Results from Young-of-Year Rockfish Surveys in Puget Sound

2015-2018

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Abstract

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 Puget Sound. To address this need, the National Marine Fisheries Service collaborated with state and federal agencies, non-profit groups, and academic institutions to develop a citizen science SCUBA survey program directed at young-of-year (YOY) rockfish. In this program, divers perform timed roving surveys in discrete habitat types, taking data on rockfish abundance in four morphological classes and qualitative habitat data. These methods were implemented from 2015-2018 throughout Puget Sound to gather baseline data and develop relationships with citizen groups to inform the development of a larger YOY monitoring program. During this four-year period, divers surveyed 328 transects over 2,955.5 minutes at depths ranging from five feet to 105 feet and found 669 YOY rockfish. The data generated from this work are not yet of sufficient size to make statistical inferences regarding recruitment patterns; however, these results will guide future survey efforts. For example, rockfish may be encountered throughout the year, suggesting that survey efforts should not be limited temporally. Of equal importance is the annual increase in survey effort, suggesting this program is viable and will contribute a portion of the data necessary to characterize rockfish recruitment that is called for in the Rockfish Recovery Plan.

Introduction

Rockfish comprise a suite of viviparous species within the genus *Sebastes* that function as mid-level predators in a variety of marine habitats. While rockfish are found throughout the west coast of the United States, the populations in Puget Sound have decreased in the past century primarily as a result of overfishing and reductions in habitat quality. In 2015, NOAA's National Marine Fisheries Service (NMFS) listed yelloweye rockfish (*Sebastes ruberrimus*) as threatened and bocaccio (*Sebastes paucispinis)* as endangered under the U.S. Endangered Species Act (79 FR 68041, 02/11/2015), and subsequently released a final recovery plan in October of 2017 (NMFS 2017). An important action listed in the recovery plan is to enable a greater understanding of listed rockfish population abundance and habitat associations. This action includes conducting annual surveys of young-of-year (YOY) rockfish throughout Puget Sound to understand primary rearing habitats, habitat threats, and restoration opportunities. With enough effort, these surveys could provide documentation of episodically successful settlement events. Because listed YOY rockfish are particularly rare, and YOY bocaccio have yet to be documented in Puget Sound, a comprehensive effort to gain information on rockfish 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.

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 (Love et al. 2002). 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 reproduce 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). This information on rockfish life history informs a more robust, long-term sampling program that quantifies recruitment strength and may be applied to stock assessments and habitat management.

Figure 1. Juvenile copper rockfish in eelgrass habitat.

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 citizen divers provides an opportunity to collect sufficient data to answer the project's core questions and partner with a valuable stakeholder group for rockfish recovery. In addition, working with SCUBA divers, a stakeholder group that more frequently comes into contact with and observes rockfish, is listed as a recovery action in the final rockfish recovery plan.

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 broader Puget Sound area has an active dive community that could support such an effort. Given the biology of rockfish, effectiveness of citizen dive surveys and pool of available divers, NMFS and partners began designing a program to monitor YOY rockfish abundance throughout Puget Sound. This report presents results from development and preliminary data collection in support of a long-term YOY rockfish monitoring program.

Methods

Survey methodology was designed with the Washington Department of Fish and Wildlife, Northwest Straits Initiative, The Seattle Aquarium, Seadoc Society, NOAA's Northwest Fisheries Science Center, and Reef Environmental Education Foundation (Obaza and Tonnes 2017). A pamphlet for divers was created in 2016 by the Seattle Aquarium. The pamphlet details the survey methodology, fish identification aids, and habitat types. The primary method of fish and habitat data collection are timed roving SCUBA surveys within discrete habitat types and depth zones. During 2015, the swimming path was a five-minute transect (i.e., a single heading) while in 2016-2018 divers utilized a timed roving survey. Divers worked either as a buddy pair, where one diver recorded fish while the second noted changes in habitat and depth, or alone, where each diver collected both fish and habitat data concurrently. If visibility and habitat structure allowed, divers simultaneously surveyed adjacent depth bins while maintaining a safe buddy distance.

