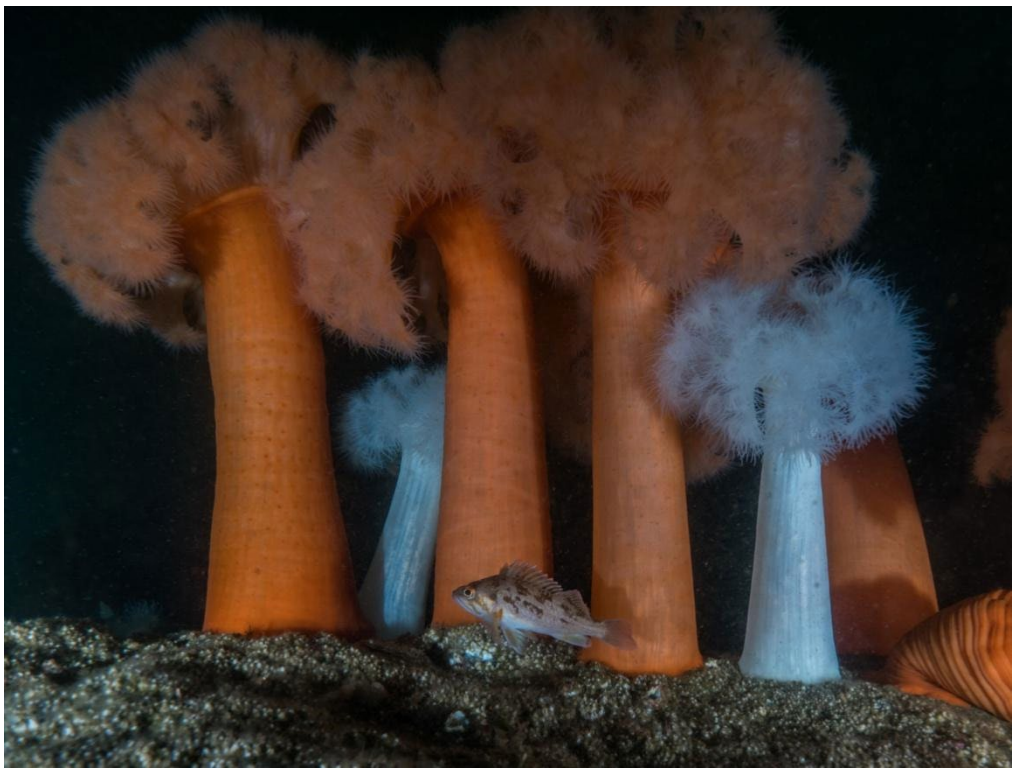
Results from Young-of-the-Year Rockfish Surveys in the southern Salish Sea 2015-2020



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Summary

Knowledge of rockfish recruitment dynamics and habitat utilization by recently settled rockfishes is valuable for developing appropriate fishery management and recovery actions. Until 2015, no survey effort sought the spatial and temporal data necessary to fill these gaps 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) rockfish. In this program, divers perform timed roving surveys in discrete habitat types, recording data on rockfish abundance in four morphological classes, as well as qualitative habitat data. Continued and focused outreach effort has led to increased survey participation over time, while better coordination and agency support has allowed for more frequent professional surveys. A new partnership has been established with Ocean Wise, which collects similar YOY data for the Strait of Georgia, allowing for a more complete analysis of recruitment in the Salish Sea. Data presented in this report quantify the impact of outreach on partner organization dive productivity and provide a preliminary evaluation of data consistency across partner groups. General trends in YOY encounter across basins, habitat types, and seasons are also explored, along with the influence of current on YOY encounter rates and a basic interpretation of whether 2020 was a jackpot recruitment year. The applications of these data are growing as partner participation spreads and additional years of data better define a baseline of YOY recruitment in Puget Sound and connected waters. After six years of program operation, it continues to grow and provide products that will be integral to recovering rockfish populations in the region.

Introduction

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 the United States and Canada, populations in 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). NOAA's National Marine Fisheries Service (NMFS) listed canary rockfish (*Sebastes pinniger*), yelloweye rockfish (*S. ruberrimus*), and bocaccio (*S. paucispinis)* 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 yelloweye rockfish and bocaccio was released in October of 2017 (NMFS 2017). An important action identified in the recovery plan is to better understand listed rockfish population abundance and habitat associations. Included under this action are annual surveys of young-of-the-year (YOY) rockfish throughout Puget Sound and connected waters of the Salish Sea. 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 shed additional light on recruitment dynamics in association with climatic, oceanic, and habitat variables, and help shape various management efforts.

Figure 1. Juvenile copper rockfish in eelgrass habitat in Puget Sound, WA.

Rockfish begin their life cycle as planktonic larvae that drift throughout pelagic habitat. After three to six months, they settle as juveniles into nearshore or benthic habitats. Juveniles are known to aggregate in areas of high rugosity or submerged aquatic vegetation, such as kelp and seagrass (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 can be developed to support stock assessments and habitat management.

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 young rockfish throughout Puget Sound. Engaging with 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 could support such an effort. Given the biology of rockfish, demonstrated effectiveness of citizen dive surveys, and pool of available divers, NMFS initiated a program to monitor YOY rockfish abundance throughout Puget Sound.

In 2014, a survey program was developed in response to the data requirements outlined in the draft recovery plan and the first data were collected in 2015. Methodology was drafted with input from multiple regional experts including the Washington Department of Fish and Wildlife, The Northwest Straits Initiative, the Seattle Aquarium, The SeaDoc Society, NOAA's Northwest Fisheries Science Center, 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 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 gratification of their contributions being on equal footing as professionals, but also presents unique data comparison opportunities as the database grows.

As the program has grown over time, the ability to address an expanding range of questions has developed. For example, Puget Sound and the Strait of Georgia are components of the larger Salish Sea Ecosystem (US Board on Geographic Names 2009; MacCready et al. 2020), as formally recognized by both the US and Canada, and to investigate only one of these regions will inevitably yield conclusions based on incomplete data. The need for coordination across borders to most effectively manage shared marine resources has long been recognized (Fraser et al. 2006). Ocean Wise, a research Institute in Vancouver, Canada, conducts a similar rockfish survey program in the Strait of Georgia. The methods align, as does the incorporation of data from citizen surveyors, making data comparable across regions. In order to better understand rockfish dynamics across the Salish Sea, Ocean Wise and NOAA agreed to collaborate on this project in 2020. Without continued growth of the program, this collaboration would not have been possible. Database expansion to date may also allow researchers to answer whether any given survey year is a jackpot for YOY recruitment. Identifying drivers of rockfish recruitment is a primary goal of this project and the first step is to quantitatively classify jackpot years.

This report serves to evaluate the survey program itself, along with the data it provides. Preliminary data on overall survey effort, participation of partner groups, along with the validity of the data they collect, are presented to assess the need for any changes in program implementation. Trends in YOY abundance,

comparison across regions, and, to the best of these data's capacity, determination as to whether 2020 was a jackpot year for rockfish recruitment, are also highlighted to provide the most up-to-date information on a key element for rockfish recovery in the Salish Sea.

