SEAMAP Reef Fish Video Survey: Relative Indices of Abundance of Yellowtail Snapper

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Introduction

The primary objective of the annual Southeast Area Monitoring and Assessment Program (SEAMAP) reef fish video survey is to provide an index of the relative abundances of fish species associated with topographic features (e.g reefs, banks, and ledges) located on the continental shelf of the Gulf of Mexico (GOM) from Brownsville, TX to the Dry Tortugas, FL (Figures 1, and 5-26). Secondary objectives include quantification of habitat types sampled (video, multi-beam and side-scan), and collection of environmental data throughout the survey. Because the survey is conducted on topographic features the species assemblages targeted are typically classified as reef fish (e.g. red snapper, *Lutjanus campechanus*), but occasionally fish more commonly associated with pelagic environments are observed (e.g. Amberjack, *Seriola dumerili*). The survey has been executed from 1992-1997, 2001-2002, and 2004-present and historically takes place from April - May, however in limited years the survey was conducted through the end of August. The 2001 survey was abbreviated due to ship scheduling, during which, the only sites that were completed were located in the western Gulf of Mexico. Types of data collected on the survey include diversity, abundance (min-count), fish length, habitat type, habitat coverage, bottom topography and water quality (Appendix 1 for a complete list). The size of fish sampled with the video gear is species specific however yellowtail snapper sampled over the history of the survey had fork lengths ranging from 76 – 730 mm, and mean annual fork lengths ranging from 187 – 309 mm (Table 4, Figure 27). Age and reproductive data cannot be collected with the camera gear but beginning with the 2012 survey, a vertical line component was coupled with the video drops to collect hard parts, fin clips, and gonads and was included in the life history information provided by the NMFS Panama City Laboratory.

Methods

Sampling design

Total reef area available to select survey sites from is approximately 1771 km^2, of which 1244 km^2 is located in the eastern GOM and 527 km^2 in the western GOM. The large size of the survey area necessitates a two-stage sampling design to minimize travel times between stations. The first-stage uses stratified random sampling to select blocks that are 10 minutes of latitude by 10 minutes of longitude in dimension (Figure 1). The block strata were defined by geographic region (4 regions: South Florida, Northeast Gulf, Louisiana-Texas Shelf, and South Texas), and by total reef habitat area contained in the block (blocks ≤ 20 km^2 reef, block > 20 km^2 reef). There are a total of 7 strata. A 0.1 by 0.1 mile grid is then overlaid onto the reef area contained within a given block and the ultimate sampling sites (second stage units) are randomly selected from that grid.

Gear and deployment

The SEAMAP reef fish survey has employed several camcorders in underwater housings since 1992. Sony VX2000 DCR digital camcorders mounted in Gates PD150M underwater housings were used from 2002 to 2005 and Sony PD170 camcorders during the years 2006 and 2007. In 2008 a stereo video camera system was developed and assembled at the NMFS Mississippi Laboratories - Stennis Space Center Facility and has been used in all subsequent surveys. The stereo video unit consists of a digital stereo still camera head, digital video camera, CPU, and hard drive mounted housed in an aluminum casing. All of the camcorder housings are rated to a maximum depth of 150 meters while the stereo camera housings are rated to 600 meters. Stereo cameras are mounted orthogonally at a height of 50 cm above the bottom of the pod and the array is baited with squid during deployment.

At each sampling site the stereo video unit is deployed for 40 minutes total, however the cameras and CPU delay filming for 5 minutes to allow for descent to the bottom, and settling of suspended sediment following impact. Once turned on, the cameras film for approximately 30 minutes before shutting off and retrieval of the array. During camera deployment the vessel drifts away from the site and a CTD cast is executed, collecting water depth, temperature, conductivity, and transmissivity from the surface to the maximum depth. Seabird units are the standard onboard NOAA vessels however the model employed was vessel/cruise dependent.

Video tape viewing

One video tape from each station is randomly selected for viewing out of all viewable videos. Videos that have issues with visibility, obstructions or camera malfunction cannot be randomly selected and are not viewed. Selected videos are viewed for twenty minutes starting from the time when the view clears from suspended sediment. Viewers identify, and enumerate all species to the lowest taxonomic level during the 20 minute viewable segment. From 1993-2007 the time when each fish entered and left the field of view was recorded a procedure referred to as time in - time out (TITO) and from these data a minimum count was calculated. The minimum count is the maximum number of individuals of a selected taxon in the field of view at one instance. Each 20 minute video is evaluated to determine the highest minimum count observed during a 20 minute recording. From 2008-present the digital video allows the viewer to record a frame number or time stamp of the image when the maximum number of individuals of a species occurred, along with the number of taxon identified in the image, but does not use the TITO method. Both the TITO and current viewing procedure result in the minimum count estimation of abundance (i.e. - mincount). Minimum count methodology is preferred because it prevents counting the same fish multiple times (e.g. if a fish were swimming in circles around the camera). Annotated data from the video include: year (Y), region (R), block (B), strata (ST), depth (D), water temperature (T), dissolved oxygen (DO), salinity (S), silt sand clay (SSC), shell gravel (SG), rock (RK), attached epifauna (AE), grass (G), sponge (SP), unknown sessiles (US), algae (AL), hardcoral (HC), softcoral (SC), seawhips (SW), relief maximum (RM), relief average (RA), reef (RF), habitat diversity (Hperc), habitat diversity (Hbin), habitat evenness (Jperc). Data definitions are listed in appendix 1.

Fish length measurement

Beginning in 1995 fish lengths were measured from video using lasers attached on the camera system with known geometry. However, the frequency of hitting targets with the laser is low and to increase sample size any measureable fish during the video read was measured (i.e. not just at the mincount), and fish could have potentially been measured twice. The stereo cameras used in 2008-present allow size estimation from fish images. From 2008-2013 Vision Measurement System (VMS, Geometrics Inc.) was used to estimate size of fish and in 2014 we began use of SeaGIS software (SeaGIS Pty. Ltd.). Fish measurement is only performed at the point in the video corresponding to the mincount therefore there is no potential to measure any fish twice.

Data reduction

Various limitations either in design, implementation, or performance of gear causes limitations in calculating mincount and are therefore dropped from the design-based indices development and analysis as follows. From 1998 – 2000. In 2001 the survey was spatially restricted to the west and was an abbreviated survey and therefore we removed that year as well. In 2013 and again in 2015 ship issues prevented the survey from being conducted in the Dry Tortugas. Occasionally tapes are unable to be read (i.e. organisms cannot be identified to species) for the following reasons including: 1) camera views are more than 50% obstructed, 2) sub-optimal lighting conditions, 3) increased backlighting, 4) increased turbidity, 5) cameras out of focus, 6) cameras failed to film. In all of these cases the station is flagged as 'XX' in the data set and dropped. Sites that did not receive a stratum assignment are also dropped and all of those occurred early in the survey (1994-1995).

Index Construction

Video surveys produce count data that often do not conform to assumptions of normality and are frequently modeled using Poisson or negative-binomial error distributions (Guenther et al. 2014). Video data frequently has high numbers of 'zero-counts' commonly referred to as 'zero-inflated' data distributions, they are common in ecological count data and are a special case of over dispersion that cannot be easily addressed using traditional transformation procedures (Hall 2000). Delta lognormal models have been frequently used to model video count data (Campbell et al. 2012) but recent exploration of models using negative-binomial, poisson (SEDAR 2015), zero-inflated negative-binomial, and zero-inflated poisson models(Guenther et al. 2014) have been accepted for use in assessments in the southeast U.S. We explored model fit using three different error distribution models to construct relative abundance indices including delta-lognormal, poisson and negative binomial.

Because there were very few observations of yellowtail snapper at sites outside of the Dry Tortugas region we restricted the data spatially to that area (Figure 5) for all analysis presented in this report. The final model run included only the Tortugas data only (excludes sites north of Pulley Ridge) and the year variable was always included in all models as a class variable. In addition we tested several habitat complexity variables (Hperc, Hbin and Jperc) estimated using Shannon-Wiener and Pielou's J calculations and which were included as continuous variables. Evaluating fit criteria information included effect on CV we selected Hperc for the final model. No other variables improved fit or explained variability and were thus dropped from the model. Final model formulation is: mincount ~ year + hperc in both the binomial and lognormal submodels. We used the composite variable habitat complexity variable Hperc rather than the percent coverage of individual habitat variables because of the strong relationship yellowtail snapper have with reef habitat and as a simplifying/aggregating variable to scale the complexity of the reef habitat observed at a site. The GLIMMIX and MIXED procedure in SAS (v. 9.4) were used to develop the binomial and lognormal sub-models in the delta lognormal model (Lo et al. 1992), and GLIMMIX used to develop the poisson and negative binomial models. Best fitting models were determined by evaluating the conditional likelihood, over-dispersion parameter (Pearson chi-square/DF), and visual interpretation of the Q/Q plots.