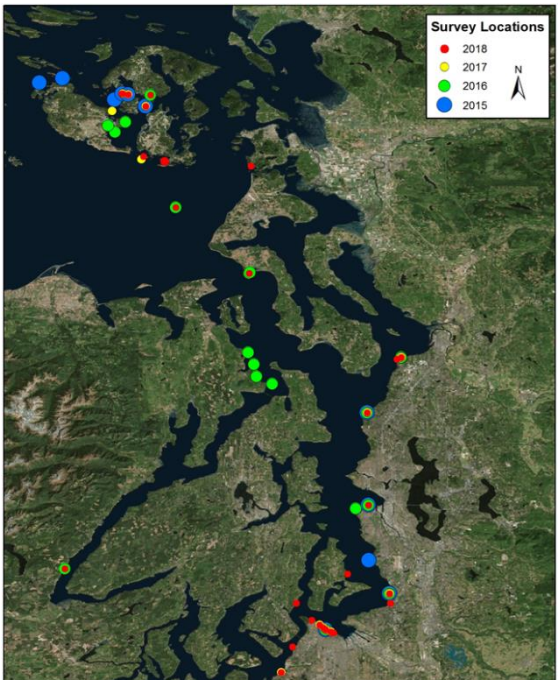

Figure 2. Survey locations in Puget Sound from 2015-2018. Points are color coded to indicate timing of survey.

Fish

The diver recording fish (if surveying as a buddy pair with separate roles) documented all visible YOY/juvenile rockfish (individuals < 10 cm) within 1 meter on either side of their swimming path and 1 meter above the substrate. This survey was timed and lasted as long as the single habitat and depth bin was being searched. If habitat was patchy (i.e., areas of one habitat type was separated by a distinctly different habitat type), distinct patches were counted as separate surveys. If macroalgae or eelgrass were being surveyed, the diver lightly disturbed the vegetation to better expose individuals. Within rocky substrata, the diver used a flashlight to illuminate potential hiding places. YOY rockfish were not recorded to species. Instead, they were classified into one of four categories based on NMFS' 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 could not classify the individual to one of those groups, "Unidentified YOY" was simply noted.

Habitat

A second diver (if surveying as a buddy pair) followed the fish sampler and took data on habitat type. As each survey was completed in an area dominated by a single habitat type, the sampler recorded several categorical metrics to further describe the habitat. These metrics were general and could be completed following the dive based on discussion between both divers. In some cases, video or still images were taken to improve evaluation of habitat-type metrics, though were not necessary. In addition, survey depths were recorded and categorized within one of three depth bins: shallow (≤ 20 feet), intermediate (21-60 feet), and deep (> 60 feet). Therefore, each survey had an associated habitat type and depth bin. Habitat metrics are defined below:

Rocky Reef

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

Presence of benthic macroalgae: common, occasional, or rare to non-existent

Substrata: Natural or artificial substrata

Eelgrass

Density: high (greater than 10 turions/square foot), medium (1-9 turions/square foot), or low (< 1 turions/square foot). These measurements are approximate as the divers do not carry a quadrat.

Length: These measurements are approximate as the divers do not carry a measuring device.

Kelp Forest

Kelp density: high (> 100 stipes encountered during five minutes of survey), medium (20-100 stipes encountered during five minutes of survey), or low (< 20 stipes encountered during five minutes of survey).

Canopy height: These measurements are approximate as the divers do not carry a measuring device.

Soft-bottom

Sediment type: sand or silt

Detrital algae: common, occasional, or rare to non-existent

Both volunteer citizen divers and professional scientific divers collected YOY and habitat data throughout Puget Sound during all months of the year from 2015-2018 (Figure 2). 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 by an experienced surveyor for fish and habitat identification competence.