Methods

Site Selection

Survey sites in Puget Sound were initially chosen for presence of suitable YOY habitat, ease of access, and popularity as regularly visited dive sites. This approach was adopted to encourage divers to consistently survey the same sites throughout the year and improve temporal coverage at select sites. Over time, as both citizen and professional diver survey effort increased, additional sites were added within each of five sub-basins (Central Sound, South Sound, Whidbey, San Juan Islands, and Hood Canal). 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 diversity of habitat types within each region known to support YOY, including kelp forests, eelgrass beds, rocky and artificial reefs, and other beneficial 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 may still be useful to include these sites to evaluate if YOY rockfish ever arrive in the case of a major recruitment event or changes in species distribution. Figure 2 identifies all sites within the southern Salish Sea surveyed from 2015 to 2020, with point size corresponding to annual effort and color to sub-basin surveyed.

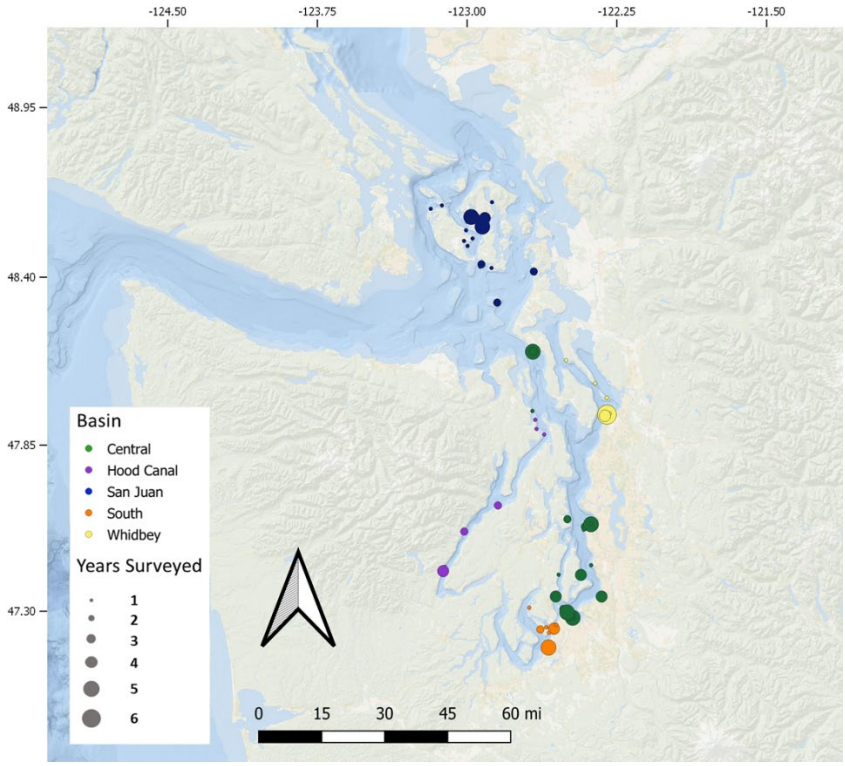

Figure 2. Young-of-year rockfish survey locations in the southern Salish Sea from 2015-2020. Point size indicates annual effort and color corresponds to basin.

Surveys

Surveyors collect data using a timed roving dive approach in discrete habitat and depth bins. 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/juvenile rockfish (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 2016-20 divers conducted transects of any length as long as novel habitat was still being searched. If habitat is patchy (i.e., areas of one habitat type are separated by a distinctly different habitat type), distinct patches are counted as separate surveys. If macroalgae or eelgrass are being surveyed, the diver lightly disturbs the vegetation to better expose individuals. If rocky substrate is present, the surveyor should use 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 1): 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.

As each survey is completed in an area dominated by a single habitat type, the sampler may record several categorical metrics to further describe each habitat type encountered (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 contained within one of three bins: shallow (<7m), intermediate (7-18m), and deep (>18m). Therefore, each survey will have an associated habitat type and depth bin.

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 2015-20. 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.

Data Analysis

Survey Effort, Fish, and Habitat

Survey effort, or the total bottom time expended actively searching for YOY, was evaluated at multiple levels. Survey times were summed for each year and evaluated by: 1) surveyor type (citizen or professional); 2) sub-basin; 3) habitat type; 4) month; and 5) region (Puget Sound and Strait of Georgia). The response variable of these surveys is encounter rate, calculated as the number of YOY observed per minute of survey time. Encounter rates were evaluated against several explanatory variables including, season (monthly), year, sub-basin, habitat type, depth bin, and morphological type (body shape and presence/absence of dorsal spot).

To assess an additional potential explanatory factor, encounter rates were compared with tidal current data. NOAA maintains a series of buoys in the survey area that collect data on current speed (https://tidesandcurrents.noaa.gov/noaacurrents/Stations?g=698). The absolute value of the mean maximum ebb current or mean maximum flood current were averaged across the entire year of 2020 to return a single current speed representative of relative tidal energy at each site. Buoys were selected by proximity to survey sites and are considered the best representation of tidal energy available. Current data calculated from the above were merged with the mean YOY encounter rate by site for all years combined. These data were then evaluated by sub-basin and habitat type.

Data Integration with Ocean Wise

Since 2005, the Ocean Wise Research Institute has led a citizen rockfish survey effort in the months from August to October. Data are collected by SCUBA divers swimming timed roving surveys. All recorded rockfish are identified to species and broken into age classes of adult (> 20 cm), juvenile (10-20 cm) and baby (< 10 cm). Results are split regionally; a total of twenty-eight survey regions stretch from British Columbia's central coast to Puget Sound and Washington's outer coast. Within the Salish Sea, twenty regions are identified on the Canadian side and four on the US side. Distinct habitat types and depth bins are not included as part of the survey, though surveys on soft bottom habitat are discouraged. Encounter rates are recorded as rockfish observed per survey hour.

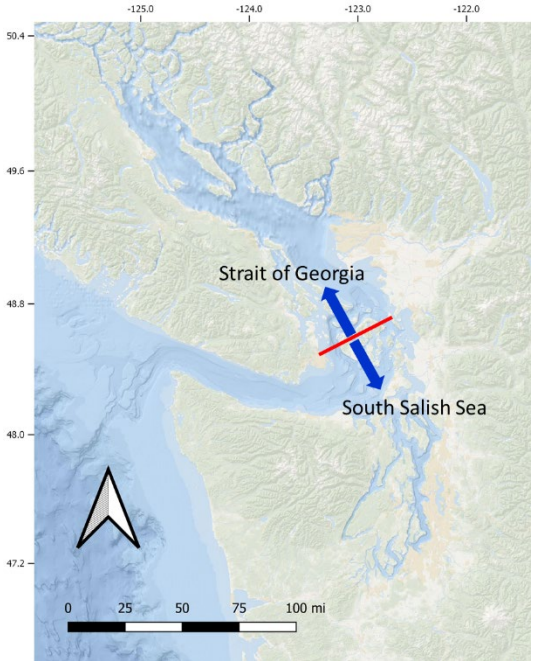

Figure 3. Delineation of survey effort between Ocean Wise in Strait of Georgia and NOAA in South Salish Sea

Because surveys by Ocean Wise and those in the present study return encounter rate as their response variable, data integration is mathematically straightforward. In order to standardize data, results from Ocean Wise were filtered to include only YOY rockfish and surveys from the Strait of Georgia, and their results were converted to YOY observed each minute. Also, species recorded by Ocean Wise were converted to morphological group. NOAA data were filtered to include only eelgrass, kelp forest, and reef habitats, as

well as only those surveys conducted during August through October (approximately 33% of transects). Years 2015 and 2016 of the NOAA data were excluded from comparison because low survey effort at the program's outset may bias results. Note, data filtering was conducted for comparison with Ocean Wise surveys only, and all other analyses in this report include the full complement of NOAA surveys. NOAA and Ocean Wise data were combined to examine survey effort and mean YOY encounter rates by region over time and encounter rates by morphological group.