Results

Initial runs of the delta lognormal model produced good fits to the data (Figure 4) that were linear (e.g. 'S shaped' QQ plots) whereas the Poisson and negative binomial error distributions showed worse fits in comparison. Evaluation of model iterations showed improved fit statistics for the delta-lognormal model compared to the Poisson and negative binomial models. Therefore the delta lognormal model was selected as the best fitting model and all analysis presented in this report reflects that model selection. In all but three years no yellowtail snapper were observed outside of the Dry Tortugas (5-26) with the exceptions being in 2005, 2012, and 2016 and in those years they represented single observations for those years. Therefore we restrict this analysis to the Dry Tortugas region depicted wholly by maps 5-26.

Spatial distributions of yellowtail snapper we observed primarily in the Dry Tortugas with just a few exceptions. Within the Dry Tortugas they are found throughout our sampling universe and throughout the range of the feature (Figures 5-26). In most years the survey shows good coverage in the defined sampling universe within the Dry Tortugas. However, it should be noted that because of the operational depths for most of the ships used in the survey the shallow regions (< 15 m) of the Dry Tortugas are not sampled with the gear. Thus this data does not entirely encompass all depths and habitats occupied by yellowtail snapper in this region.

In the final model choice both year and habitat complexity (HPerc) were significant variables in both the binomial and lognormal submodels (Tables 1 and 2). Because the variable reef measures whether or not we believe the camera landed on the reef and the habitat complexity variable scales the complexity of the habitat we believed these variables were correlated and thus models were reduced to use one of them. Further because model fits was improved and resulted in decreased coefficient of variation's (CVs) we selected the Shannon's H' habitat complexity (Hperc) for use in final model selection. Inclusion of all other variables did not improve precision of the index (e.g. decreased CV) and thus were left out of the final model selection.

Through time it appears that the Gulf wide index shows a lot of variability. The index indicates a high but declining observation rate from 1993-1997 followed by increasing trends from 2002-2014, with a final slight downturn thereafter. Proportion positives followed a similar pattern of being highest but steadily declining in the early years of the survey (1993-1997), showing increasing trends through 2014 and thereafter slightly declining. Therefore proportion positives generally reflect the abundance trends (Table 3, Figures 2-3) and since 2014 mincount observations of yellowtail snapper appear to be fairly stable in the Tortugas (Figures 2 and 3).

The size of fish sampled with the video gear is species specific however yellowtail snapper sampled over the history of the survey had fork lengths ranging from 76 – 730 mm, and mean annual fork lengths ranging from 187 – 309 mm (Table 4, Figure 27). There does not appear to be any trend through time.

Literature cited

Campbell, M.D., K.R. Rademacher, P. Felts, B. Noble, M. Felts, and J. Salisbury. 2012. SEAMAP Reef Fish Video Survey: Relative Indices of Abundance of Red Snapper, July 2012. SEDAR31-DW08. SEDAR, North Charleston, SC. 61 pp.

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Lo, N. C. H., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49: 2515-1526.

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Figure 1. Spatial distribution of known reef from which stations are randomly selected for sampling for the reef fish video survey. Over the history of the survey (1992-2013) new reef tract has been discovered and mapped and therefore this map represents what was available in 2013, and not necessarily what has been available over the entire time series.

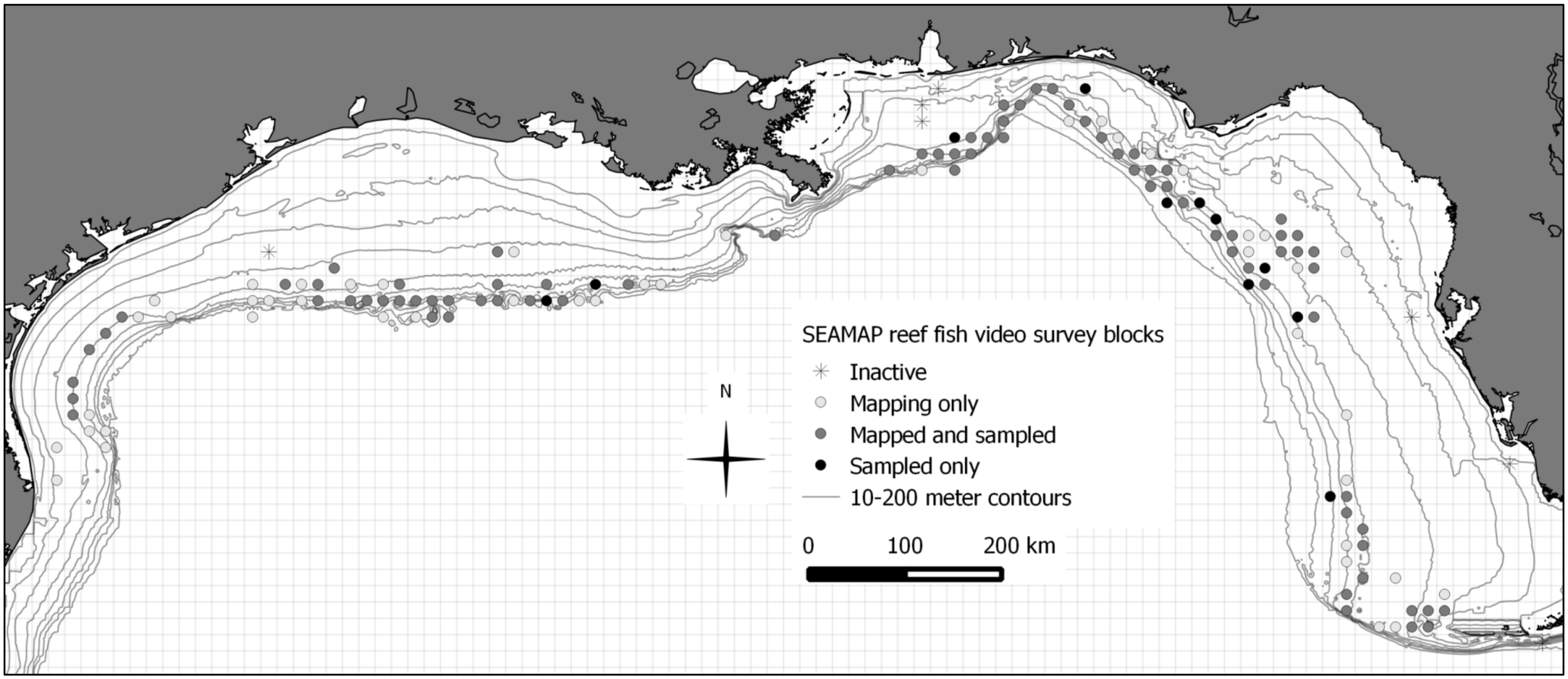


Table 1. Yellowtail snapper (Tortugas data only) binomial submodel test of type III fixed effects.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr>ChiSq*	*Pr>F*
year	18	595	54.33	3.02	<.0001	<.0001
Hperc	1	595	90.81	90.81	<.0001	<.0001

Table 2. Yellowtail snapper (Tortugas data only) lognormal submodel test of type III fixed effects.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr>F*
year	18	351	3.25	<.0001
Hperc	1	351	4.54	0.0338

Table 3. Output for the negative binomial index of relative abundance of yellowtail snapper by year (Tortugas data only).

Year	*Frequency*	*N*	*LoIndex*	*StdIndex*	*SE*	*CV*	*LCL*	*UCL*
1993	0.64286	14	2.96142	1.14196	1.29186	0.43623	0.49559	2.63136
1994	0.87500	8	4.36365	1.68268	1.85381	0.42483	0.74507	3.80021
1995	0.60000	15	1.10966	0.42790	0.44800	0.40373	0.19671	0.93082
1996	0.52632	19	1.26678	0.48849	0.60099	0.47443	0.19838	1.20283
1997	0.66667	33	1.13979	0.43952	0.34389	0.30171	0.24356	0.79315
2002	0.51515	33	1.20174	0.46341	0.43365	0.36085	0.23018	0.93294
2003	0.55556	18	0.90541	0.34914	0.38810	0.42865	0.15355	0.79383
2004	0.57692	26	2.62749	1.01320	0.91990	0.35011	0.51326	2.00007
2005	0.43243	37	1.12046	0.43207	0.41733	0.37246	0.21013	0.88842
2006	0.44444	45	1.68583	0.65008	0.57137	0.33892	0.33616	1.25714
2007	0.48276	58	2.29172	0.88372	0.58034	0.25324	0.53674	1.45499
2008	0.62500	32	4.16528	1.60619	1.09805	0.26362	0.95643	2.69736
2009	0.62222	45	2.37644	0.91639	0.54999	0.23143	0.58033	1.44705
2010	0.60000	45	1.81864	0.70129	0.42693	0.23475	0.44129	1.11449
2011	0.76087	46	4.30033	1.65826	0.78614	0.18281	1.15391	2.38307
2012	0.67347	49	3.03399	1.16995	0.58151	0.19167	0.80018	1.71059
2014	0.75862	29	4.61956	1.78136	1.01101	0.21885	1.15579	2.74554
2016	0.76000	25	3.75211	1.44687	0.94575	0.25206	0.88076	2.37684
2017	0.60976	41	4.53186	1.74754	1.16041	0.25606	1.05570	2.89277

Figure 2. Plot of the observed and expected yellowtail snapper proportion positives estimated in the binomial submodel (Tortugas data only).