Analysis

Exploratory data review was conducted to provide preliminary understanding of the work completed to date. Although the data are not yet of sufficient size to conduct formal statistical analyses, the results may still provide useful information on general trends and inform future survey efforts.

Results

Effort

Survey time increased annually throughout the reporting period for both citizen and professional scientific divers (Figure 3). That trend was consistent with the total number of transects completed, where 42 were surveyed in 2015 compared with 185 in 2018. The highest proportion of surveys among all years were completed in the Central and San Juan Basins (Figure 4). Kelp forests were the least sampled habitat in 2016-2018, remaining low in effort while survey time in all other habitat types increased. Artificial reefs received the highest amount of effort, likely owing to the number of popular dive sites featuring these structures (Figure 5), and their accessibility for shore-based diving. The coefficients of variation, a measure of variability about the mean, decreased from 3.53 in 2015 to 2.05 in 2018.

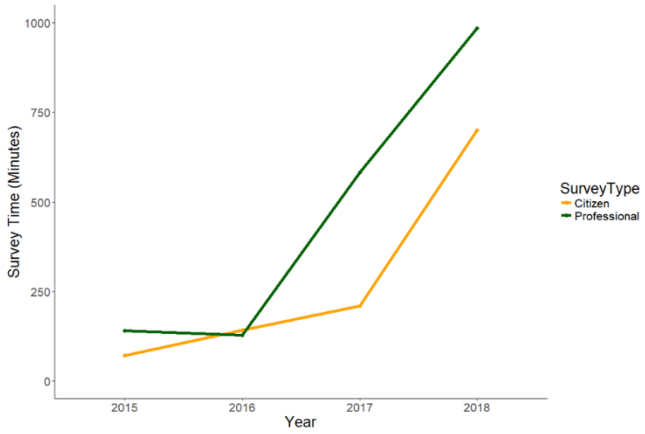

Figure 3. Survey effort over time for both citizen and professional scientific divers.

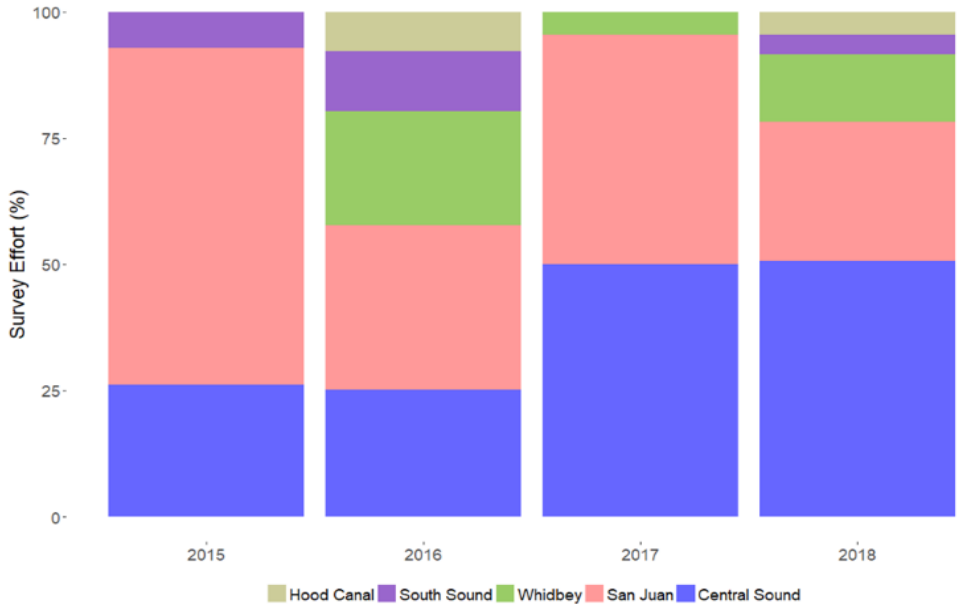

Figure 4. Relative effort (percent of survey minutes) in each basin from 2015-2018.