Citizen Scientist Data Viability

During the 2019 and 2020 seasons, two new protocols were implemented to evaluate the accuracy of YOY identification and encounter rates using data collected by citizen surveyors. First, the lead project PI evaluated photos or videos of YOY shared by citizen divers. Each diver submitted media along with the identification and number of YOY in the photo/video. Where possible, the diver would identify to species, otherwise YOY were classified based on morphological type or simply as "YOY." Photos and identification data were assessed by the lead project PI for accuracy using a simple "Yes" or "No" classification scheme.

The second evaluation protocol involved a comparison among data collected by a team of professional divers and a separate team of citizen divers for surveys at the same site and on the same day. Because these events were rare, there were insufficient data to conduct a formal analysis, though a coarse comparison provided some useful information.

Influence of Outreach on Citizen Dive Effort

Outreach to partner groups in the form of presentations, guided dives, and meeting attendance was used to generate interest in program participation. Events performed for consistently participating groups were summed over each year and compared with the total dives each group completed in that year for 2015-19. Not included were emails, phone calls, and development of outreach materials. Those aspects of outreach take time and undeniably contribute to participation, but quantifying them is substantially more difficult as calls and emails were not logged and several prominent outreach materials were distributed in 2019, leaving too little time to analyze their effectiveness. The relationship between outreach and dive effort was quantified using a linear regression. Because project leads have noticed long-term relationships are also important in driving participation, a cumulative effort regression was also calculated.

Results

Survey Effort

Survey time increased annually in the south Salish Sea for both citizen and professional scientific divers, with the exception of 2020 for professional surveys, due to SARS-CoV2 Pandemic travel restrictions (Figure 4A). This trend in increased survey effort was consistent with the total number of transects completed, which increased from 185 in 2018 to 348 in 2019, with a small decrease to 335 in 2020. Effort data from Ocean Wise, which has been conducting rockfish surveys since 2005, show a similar striking trend of increased survey effort over time in the Strait of Georgia (Figure 4B). The highest proportion of surveys in the southern Salish Sea were completed in the Central and San Juan sub-basins for all years (Figure 5A). Unfortunately, partners were unable to conduct annual surveys in the San Juan Islands in 2020, also due to COVID restrictions. Kelp forests were the least sampled habitat from 2016 to 2020, remaining relatively low in effort, while survey time in all other habitat types increased. Artificial reefs

continued to receive the highest amount of effort, likely owing to the number of popular dive sites featuring these structures (Figure 5B).

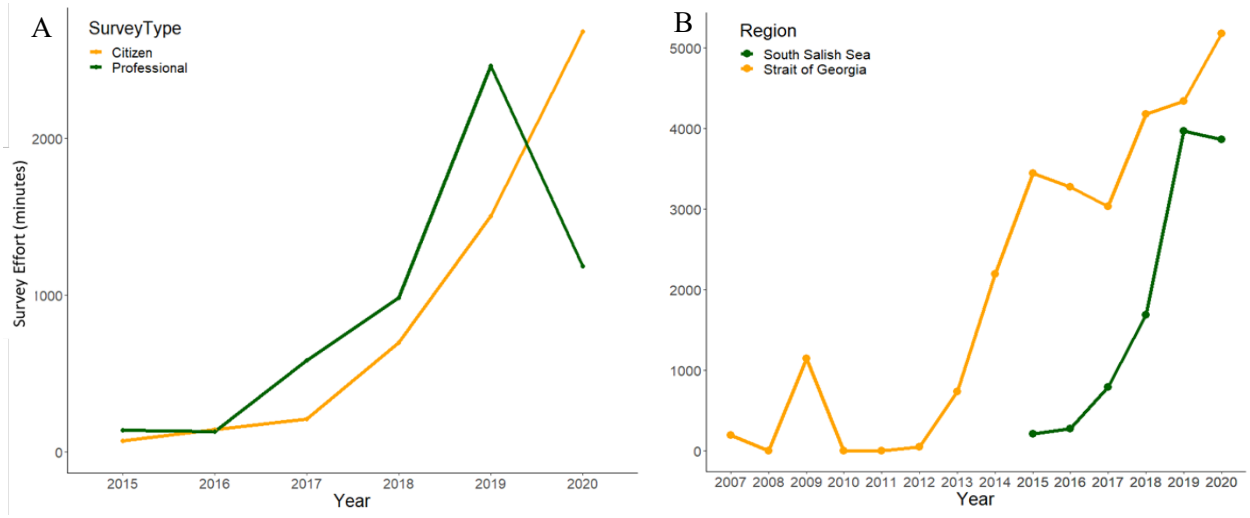

Figure 4. Survey effort (minutes) for both citizen and professional scientific divers in South Salish Sea from 2015 to 2020 (A) and by regional survey program (B). Note the difference in both x- and y-axis scales.

Fish and Habitat

In 2019 and 2020, a total of 1,081 total YOY were observed, as compared with 669 total YOY recorded during the first four years of the program (2015-18). The majority of these fishes (82.2%) for all years were in the deep body with no dorsal spot category, followed by elongate with no dorsal spot (8.6%). The deep body with no dorsal spot category comprises some of the most common shallow, nearshore, benthic rockfish species (e.g., copper, quillback, and brown; Appendix 1). Though rockfish may be found throughout the calendar year, an increase in encounter rate is evident in the summer and fall months, as well as March (Figure 6). A dip in August and September may be the result of annual intensive surveys in the San Juan Islands that frequently record few YOY rockfish, introducing spatial bias and leading to an artificially low overall encounter rate when data are aggregated.

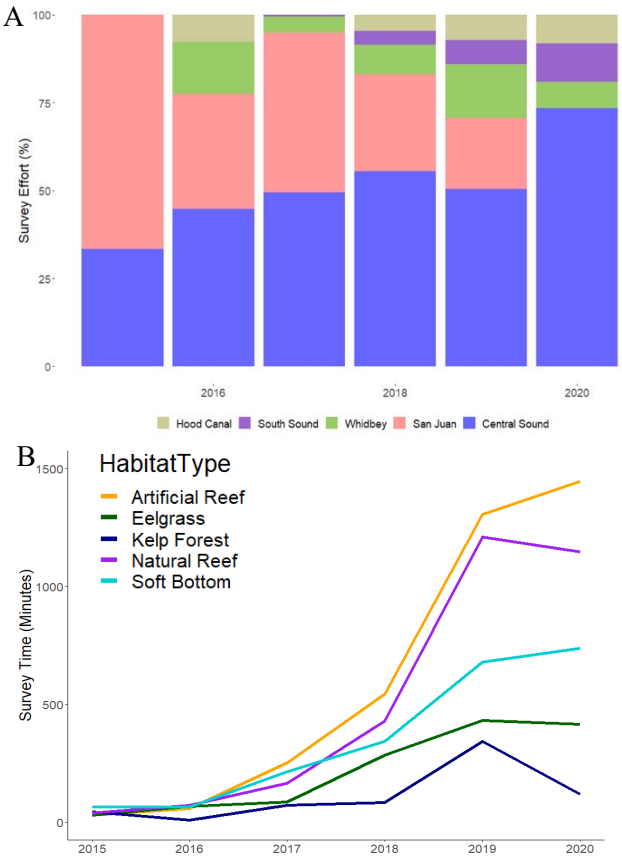

Figure 5. Relative effort as a percent of survey minutes in each basin (A) and by survey time for each habitat type (B) in Puget Sound, WA from 2015-2020.