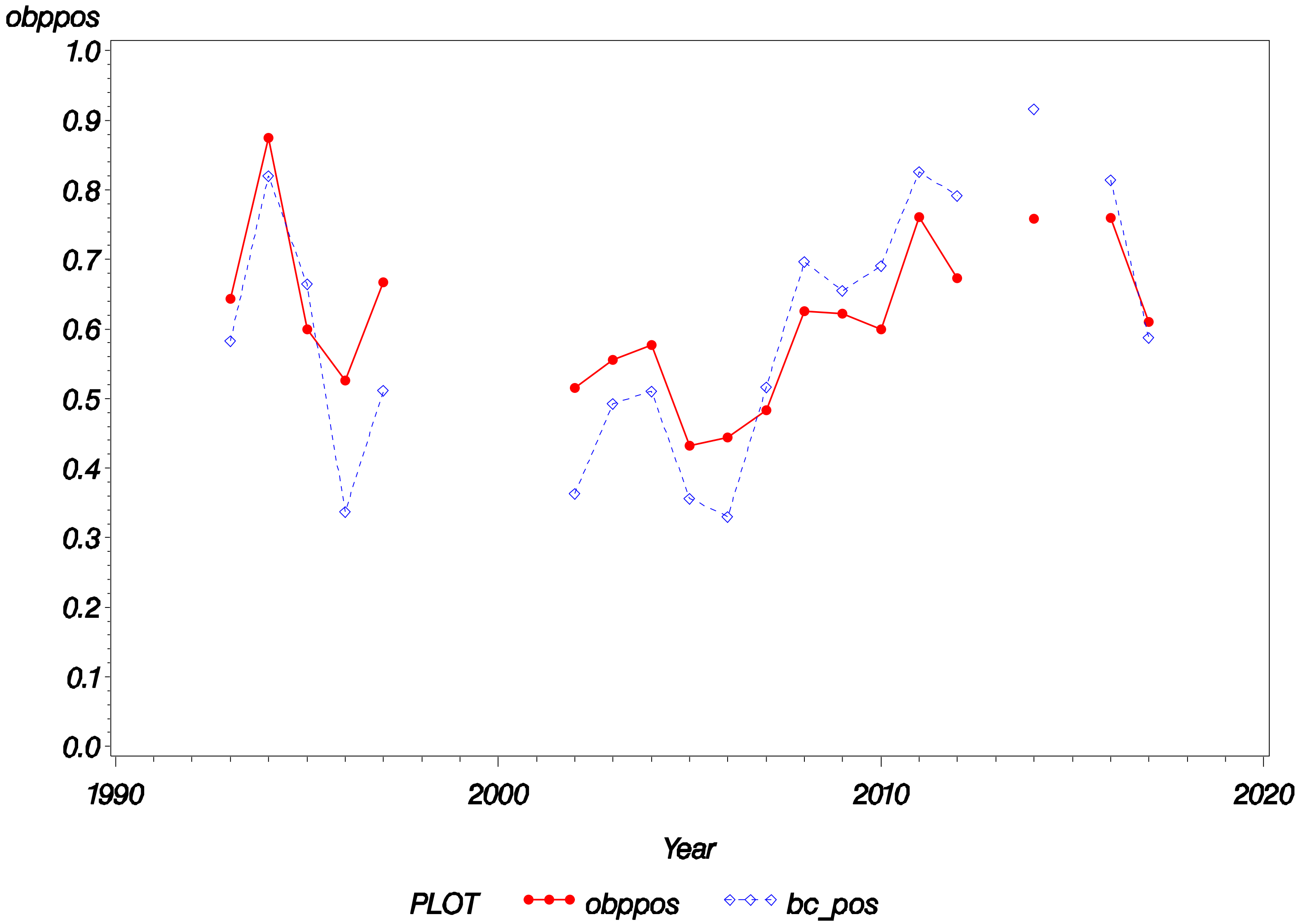


Figure 3. Delta lognormal observed (solid red) and predicted (solid blue) yellowtail snapper mincounts (Tortugas data only) with 95% CI (dashed blue).

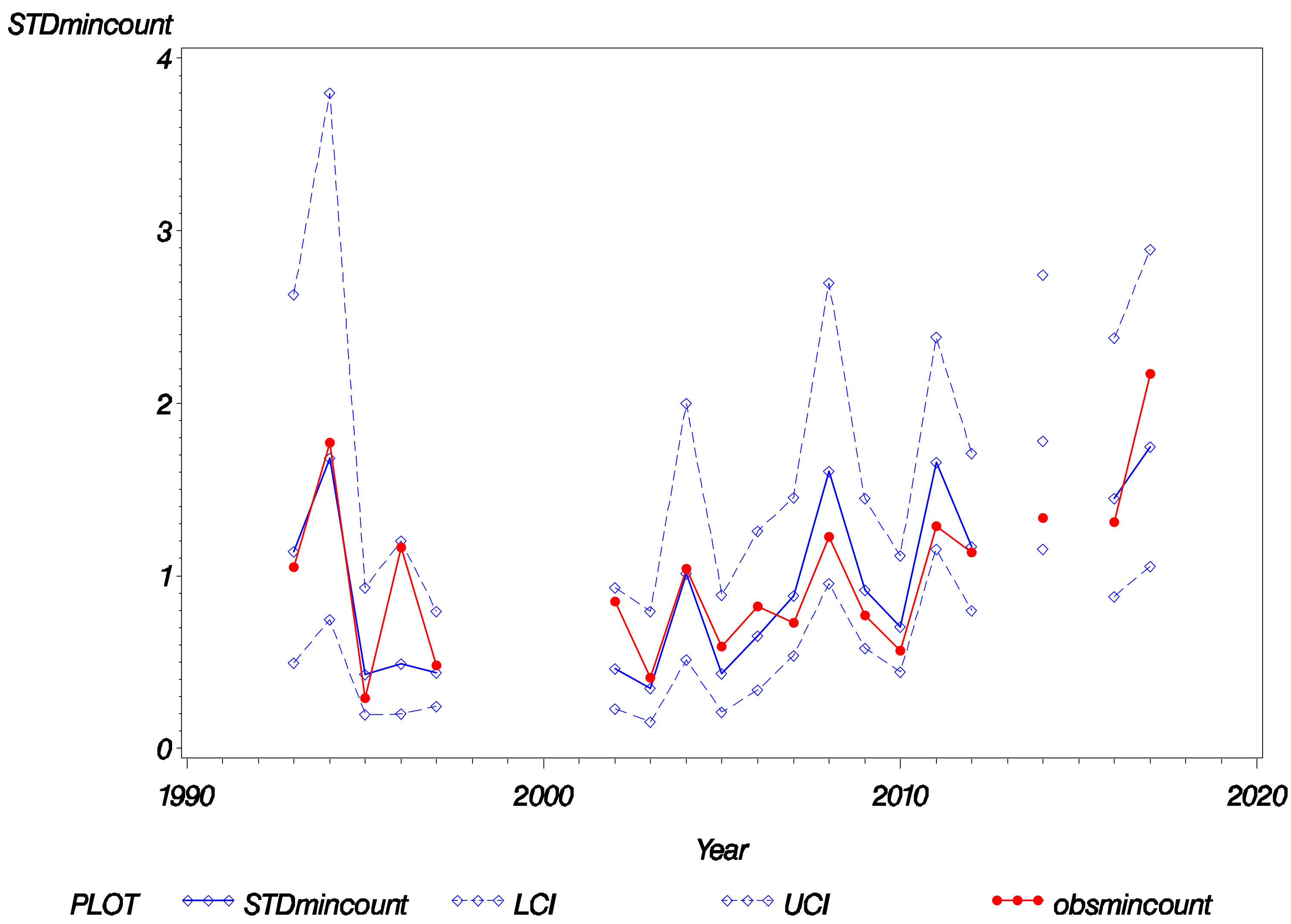


Figure 4. QQ plot of conditional residuals showing linear trend (Tortugas data only).