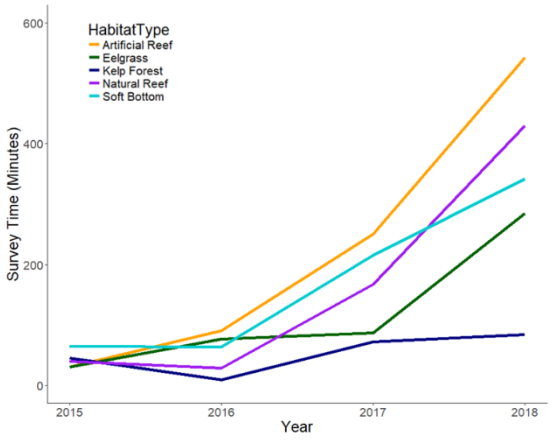

Figure 5. Actual effort (survey minutes) in each major habitat type from 2015-2018.

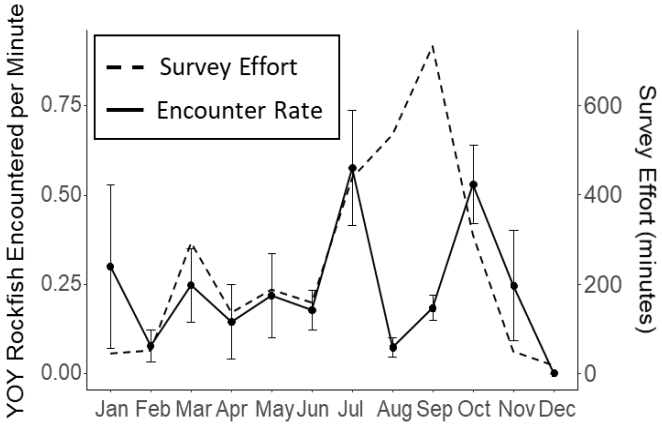

Figure 6. Change in mean encounter rate averaged across all years by month contrasted with survey effort. Error bars for encounter rate are standard error.

Fish

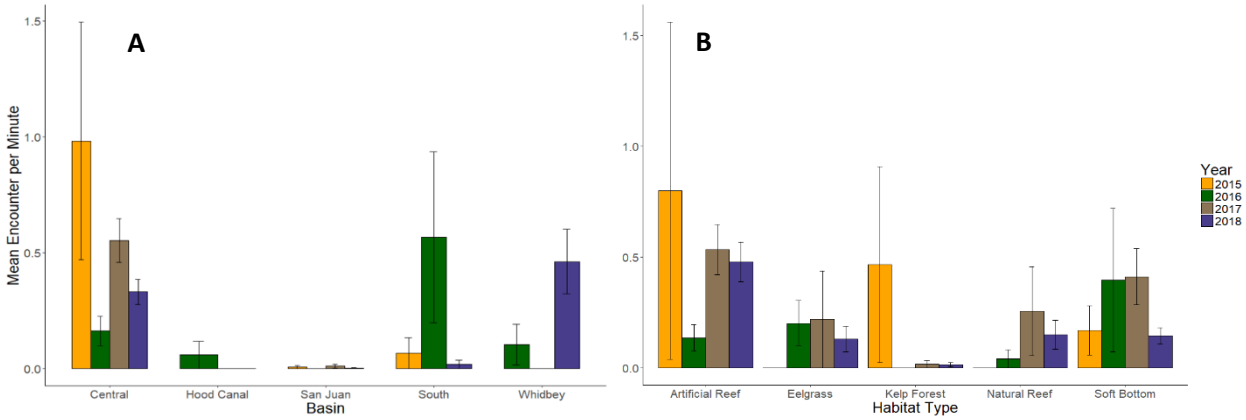

Figure 7. Mean YOY encounter rate by (A) Basin and (B) Major Habitat Type across years.