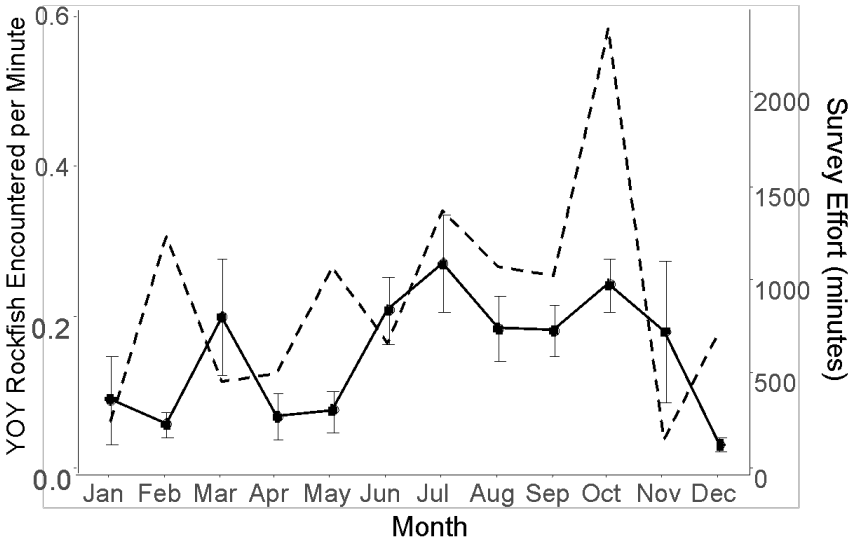

Figure 6. Change in mean YOY rockfish encounter rate (solid black line) averaged across all years (2015-20) and months contrasted with survey effort (broken line) for surveys in Puget Sound, WA. Error bars for encounter rate are standard error.

Encounter rate was most consistent in the Central and San Juan sub-basins (Figure 7A), possibly resulting from both site familiarity due to repeat visits (Figure 2) and higher sampling effort prior to 2020 (Figure 4A). Encounter rate in both the San Juan and Hood Canal sub-basins remains very low. Annual trips to the San Juan Islands consisting of 2-3 consecutive dive days by at least two surveyors encountered at most four YOY. This result is curious given the extensive natural reef habitat in the region, considered high quality rockfish habitat. Hood Canal consistently has the fewest encounters of YOY, with two being the greatest number recorded in a single year, though survey effort in that basin has been limited to date. YOY were encountered most frequently in artificial reef habitat in all but one year, though it is noteworthy that YOY were found in all sampled habitats (Figure 7B). Also, kelp forests, often considered high quality YOY habitat, exhibited low encounter rates. Encounter rate was higher than expected in soft-bottom habitats, as those areas lack rigid physical structure that provides shelter.

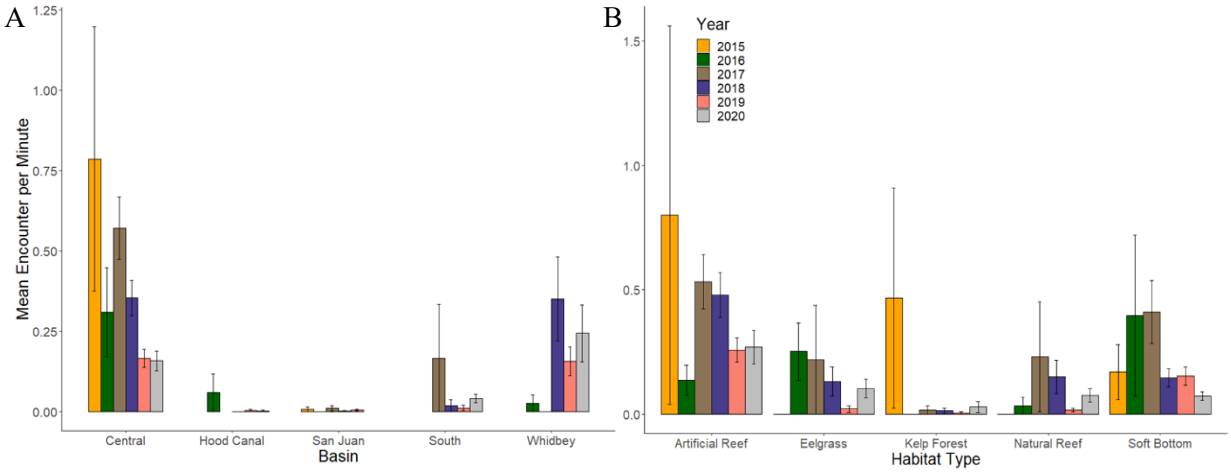

Figure 7. Mean YOY rockfish encounter rate by basin (left) and major habitat type (right) in Puget Sound, WA for all years (2015-20).

An analysis of mean YOY encounter rate by site for all years surveyed and current speed indicates that, except for one site, YOY are less frequently encountered at sites with a mean current speed greater than 0.75 knots (indicated by the solid vertical line in Figure 8A; $t = 2.82$, $df = 55.8$, $p < 0.01$). Mean encounter at sites with average maximum currents less than 0.75 knots was 0.11 YOY/minute +/- 0.13 YOY/minute (standard deviation) and 0.03 YOY/minute +/- 0.09 YOY/minute at sites greater than 0.75 knots. One outlier site, Keystone Jetty, located within the Whidbey basin, which has a mean current speed of 3.12 knots, also had one of the highest encounter rates (0.46 YOY/minute) among all years. Keystone Jetty is also the only artificial reef site surveyed in an area with a mean current speed greater than 0.75 knots.