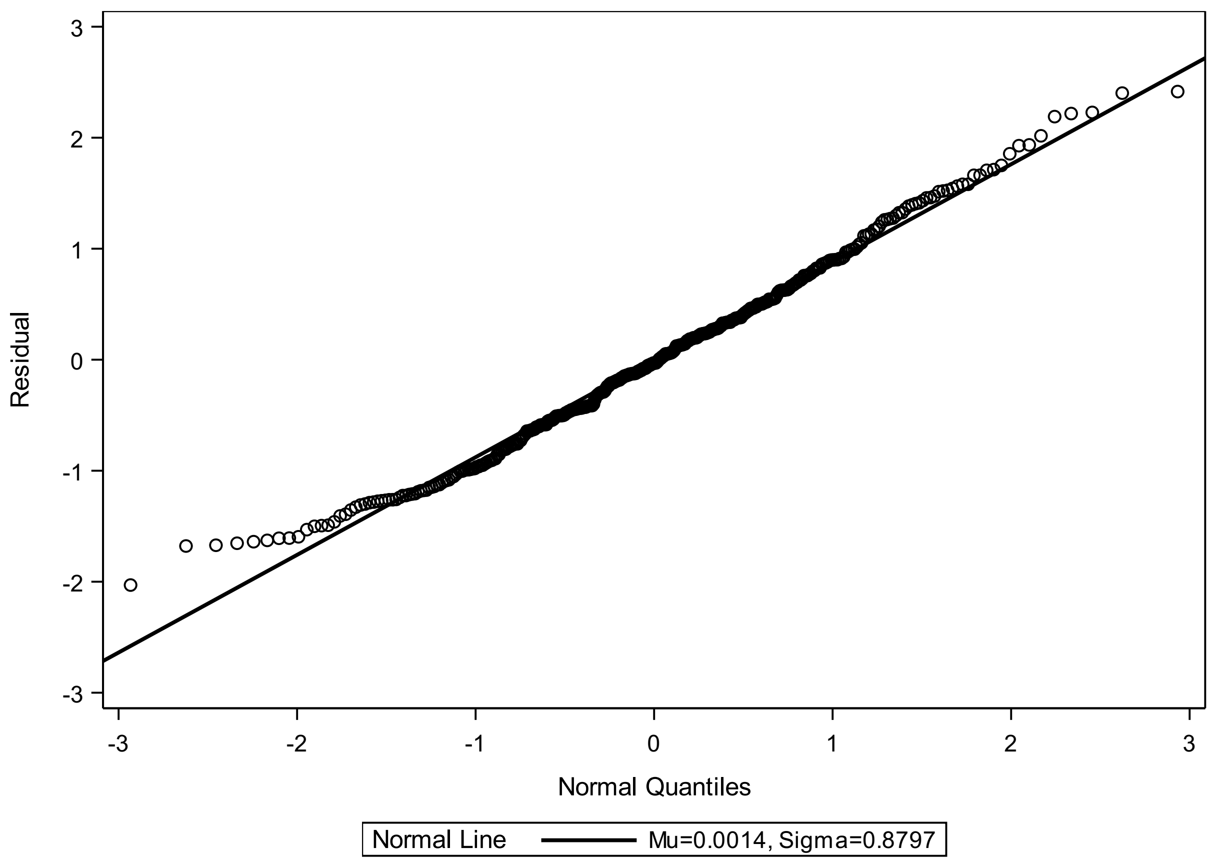


Figure 5. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 1993.

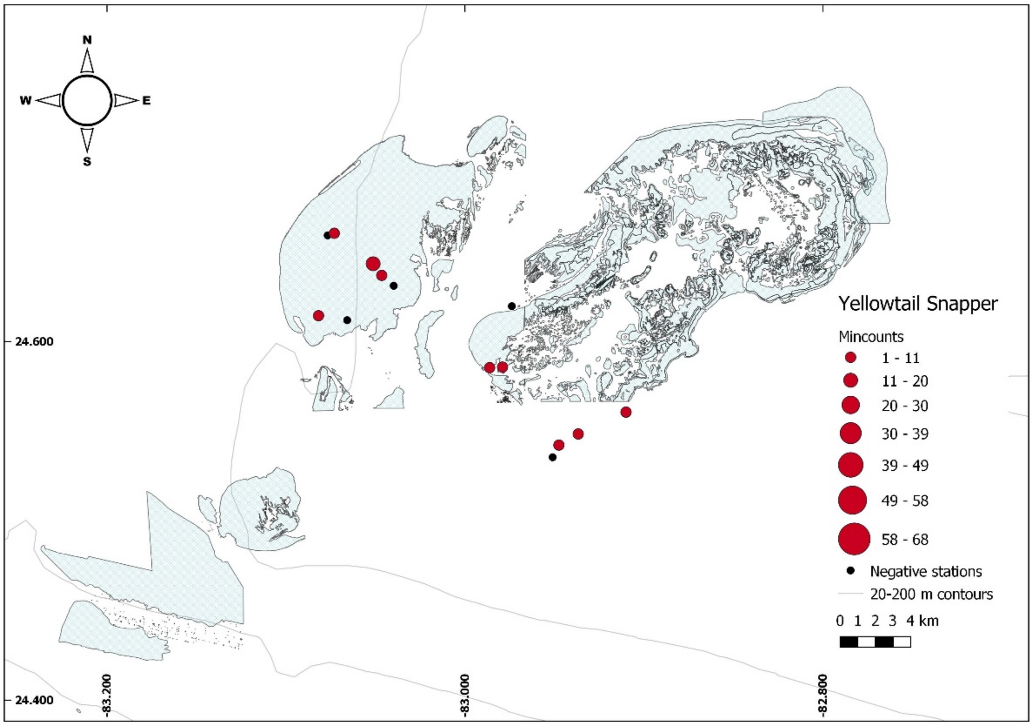


Figure 6. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 1994.

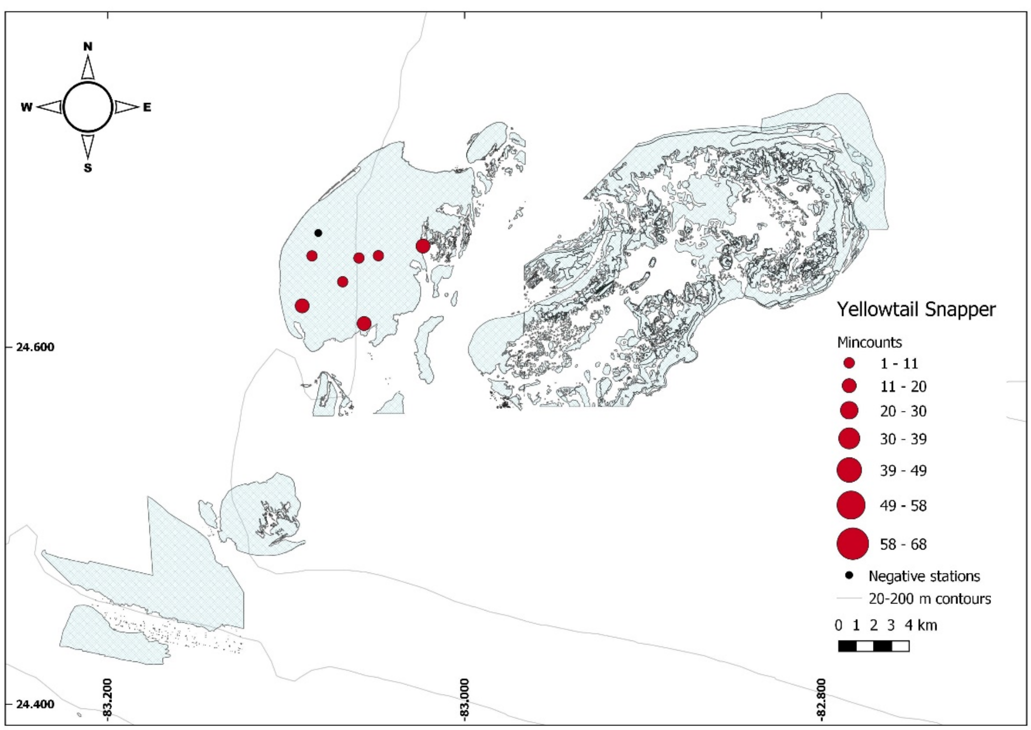


Figure 7. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 1995.