A total of 669 YOY rockfish were counted during surveys from 2015-2018. The vast majority of these fishes (78.2%) were in the deep body with no dorsal spot category, followed by elongate with no dorsal spot (15.2%). As the deep body with no dorsal spot category is comprised of some of the most common shallow, nearshore rockfish species (e.g., copper, quillback, and brown; Appendix 1), their prevalence was not surprising. YOY rockfish were found during every month except December (Figure 6), during which comparatively few surveys were conducted. Though rockfish may be found throughout the calendar year, an increase in encounter rate was evident in the summer and fall months. A dip in August and September may have been the result of annual intensive surveys in the San Juan Islands that have frequently recorded few YOY rockfish and likely led to low encounter rates.

Detrital Algae Frequency	Mean Encounter Rate	Standard Deviation
Absent	0.0417	0.06
Rare	0.168	0.4
Occasional	0.152	0.36
Common	0.449	0.4

Table 1. Mean encounter rate along with standard deviation for four levels of detrital macroalgae on soft bottom habitat.

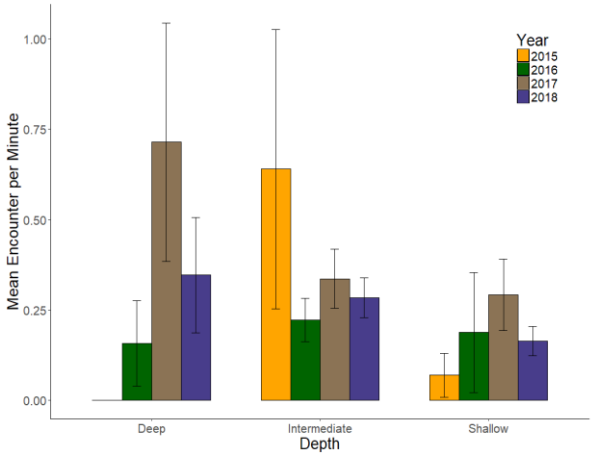

Figure 8. Change in mean encounter rate averaged within each year and compared across the three depth strata.

Encounter rate was most consistent in the Central and San Juan Basins (Figure 7A), possibly resulting from higher sampling effort (Figure 6). Encounter rate in the San Juan Basin remained very low. Annual trips to the region consisting of two to three consecutive dive days by at least two surveyors encountered, at most, two YOY rockfish. This result was curious given the extensive natural reef habitat in the region, considered high-quality rockfish habitat. 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.

A review of encounter rate as related to habitat features also showed several notable trends. For example, increased detrital macroalgae in soft bottom habitats appeared to correlate with higher encounter rates in soft bottom habitat (Table 1). The standard deviations were substantial, and therefore results should be interpreted cautiously, but the increased structure may prove beneficial to YOY rockfish and partially explain higher than expected encounter rates in this habitat type. Comparison of encounter rate across the three recorded depth zones showed a slight preference for deep (> 60 feet) and intermediate (21 – 60 feet) depths, over shallow (< 21 feet; Figure 8).

Encounter rate was highest in intermediate-relief reefs (0.1 m – 1 m) across both artificial and natural substrata (Figure 9). A noticeably sharp drop in encounters was evident on high-relief natural reefs.