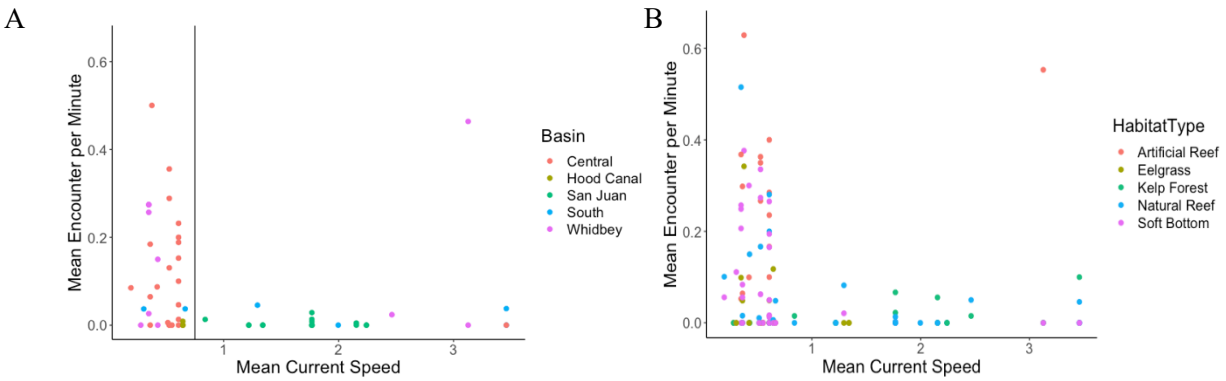

Figure 8. Young-of-year rockfish encounter rate plotted against mean current speed in knots (determined from the nearest NOAA buoy) in the southern Salish Sea. Points correspond to mean encounter rate among all years (2015-2020) for a single site grouped by basin (A) and habitat type (B). The solid vertical line in A represents 0.75 knots. Note that a single site may contain multiple habitat types surveyed, thus, encounter rates by basin (A) and habitat type (B) may not be equal.

Regionally, YOY rockfish encounter rates among Puget Sound and the Strait of Georgia are similar from 2017-19, but dramatically increase in the Strait of Georgia in 2020 (Figure 9A). An analysis of encounter rate broken down by region and morphological type shows that elongate YOY with no dorsal spot are responsible for that spike (Figure 9B). The large standard error as compared with other years in both regions suggest it may be a small subset of samples that lead to such a high mean encounter rate. Further investigation found that seven surveys, of the 127 total conducted in the Strait of Georgia in 2020, recorded between 500 and 4,000 YOY widow rockfish (*Sebastes entomelas*).

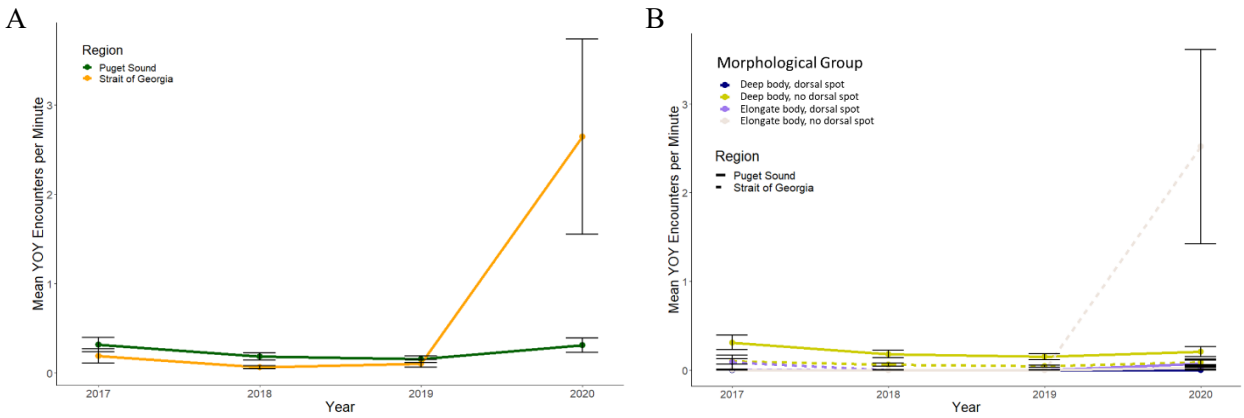

Figure 9. Mean young-of-year rockfish encounter rate between the two regions (Puget Sound and the Strait of Georgia; A) and among four morphological groups based on body shape and presence/absence of a dorsal spot (B) from 2017 to 2020.

Citizen Scientist Data Viability

A group of five citizen surveyors submitted photos and videos depicting a total of 27 YOY. Each diver identified at least three YOY among their photos and all surveyors identified YOY in photos with 100% accuracy. Identifications included "unidentified YOY," particularly for very small individuals or in videos, by morphological type (e.g., "deep body, no spot;" Figure 10A) or to species (Figure 10B).

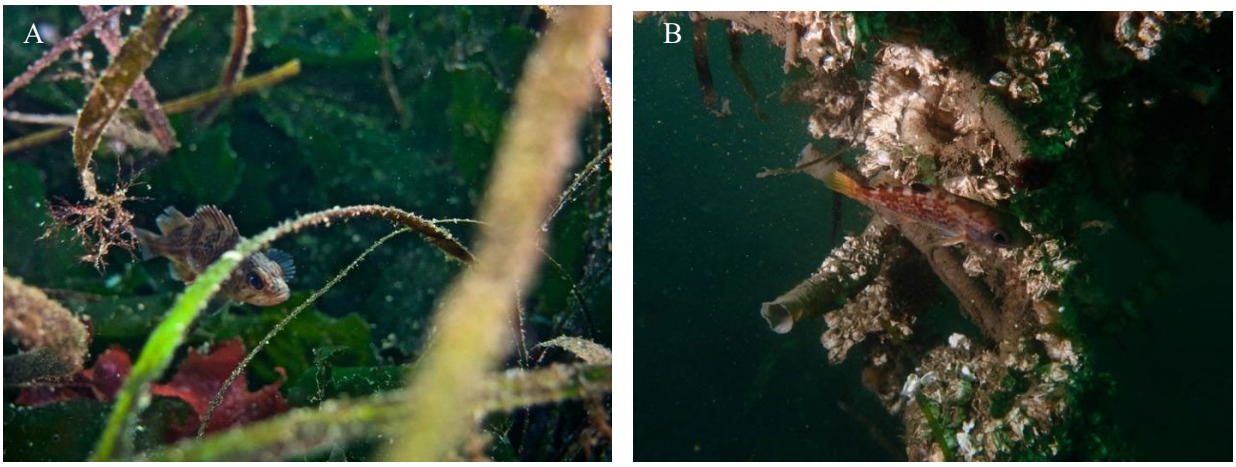

Figure 10. A YOY rockfish accurately identified as "Deep body, no spot" by photographer Jerry Dollar (A), and a yellowtail YOY identified by photographer Edgar Graudins (B) in Puget Sound, WA in 2019.

Only three transects were conducted that met the strict location and temporal proximity requirements for comparisons between professional and citizen surveyors. The first was at Fox Island West Wall and the second was artificial structure and eelgrass habitat at Edmonds Underwater Park. In all cases, the professional recorded more YOY than the citizen, with a difference in encounter rate of 0.09 YOY/minute.

Influence of Outreach on Citizen Dive Effort

A strong relationship exists between annual outreach effort and dive participation (Figure 11A), though the fit is stronger using cumulative effort (Figure 11B). Regression line slopes are 6.49 for yearly outreach and 1.88 for cumulative outreach. Therefore, over the range of outreach for which we have data,

one outreach event in a year leads to a little more than six additional dives while one more cumulative outreach event adds nearly two. Splitting the effect of cumulative outreach effects on specific participating groups shows that it took between three and five total outreach events for a group's participation to elevate (Figure 12).