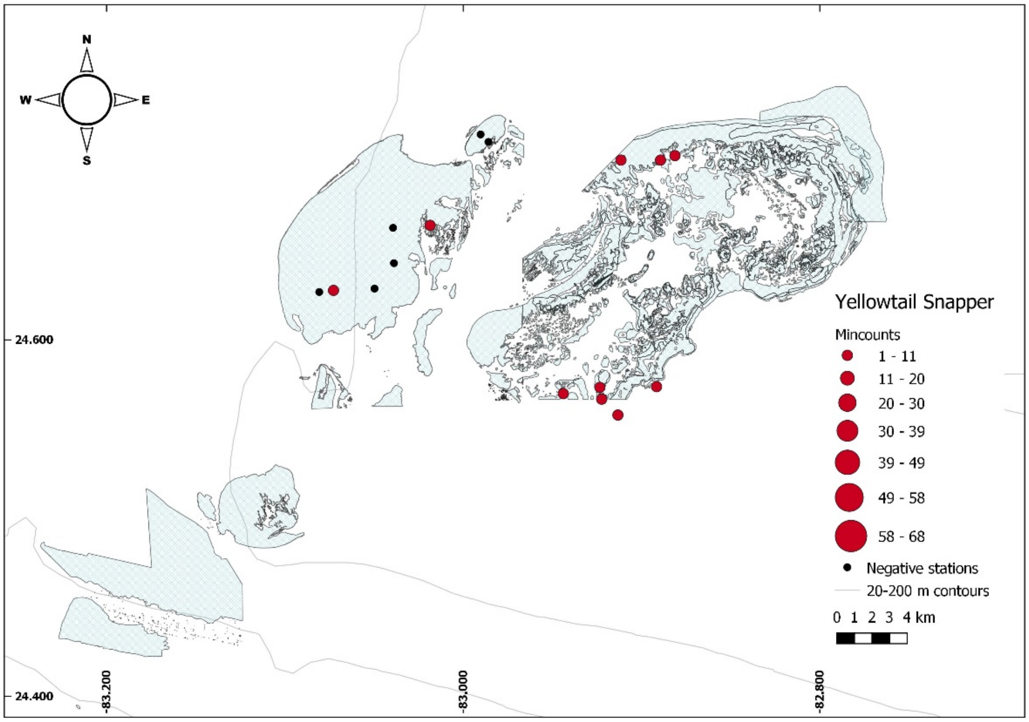


Figure 8. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 1996.

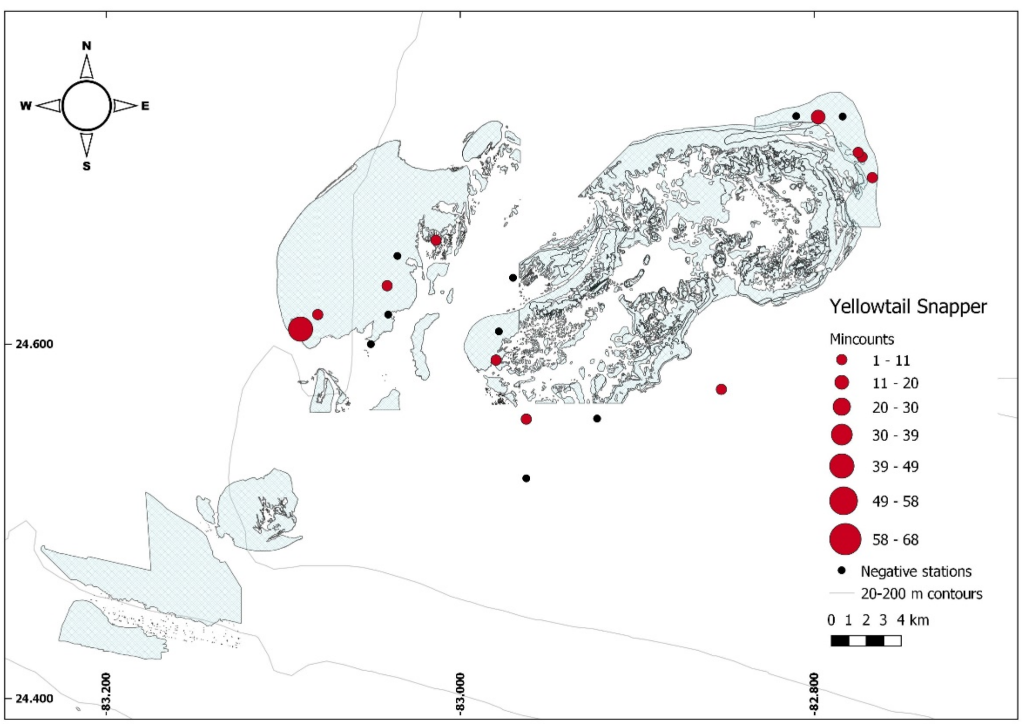


Figure 9. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 1997.

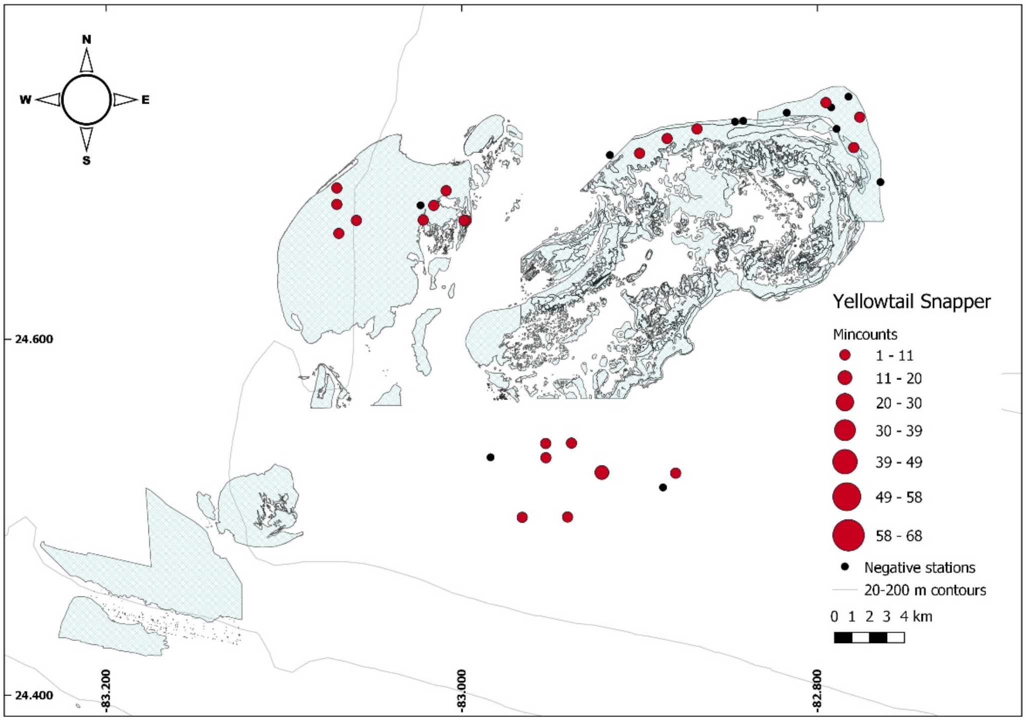


Figure 10. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2002.

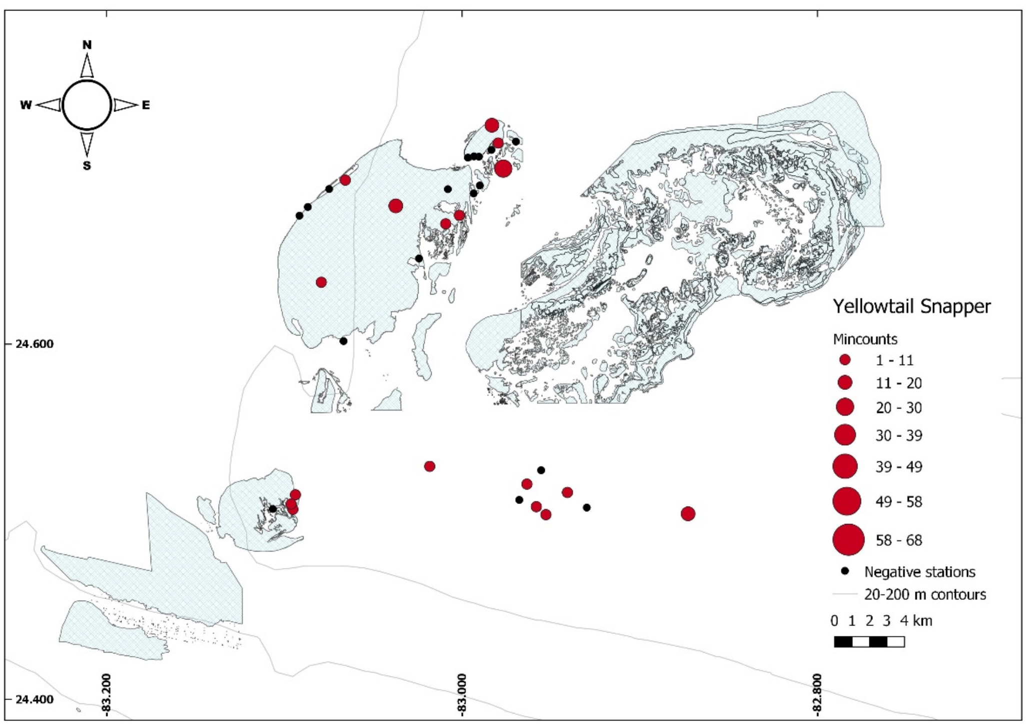


Figure 11. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2003.

