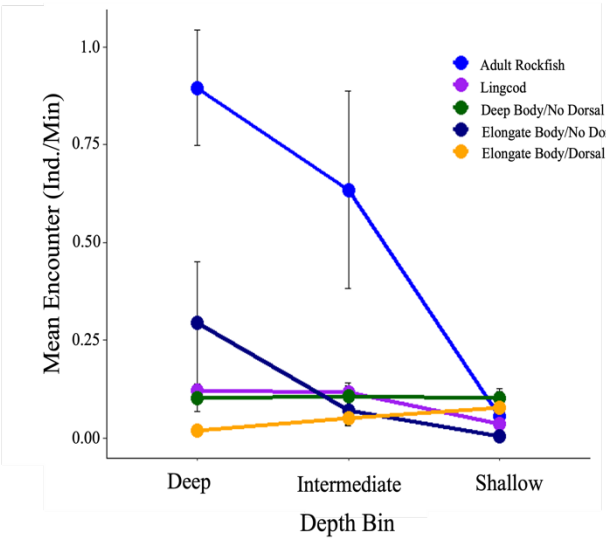


Figure 15. Mean encounter rate of three YOY morphological groups, lingcod, and adult rockfishes by depth bin for all sites across the entire program. Depth bins are defined as: Deep > 60 feet, Intermediate 21-60 feet, and Shallow < 21 feet

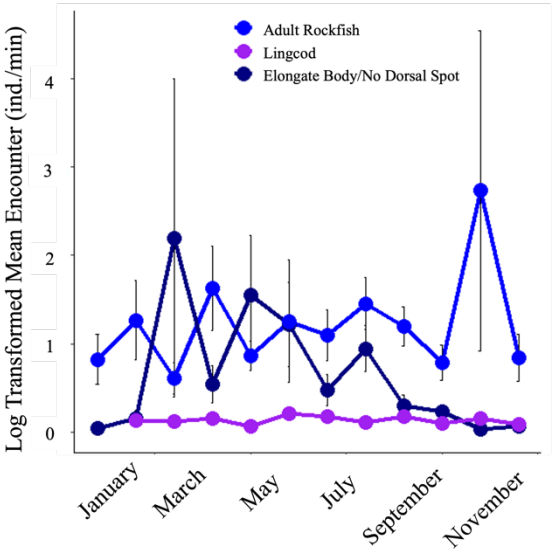


Figure 16. Log transformed encounter rate of elongate body/no dorsal spot YOY, lingcod, and adult rockfishes by month. YOY data were only included from sites where elongate body/no dorsal spot YOY were encountered

Conclusions

The YOY rockfish program has grown substantially over its ten-year existence. Data applications for recruitment patterns and linkages to select other species are expanding. This report overviews some of those applications and presents broad trends worthy of deeper investigation with suitable quantitative vigor. For example, the database is now sufficient to illustrate changes based on predictor variables, such as habitat, region, depth, and predator abundance. More ESA listed species have also been found in recent years, suggesting either improvement in search capability or increased abundance. Either option is positive. The information collected for this program is integral to both guiding and documenting recovery. Continued spatial growth coupled with maintained effort in the southern Salish Sea are necessary to improve utility. Deeper investigation of specific aspects of this database, as outlined in this document, is a necessary next step. Climatic and oceanic data have also not yet been integrated as factors that may influence recruitment. Benefits and motivations of partners also bear greater exploration. An economic valuation of the data collected would quantify commitment of partners to recovery, and further investigation into motivations would guide outreach. After ten years, the power of these data are only beginning to be realized, and their value will increase with each additional year of surveys.

Acknowledgments

This work is a testament to all of the partners that have made this work a priority, and their role in rockfish recovery cannot be overstated.



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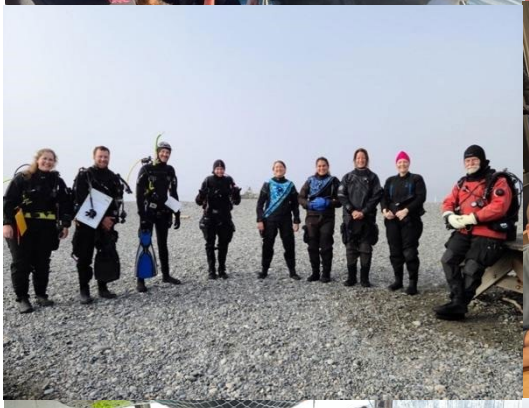