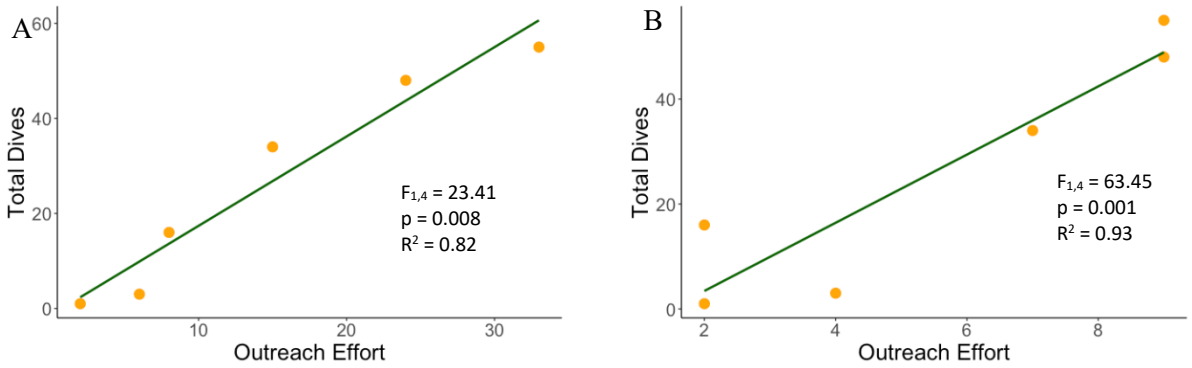

Figure 11. Plots of outreach effort against dive activity for A) events in each year and B) cumulative effort throughout the project summed for all participating groups from 2015-20. Each point represents a single year.

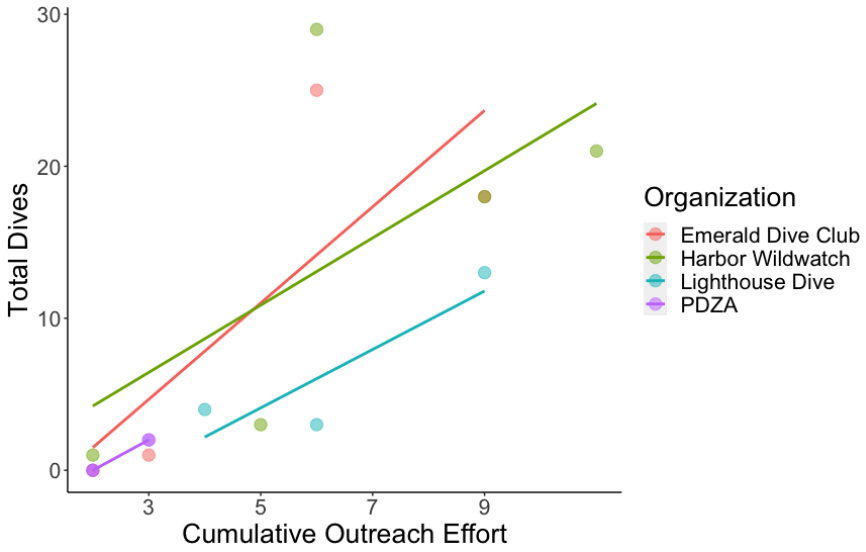

Figure 12. Plot of cumulative outreach effort of project PIs and the number of dives conducted annually by four prominent participating citizen survey groups from 2015-20. Each point represents a single year of dives for each corresponding organization.

Was 2020 a Jackpot Year?

By three different metrics, 2020 was not a jackpot year for rockfish recruitment in Puget Sound. Encounter rate in 2020 was not higher than the mean across all other survey years (baseline) in three of four sub-basins (Figure 13A). The fifth sub-basin, San Juan Islands, was not included given its low effort in 2020 resulting from COVID restrictions. Whidbey Basin did exhibit a higher encounter rate in 2020,

though was within a standard error of the baseline. Divers were more likely to encounter YOY in Whidbey Basin and South Sound, but less likely in Hood Canal and Central Sound (Figure 13B). Deep body YOY without a dorsal spot, the most common morphological type throughout all surveys, were substantially less frequently encountered in 2020. Elongate YOY with a dorsal spot, specifically yellowtail and black rockfish, were more frequently encountered in 2020. While some metrics of YOY recruitment were greater in 2020, more were roughly even or below baseline, suggesting 2020 was not an overall jackpot recruitment year.

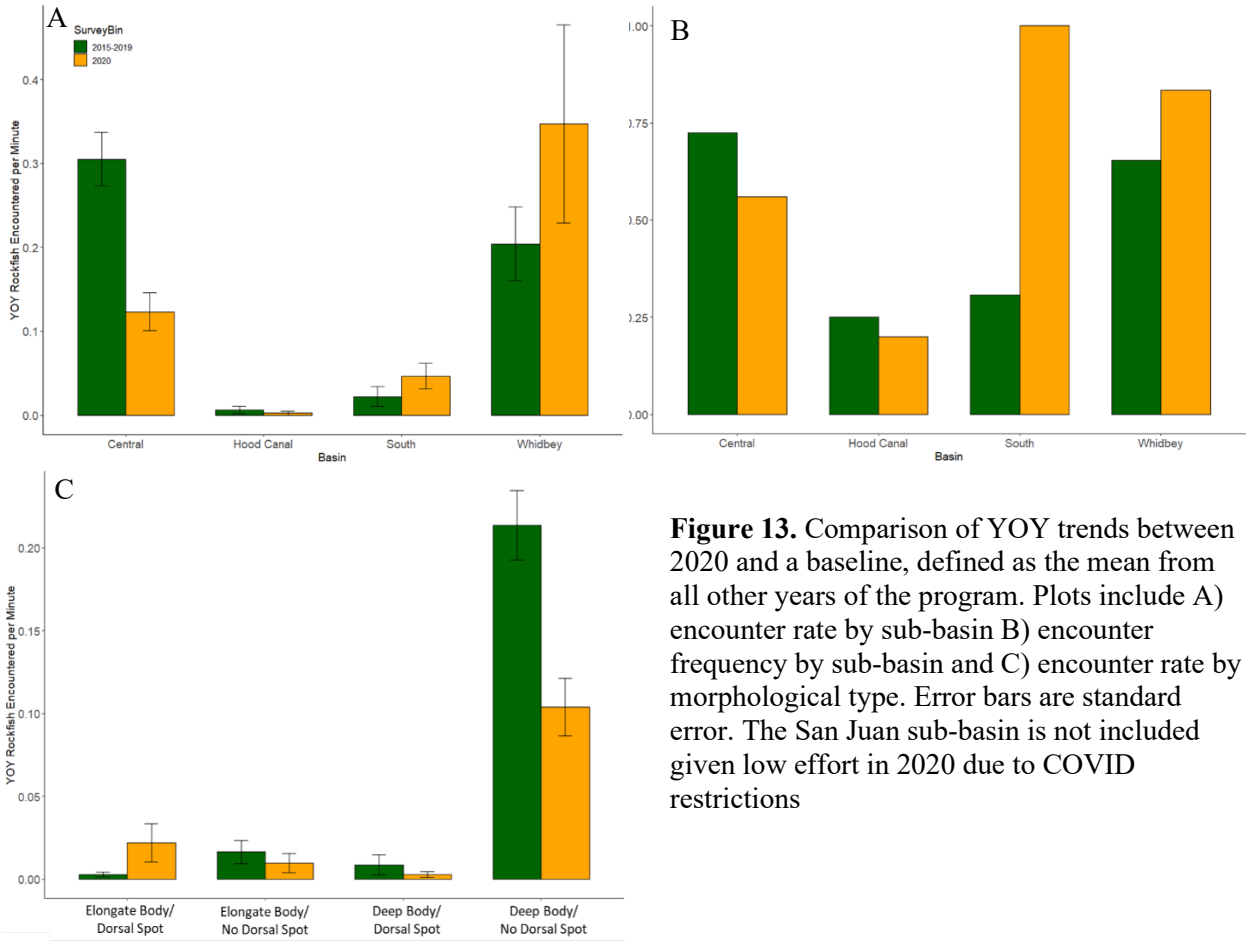

Figure 13. Comparison of YOY trends between 2020 and a baseline, defined as the mean from all other years of the program. Plots include A) encounter rate by sub-basin B) encounter frequency by sub-basin and C) encounter rate by morphological type. Error bars are standard error. The San Juan sub-basin is not included given low effort in 2020 due to COVID restrictions