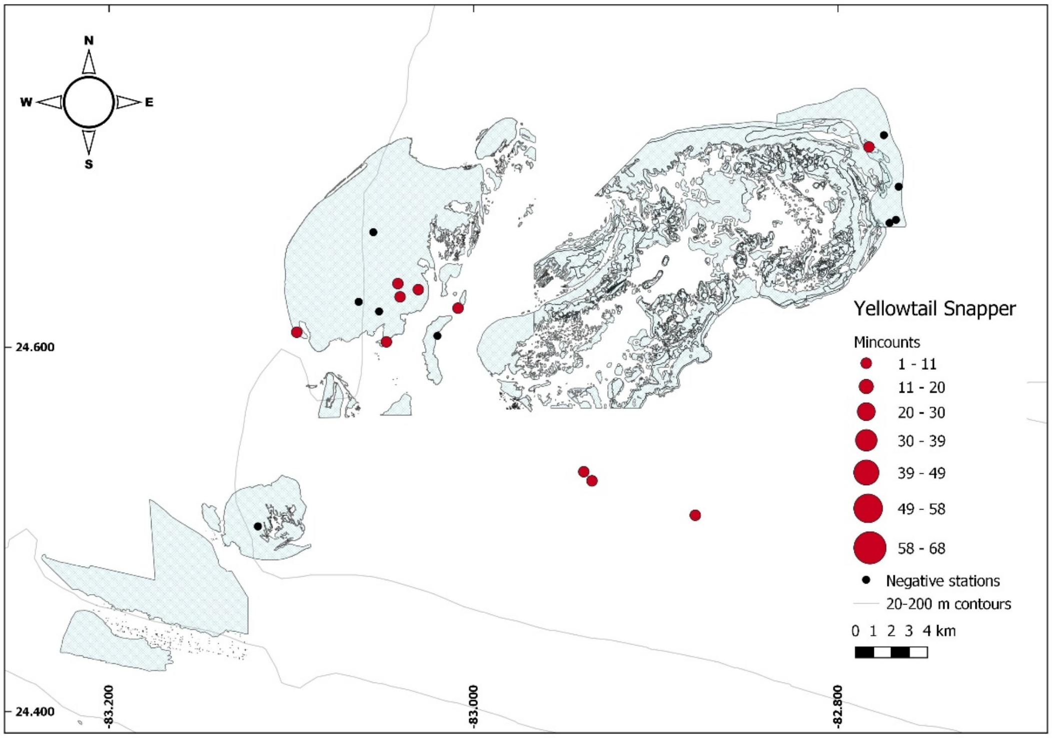


Figure 12. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2004.

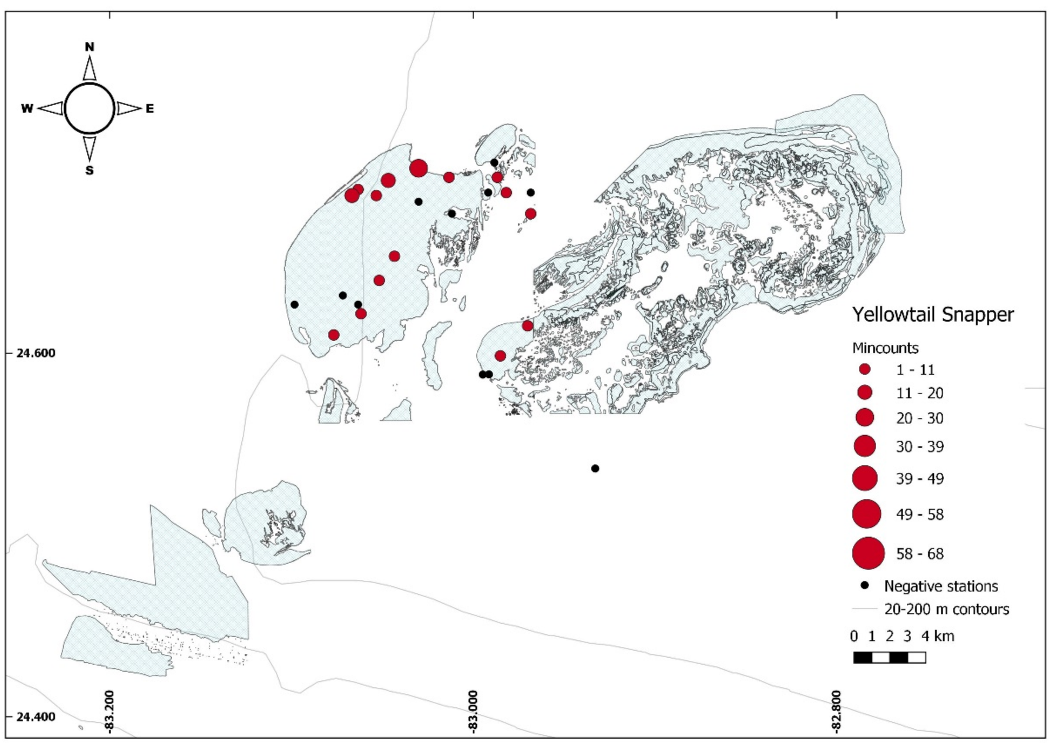


Figure 13. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2005.

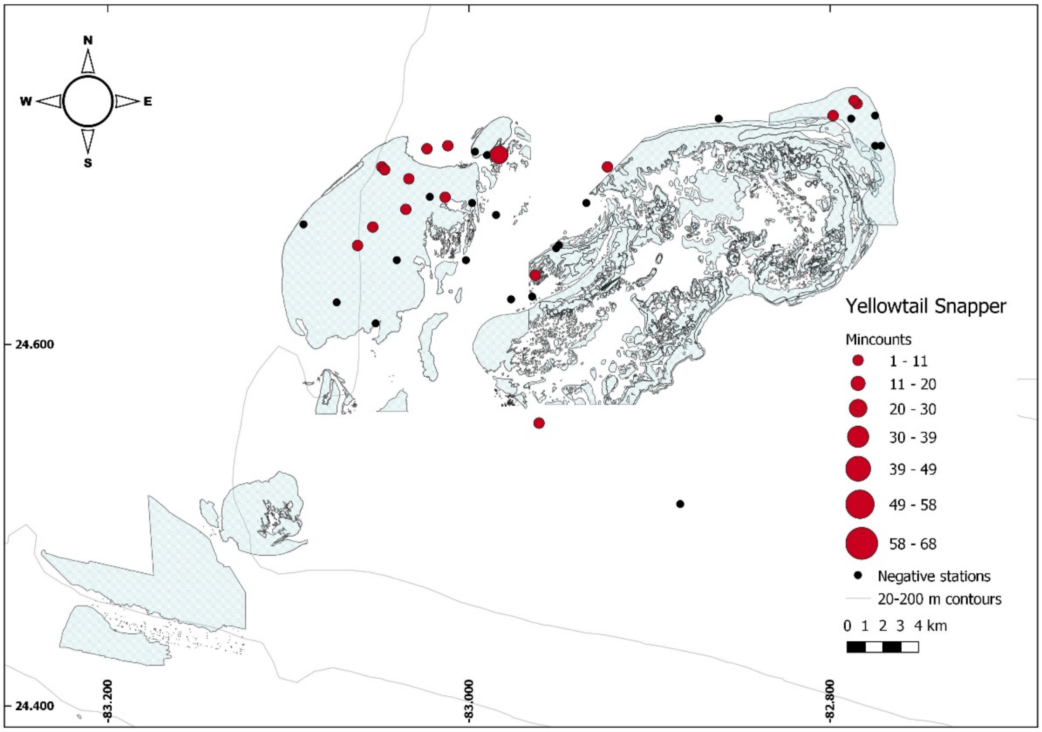


Figure 14. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2005b.