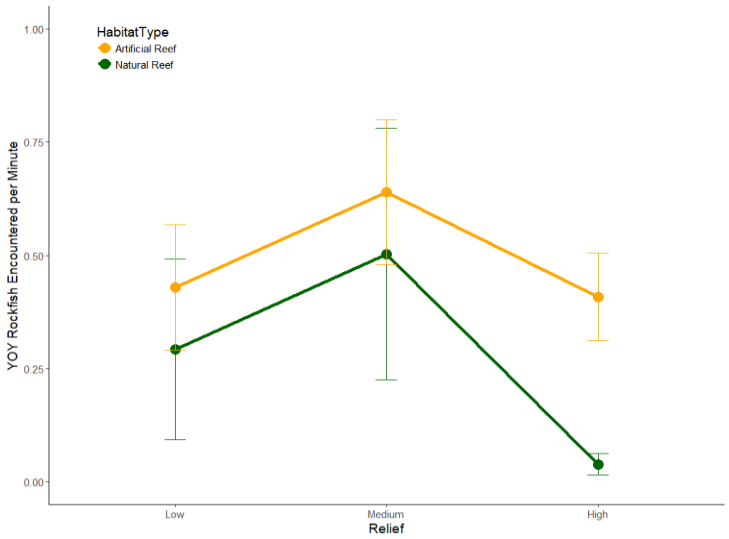

Figure 9. Change in mean encounter rate averaged across all years over different degrees of relief in artificial and natural reefs.

Discussion

Effort

The increased spatial coverage of data collection and survey time show that this project is continuing to expand throughout the region. The bump in citizen dive effort is not only beneficial for data collection but also improves engagement with the dive community in rockfish recovery efforts. This review of survey effort has identified several knowledge gaps to address. For example, the artificial reefs are the most frequently surveyed habitats in Puget Sound. 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), and these reefs are often in close proximity to facilities that promote dive activities (e.g., parking, restrooms, and shoreline access). Therefore, these sites may be more frequently promoted by local dive shops or online dive guides. These habitats are often used by adult rockfish and this study has found many YOY rockfish recruiting to them. Regardless, the increase in effort illustrate the positive direction of this program.

Fish

Despite no formal statistical tests performed on YOY habitat associations, temporal trends in encounter rate, or YOY community structure, these data provide essential information on rockfish biology and help inform future survey efforts. The dataset from this program is not yet expansive enough to answer an important central question: how strong was a given year's rockfish recruitment? However, before that question is answered, an equally crucial question must be resolved: what is the baseline for YOY encounter rates in various regions and habitats of Puget Sound? The increased effort and resulting data outlined in this report are beginning to answer that question.

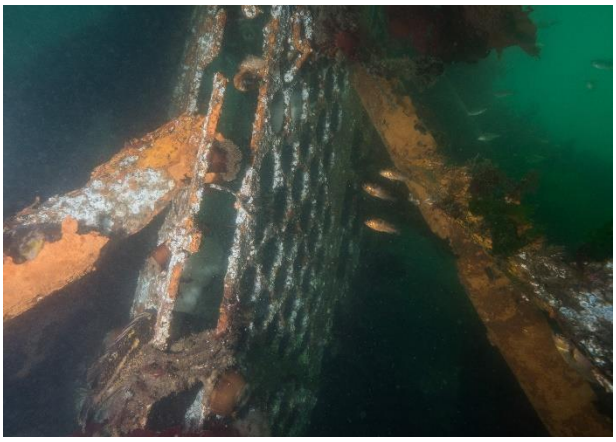

Figure 10. YOY rockfish shelter on an artificial structure in Central Puget Sound.

YOY rockfish have been found during every month except December, but this may be due to the low survey effort for that month (18.5 minutes). This illustrates the value in continual survey effort throughout the year. Encounter rate was often higher in early summer and fall months, which is consistent with Greene and Godersky's (2012) survey of larval rockfish in Puget Sound. However, Greene and Godserky (2012) found that larval rockfish abundance in surface waters fell to near zero from November through February, while encounter rate of settled YOY in the present study was greater than zero during that time. This comparison shows larval rockfish may have a 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 still under that length and are counted during these surveys. The encounter rate data provided in the present study document only one of several life stages. However, studies in other regions have examined the survivorship between life stages in marine organisms with a planktonic larval stage (Wahle and Steneck 1991; Doherty et al. 2004) to define bottlenecks. As this survey program continues to grow and data become more robust, they may be used as a complement to other survey efforts (e.g., plankton, adults) 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. Continued survey effort throughout the year provides data on a key developmental stage that fills a data gap on rockfish life history.