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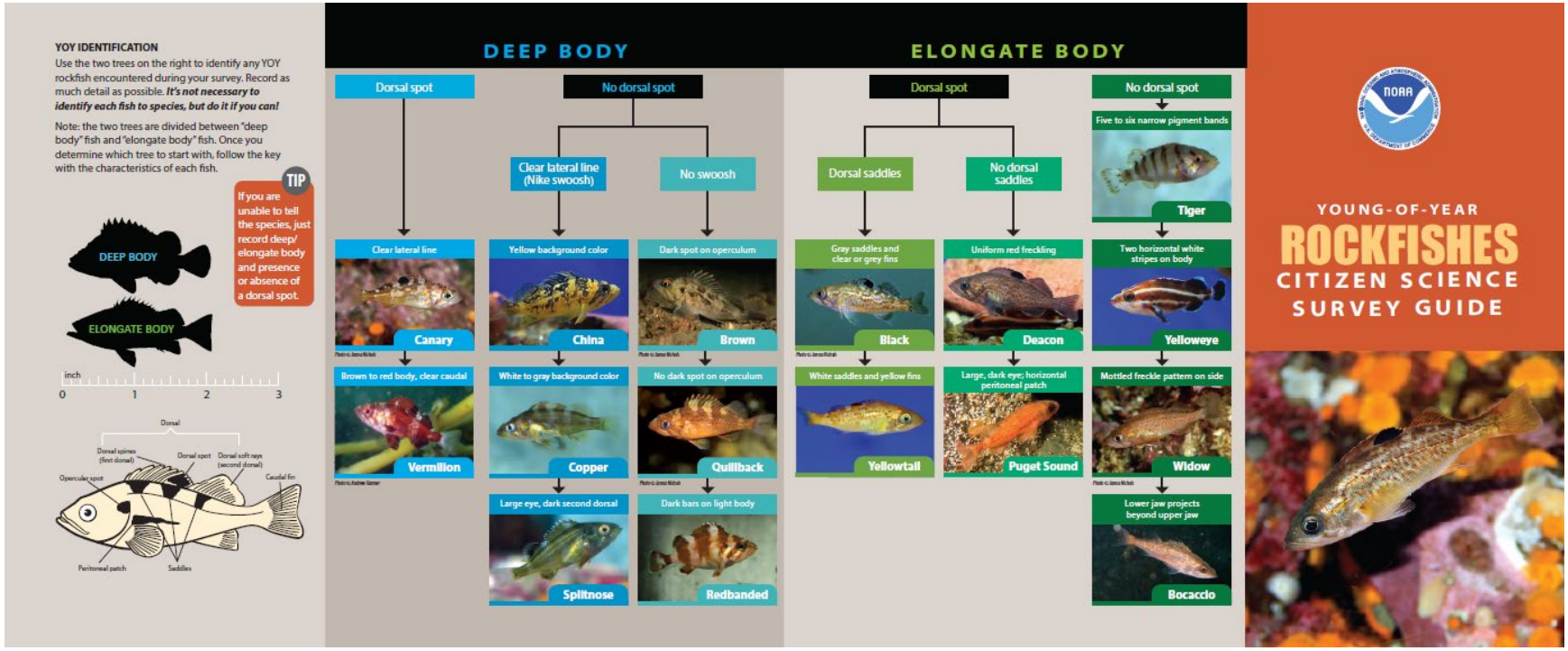
Appendix 1. Full list of partner organizations (Alphabetically Sorted)

- Aquarium of the Pacific
- Bottom Dweller Dive Club
- Department of Fisheries and Oceans
- Emerald Sea Dive Club
- Friends of Saltwater State Park
- Harbor WildWatch
- Lighthouse Diving Center
- Marine Life Sanctuaries Society
- Marker Buoy Dive Club
- Natural Resources Consultants
- NOAA Diving Center
- NOAA Fisheries
- Point Defiance Zoo and Aquarium
- Puget Sound Restoration Fund
- Reef Check Washington
- Samish Indian Nation
- Sound Water Stewards
- The SeaDoc Society
- University of British Columbia
- Washington Department of Fish and Wildlife

Appendix 2 – Map of basins.

Source https://en.wikipedia.org/wiki/South_Puget_Sound#/media/File:Map_pugetsound_with_border.png

Appendix 3 - NOAA Young-of-the-Year Rockfish Citizen Science Survey Guide



You can help save endangered rockfish!

NOAA is trying to learn about long-term trends in juvenile rockfish and needs the help of citizen divers to collect data.

You can help in one of two ways:

- Report any sightings of bocaccio, yelloweye or canary rockfish to **rockfishID@noaa.gov** and include picture, location and date information.
- Participate in the broader monitoring program outlined in this pamphlet and collect data during your regular dive trips in Puget Sound.

SAFETY FIRST! Participation is purely voluntary and not affiliated with the NOAA dive program.

SAMPLING METHOD:

Surveys are completed using a timed roving dive survey: Divers swim through a single habitat type and record young-of-year (YOY) rockfish by two morphological traits (body shape and dorsal spot presence/absence), basic habitat information and the survey duration.

A more detailed methods document and datasheets are available on the NOAA website at **westcoast.fisheries.noaa.gov/protected_species/rockfish/citizen_science_yoy_rockfish_photo.html**, or scan the QR code on the back.

SURVEY ZONE:
One habitat type and depth bin.

SURVEY PATH:
One meter on each side of swimming path and one meter off the substrate.

Share your results at rockfishID@noaa.gov

TIP

For surveys in kelp habitats that reach the surface, a survey should be run through the canopy (<2m from surface) for every survey along the bottom.

If kelp doesn't reach the surface, do a second survey at that depth.

ROCKY REEF SURVEY ZONE

Record the following data:

Relief:
- >3 feet, 1–3 feet, or <1 foot

Presence of bottom-growing kelp:
- Common, sparse or rare to non-existent

EELGRASS SURVEY ZONE

Record the following data:

Density:
- High (greater than 10 shoots/square foot)
- Medium (1–9 shoots/square foot)
- Low (< 1 shoots/square foot)

Approximate length of eelgrass in feet

SOFT BOTTOM SURVEY ZONE

Record the following data:

Sediment type:
- Sand, silt or shell gravel

KELP FOREST SURVEY ZONE

Record the following data:

Density per five–minute survey:
- High (> 100 stipes)
- Medium (20–100 stipes
- Low (<20 stipes)

Canopy height in feet

For information on reporting rockfish:

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ROCKFISH CONSERVATION
Bottom-up Recovery of Puget Sound