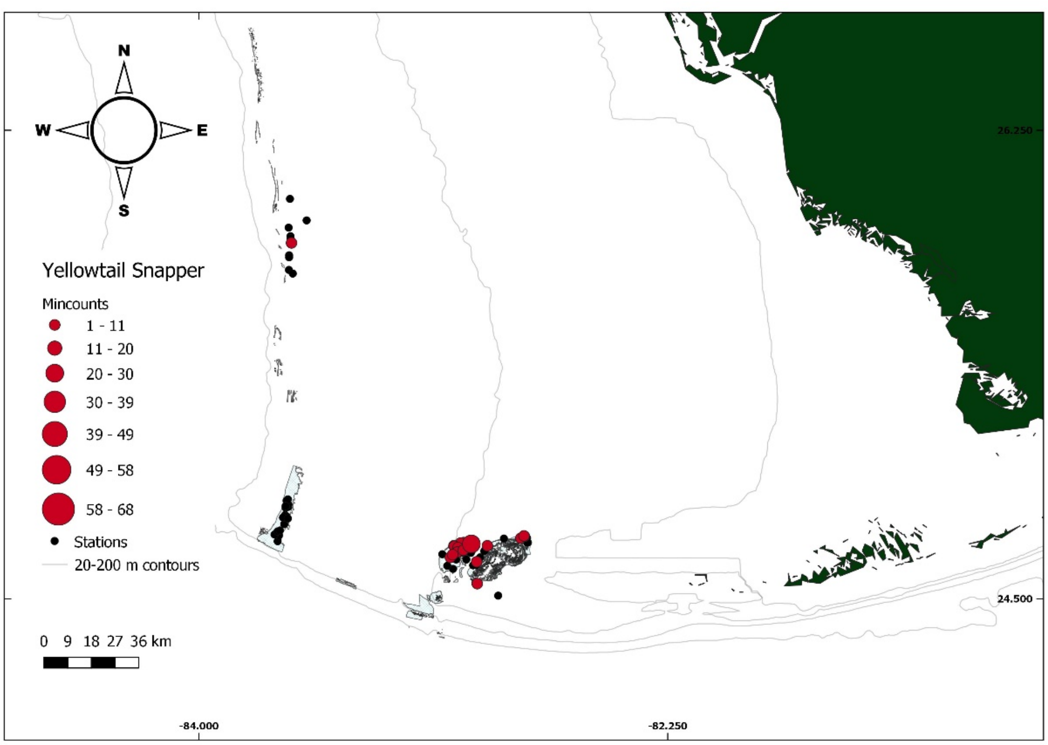


Figure 15. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2005b.

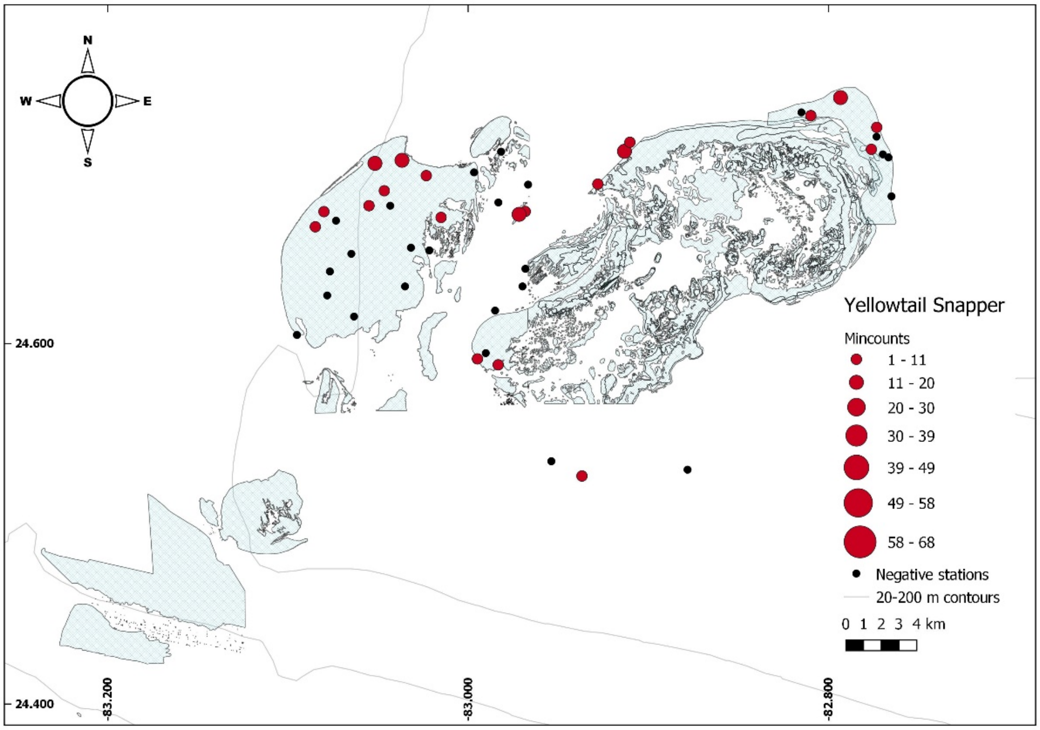


Figure 16. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2007.

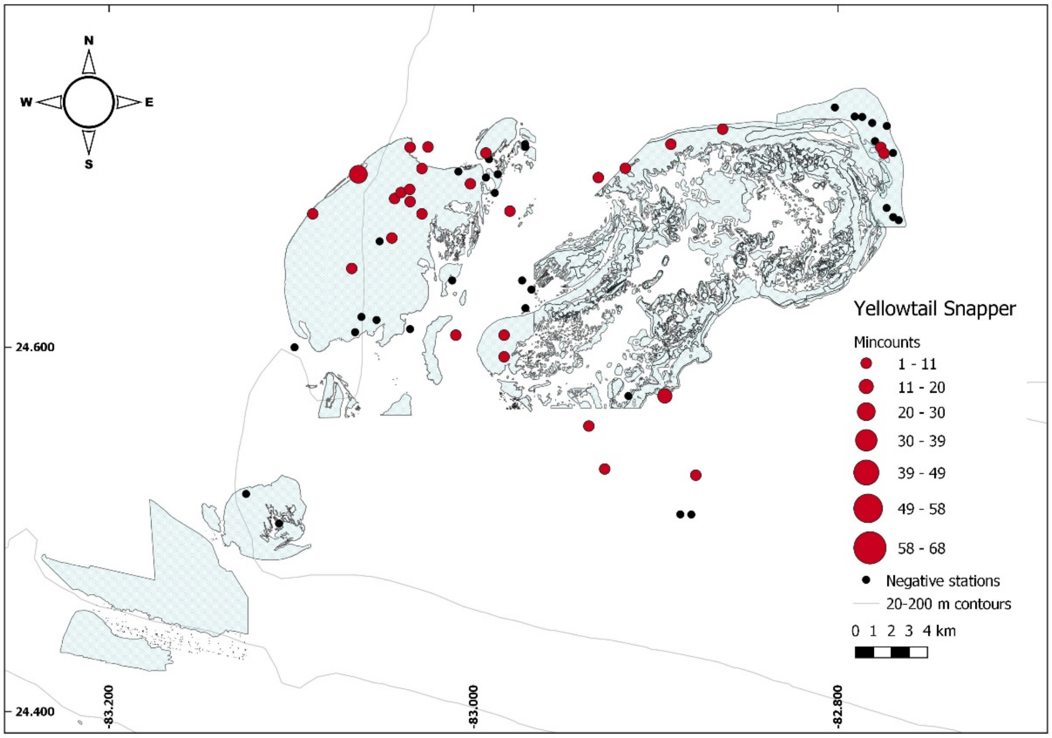


Figure 17. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2008.

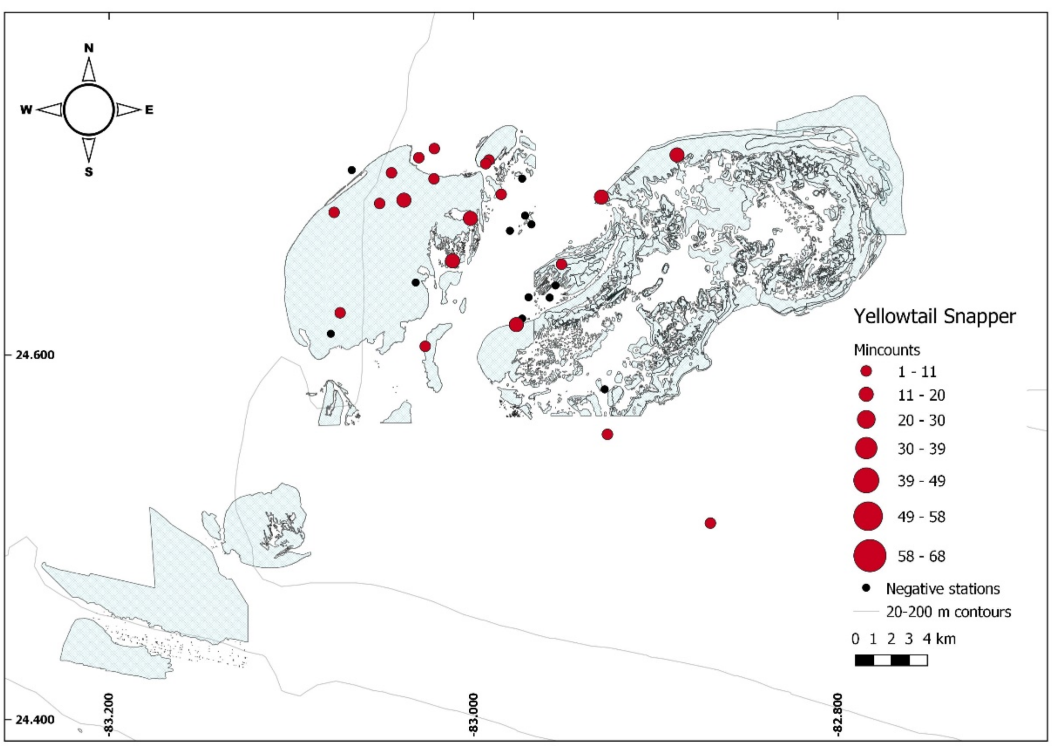


Figure 18. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2009.