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. Artificial reefs are also often smaller 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. That increased density may also result in spillover from artificial reefs onto surrounding soft bottom areas, resulting in elevated YOY encounters in soft bottom habitat. This inflation may also occur because soft bottom surveys are often done in the vicinity of a reef structure while divers are transiting to an adjacent reef, such that 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 that care must be taken in interpreting these data.

The decrease in YOY encounter rate in higher-relief structures, particularly natural reefs, is at first counterintuitive. High-relief structures are often thought to contain a greater amount of surface area and therefore shelter from predators and currents. However, it is possible that high-relief structures provide additional hiding places making it difficult for even the most motivated of surveyors to locate individuals. Alternatively, some high-relief structures, such as walls, may have few hiding locations along with a greater exposure to currents, making the habitat inhospitable.

Encounter rates in the San Juan Basin continue to be low despite having the second most survey time, behind Central Sound. 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 and therefore 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 less impacted by coastal development is curious and worth further investigation.

Applications & Recommendations

The high effort in artificial reef habitats, likely owing to the number of dive sites containing such structures, is noteworthy given that artificial reefs make up a very small subset of overall habitats in Puget Sound. Additional effort on natural substrates, such as natural reefs and kelp forests, would be informative. However, diving in these natural areas may be challenging due to lack of access, along with the overall reductions in kelp coverage across the region (Dunagan 2018). Similarly, much of the survey effort is focused in Central Sound, where greater human population density and NMFS infrastructure are located. To create a more comprehensive review of rockfish recruitment in Puget Sound, this program will need to expand survey efforts in less-visited basins, and among more natural habitats, while maintaining the growing survey effort in Central Puget Sound

As this program grows, the applications for its data increases. While these YOY rockfish data are unique, they will be more powerful when used in conjunction with other sources of data. For example, these data can be used in a multivariate, autoregressive state-space model, along with 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 completed without these data in 2016 and the additional source of data will make future estimates of rockfish abundance more robust. These results will be essential in informing the effectiveness of rockfish management actions. If this program expands

to a point that sufficient data are collected annually across season, region, and habitat type, a baseline will be created for YOY rockfish in Puget Sound. Deviations from this baseline can then be quantified and used not only to identify strong recruitment years throughout Puget Sound, but also to reveal differences in recruitment strength among regions and habitat types. The implications of these results for understanding rockfish biology and conservation provide specific information on recruitment which will inform the effectiveness of existing management and guide future management options.

Conclusion

Setting out to quantify YOY rockfish recruitment dynamics in an area as large as Puget Sound is an ambitious goal, and a great deal of expansion will be required to make meaningful conclusions regarding recruitment dynamics. The journey towards achieving this goal has already provided meaningful insights into recruitment. For example, YOY rockfish may be found throughout the year, showing sampling should not be limited to a particular "season." Also, reduced coefficients of variation with increased effort suggest that the program is substantively improving. This progress includes the invaluable outreach with citizen scientists in a key stakeholder group, recreational SCUBA divers. As this program expands over the coming years, it will be a vital component of rockfish recovery.