Discussion

Survey Effort, Fish and Habitat

Now in its sixth year, the southern Salish Sea YOY survey effort continues to grow, more effectively meeting its goals of providing robust data for recovery applications and engaging divers within the region. A positive sign of program health is the continued dedication of participants, despite the challenges presented by the SARS-CoV2 pandemic. Though project leads were unable to conduct several trips or in-person outreach, partners still frequently got in the water to [safely!] count fish. Effort among partners increased to its greatest extent in the short history of this program. However, the focus of surveys remains in artificial reef habitats. This trend makes sense for several reasons: artificial reefs provide a higher likelihood of seeing charismatic fauna than many nearby habitats (e.g., relatively featureless soft-bottom),

these reefs are often in close proximity to facilities that promote dive activities (e.g. parking, restrooms, and shoreline access), and, therefore, these sites may be more frequently promoted by local dive shops, online dive guides, etc. To be clear, the authors believe data from artificial reefs are valuable and this effort would be lacking without them. These habitats are often used by adult rockfish and this study has found many YOY rockfish recruiting to them. However, they make up a very small subset of the overall habitat available in Puget Sound. Additional effort on natural substrates, such as reefs and kelp forests, would be helpful. The authors recognize diving in these areas may be challenging from lack of access, along with overall reductions in kelp coverage (Dunagan 2018; Berry et al. 2021). Similarly, much of the survey effort is focused in Central Sound, where greater population density and NOAA infrastructure are located. To create a more comprehensive review of rockfish recruitment in Puget Sound, this program will need to grow survey efforts in less-visited sub-basins and among more natural habitats while maintaining, if not continuing to grow, present levels in Central Sound. Project leads are addressing this issue by providing charter opportunities and scheduling group dives for partners at less accessible sites.

That outreach has a positive effect on participation validates the utility of these efforts. The most interesting trend in the data shows that consistent contact needs to occur with groups if reliable participation is desired, supporting a grass-roots approach to program construction. Emerald Dive Club and Harbor WildWatch have both passed an outreach threshold while Point Defiance Zoo and Aquarium appears poised for a strong increase in the near future. Despite a strong relationship between outreach effort and citizen survey dives, many caveats exist in this exercise. For example, no two organizations are exactly the same. Lighthouse Dive group's participation is led by a single instructor using this work as a task for advanced classes and this difference, compared with more traditional non-profits and dive clubs, may explain variable trends. The program is also still young and the group with the longest participation (Harbor WildWatch) has only five data points. Therefore, while the relationship of outreach effort to all groups may appear tight, a great deal of intergroup variability exists and must be taken into account when evaluating success and next steps for this program.

YOY Encounter rate was often higher in summer and fall months, which is consistent with Greene and Godersky's (2012) survey of larval rockfish in Puget Sound. However, Greene and Godersky (2012) found larval rockfish abundance in surface waters fell to near zero from November through February, while the encounter rate of settled YOY in the present study was greater than zero during that time. This comparison shows larval rockfish may have a more discrete duration in the plankton but use nearshore habitats to mature over longer periods. Furthermore, because this study uses 10 cm as the cutoff for YOY, it is possible some rockfish from the previous year class are under that length and counted during surveys. The encounter rate data provided in the present study are complementary to planktonic larval abundance and may eventually be used to examine discrepancies. That is, if larval rockfish are abundant in a given year, but nearshore surveys report average encounter rates in some or all habitat types/regions/depth zones, researchers could examine that bottleneck. Therefore, continued survey effort throughout the year provides data on a key developmental stage and fills a data gap in the rockfish life cycle.

That YOY rockfish are encountered more frequently on artificial reefs is not surprising. These structures are often placed amidst low-relief, soft-bottom habitat and may represent the only refuge for some distance, serving to aggregate fish. Whether fish that settle on these habitats would have settled elsewhere or failed to find appropriate habitat and died is unknown, thus effects on overall population demographics cannot be examined here. Please note that this work is in no way making a statement on the conservation value or efficacy of artificial reefs. Artificial reefs are also often less expansive than natural habitats, such as eelgrass beds and rocky reefs, allowing surveyors to examine them more intensely. Similarly, the likely smaller refuge area available on artificial reefs may increase density and subsequently, encounter rate. There may also be spillover from artificial reefs onto surrounding soft bottom areas, resulting in elevated YOY encounters in soft bottom habitat. This inflation may occur because soft bottom surveys are often done in the vicinity of a reef structure (divers may perform a soft bottom survey on the way to or from a

reef or adjacent to that reef if multiple divers are present) and an additional habitat category to capture this reef proximity effect may be necessary in the future. These high encounters on artificial reefs and soft bottom habitat show care must be taken in interpreting these data.

Encounter rates in the San Juan Basin continue to be low. These results are not for lack of effort, given that the region has received the second most survey time, behind Central Sound. While adult rockfish populations are low throughout the majority of the southern Salish Sea, recent surveys have recorded the presence of adults in the region (Pacunski et al. 2013; Blaine et al. 2020; Pacunski et al. 2020), so low YOY encounters are not for lack of a source. It is possible the extensive natural reef systems in the region provide an abundance of high-quality habitat for a limited number of recruits, driving down encounters. Other regions, such as Central Sound, have very little natural reef within SCUBA depth and the scarce high-quality habitat (i.e. artificial reefs) may accumulate more YOY, inflating encounters. In addition, surveys in the San Juan Islands have been limited to intense but short-term sampling events. A more thorough survey effort throughout the year may increase encounter rate. Regardless of the cause, the low encounter rates in an area with lower population density is curious and worth further investigation.

Data Integration with Ocean Wise

A review of survey effort over time reveals that both programs have grown support as they have matured (Figure 3B), suggesting interest in rockfish conservation and that citizen science surveys are considered worthwhile endeavors across international borders. Encounter rates in both regions are similar from 2017-19, but dramatically increase in the Strait of Georgia in 2020 (Figure 9A). Encounter rate broken down by region and morphological type shows that elongate YOY with no dorsal spot are responsible for that spike (Figure 9B). The large standard error as compared with other years in both regions suggest it may be a small subset of samples that led to such a high mean encounter rate. Further investigation found that seven surveys, of the 127 total conducted in the Strait of Georgia in 2020, recorded between 500 and 4,000 YOY widow rockfish (*Sebastes entomelas*). These anomalously high encounters, located entirely in the northeast Vancouver Island sub-region and collected between October 2 and October 4, are evidence of the ephemeral nature of YOY rockfish and highlight the importance of increased survey efforts undertaken by citizen science projects. Both regions exhibit fluctuations in encounter rate over time, though deep body rockfish with no dorsal spot are most frequently encountered of all four morphological groups across regions, and elongate rockfish with a dorsal spot are more frequently encountered in the Strait of Georgia than in the southern Salish Sea.

This preliminary data integration is an important and necessary step in improving YOY rockfish monitoring in the Salish Sea. As both databases expand, particularly in the southern portion of the survey area, the questions that can be asked about rockfish recruitment will expand and the answers will become more reliable. The authors are deeply grateful for Ocean Wise staff's commitment to rockfish recovery and coordination!

Citizen Scientist Data Viability

Preliminary review of data submitted by citizen partners suggest a high level of identification accuracy and general consistency with professional surveys. While these are encouraging results, they should be interpreted cautiously. Only a subset of surveyors submitted images and only a tiny fraction of all surveys had appropriate time and location features for comparison with project leads. The goal of these exercises is to improve data accuracy. The handful of comparison transects conducted show that project leads recorded more YOY than citizen partners, resulting in a higher detection probability by professionals at lower abundance levels. This disparity may be especially crucial when considering detection of rare species, such as ESA-listed yelloweye and bocaccio. If that trend holds through many more comparison

transects, a correction factor may be added to results or training may be adapted to help partners better locate YOY. Regardless, review of data from citizen partners thus far suggest they are providing accurate data for this program.

Applications

As this program expands, the applications for its data increase. While these YOY data are unique, they will be more powerful when used in conjunction with other sources of data. For example, one use for these data is to inform a model (multivariate autoregressive state space model) that utilizes other sources of rockfish data, to improve overall abundance estimates for rockfish in Puget Sound (Tonnes 2016; Tolimieri et al. 2017). This modeling exercise was already completed without YOY encounter data in 2016 and the additional source of data will make the pursuant estimates of rockfish abundance more robust. These results will be essential to determining the effectiveness of rockfish management actions. If this program expands to such a point that sufficient data are collected annually across season, region, and habitat type, a baseline will be created for YOY in Puget Sound. Deviations from this baseline may be quantified and could not only determine when the entire Sound has a strong year, but potentially detect settlement booms specific to regions and habitat types. The implications of these results for understanding rockfish biology and conservation are clear: more specific information on recruitment can not only help determine the effectiveness of existing management but tailor new management approaches to be more effective.

Conclusions

Setting out to quantify YOY rockfish recruitment dynamics in an area as large as the southern Salish Sea is an ambitious goal and a great deal of expansion will be required to make meaningful conclusions regarding recruitment dynamics. The journey towards this goal is already providing meaningful insights into rockfish recruitment and the use of citizen science to support robust data collection. Sustained effort is required to form a relationship with a partner group and data contribution should be expected on the order of years, not months. YOY continue to be found primarily in the summer and fall months, consistent with the literature, but have been documented in every month of the year. Sites that regularly experience high currents are less likely to yield high encounter rates of YOY. The data also suggest that 2020 was not a jackpot year for YOY recruitment, though every year this program exists the baseline for annual comparisons will be more accurate. This progress leverages invaluable outreach with citizen scientists in a key stakeholder group, SCUBA divers. As this program expands over the coming years, it will be a key part of rockfish recovery.

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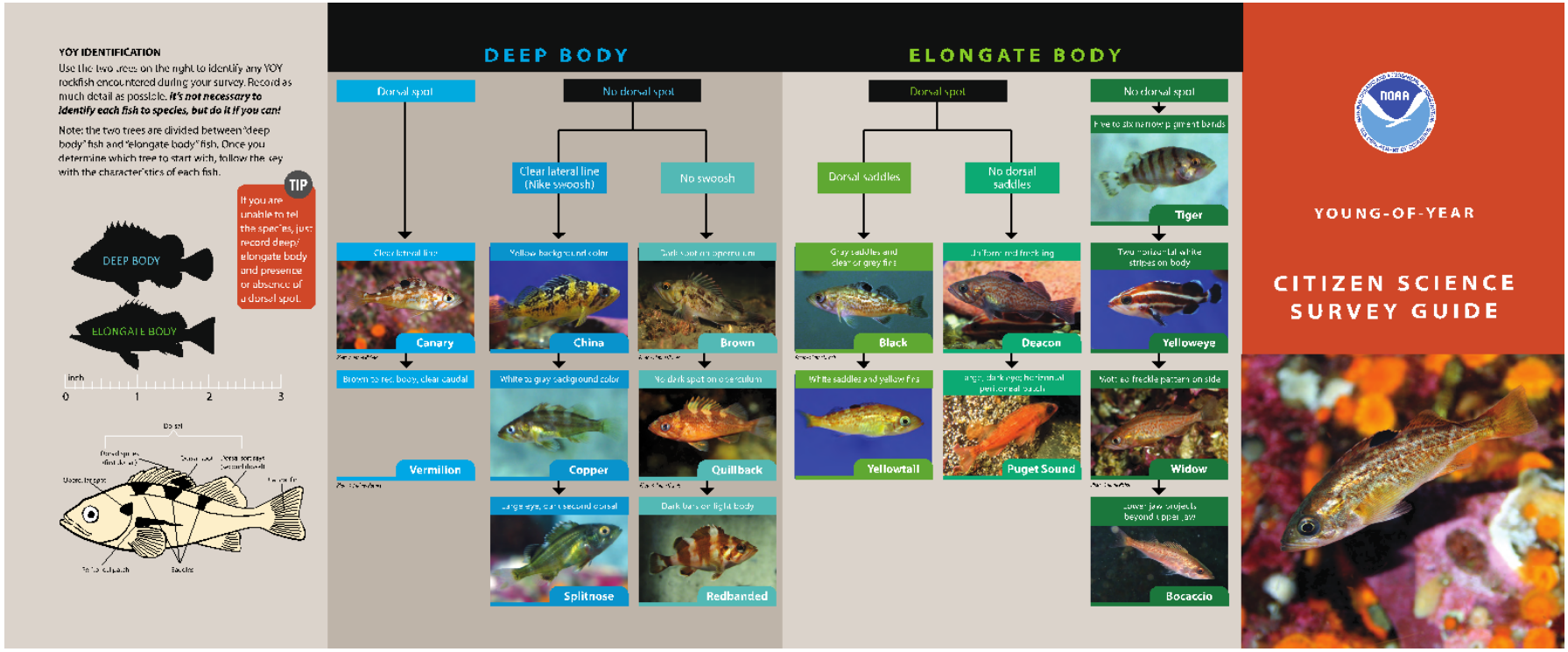
Appendix 1 - NOAA Young-of-Year Rockfish Citizen Science Survey Guide



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

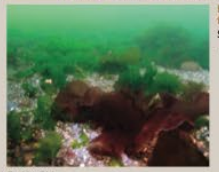
EELGRASS SURVEY ZONE

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:

SEATTLE AQUARIUM
Visit us on the web:

ROCKFISH CONSERVATION
Bottom-up Recovery of Puget Sound