Acknowledgments

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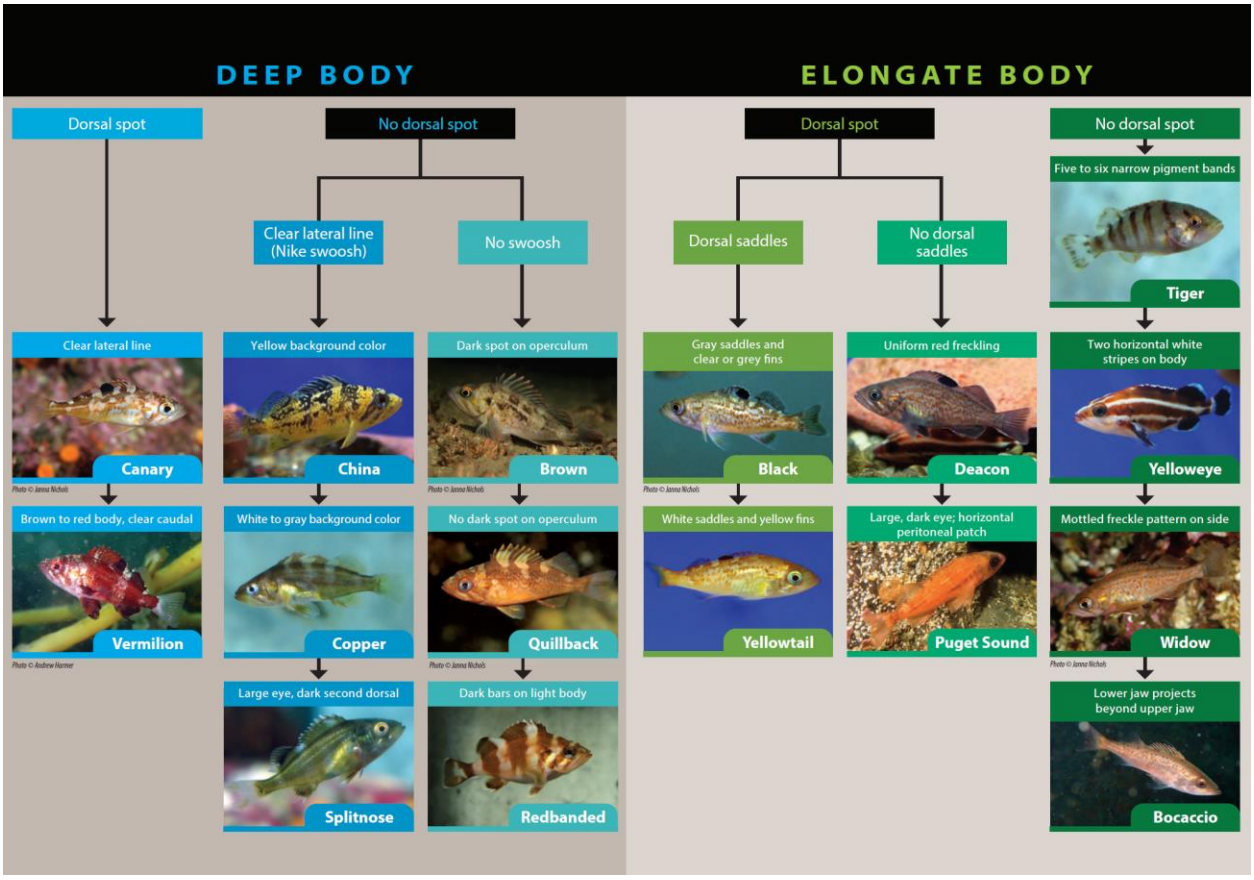
Appendix 1


DEEP BODY
ELONGATE BODY
Dorsal spot
No dorsal spot
Clear lateral line (Nike swoosh)
No swoosh
Clear lateral line
Canary
Yellow background color
China
Dark spot on operculum
Brown
Brown to red body, clear caudal
Vermilion
White to gray background color
Copper
No dark spot on operculum
Quillback
Large eye, dark second dorsal
Splitnose
Dark bars on light body
Redbanded
Dorsal spot
No dorsal spot
Dorsal saddles
No dorsal saddles
Gray saddles and clear or grey fins
Black
Uniform red freckling
Deacon
White saddles and yellow fins
Yellowtail
Large, dark eye; horizontal peritoneal patch
Puget Sound
Five to six narrow pigment bands
Tiger
Two horizontal white stripes on body
Yelloweye
Mottled freckle pattern on side
Widow
Lower jaw projects beyond upper jaw
Bocaccio