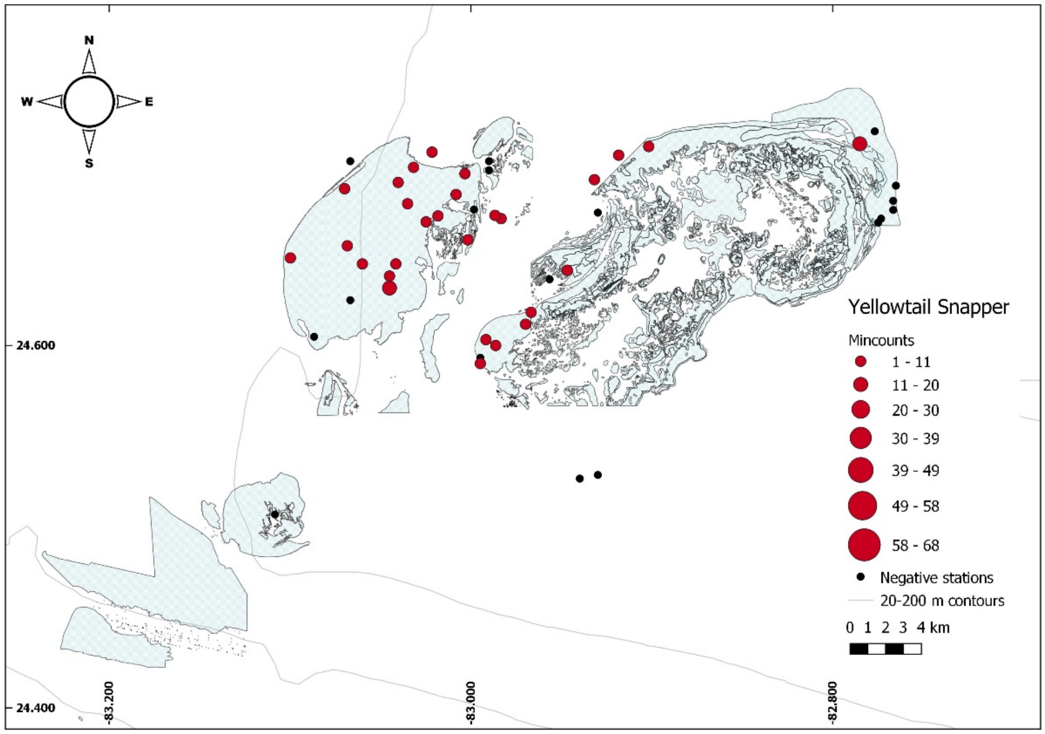


Figure 19. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2010.

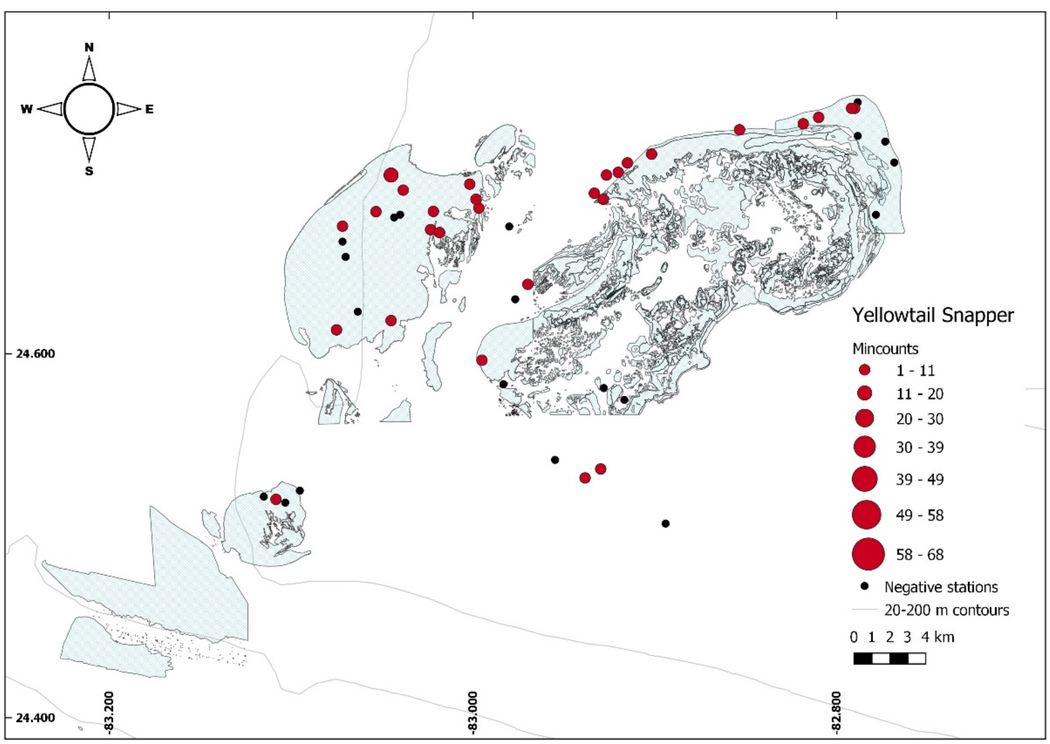


Figure 20. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2011.

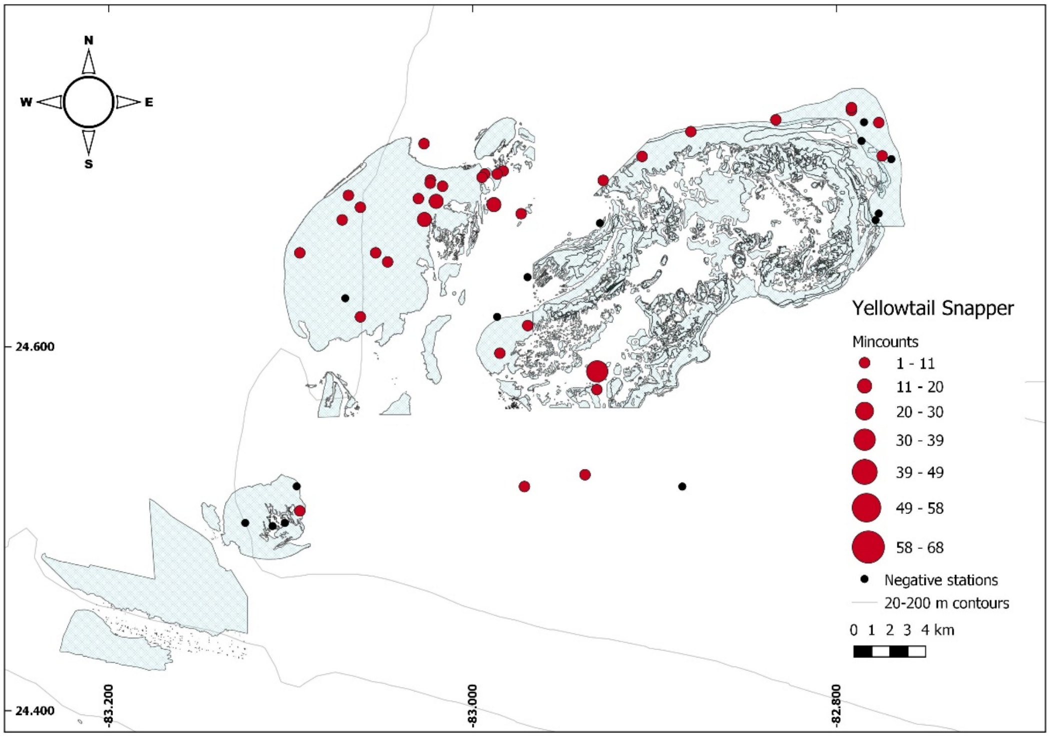


Figure 21. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2012.

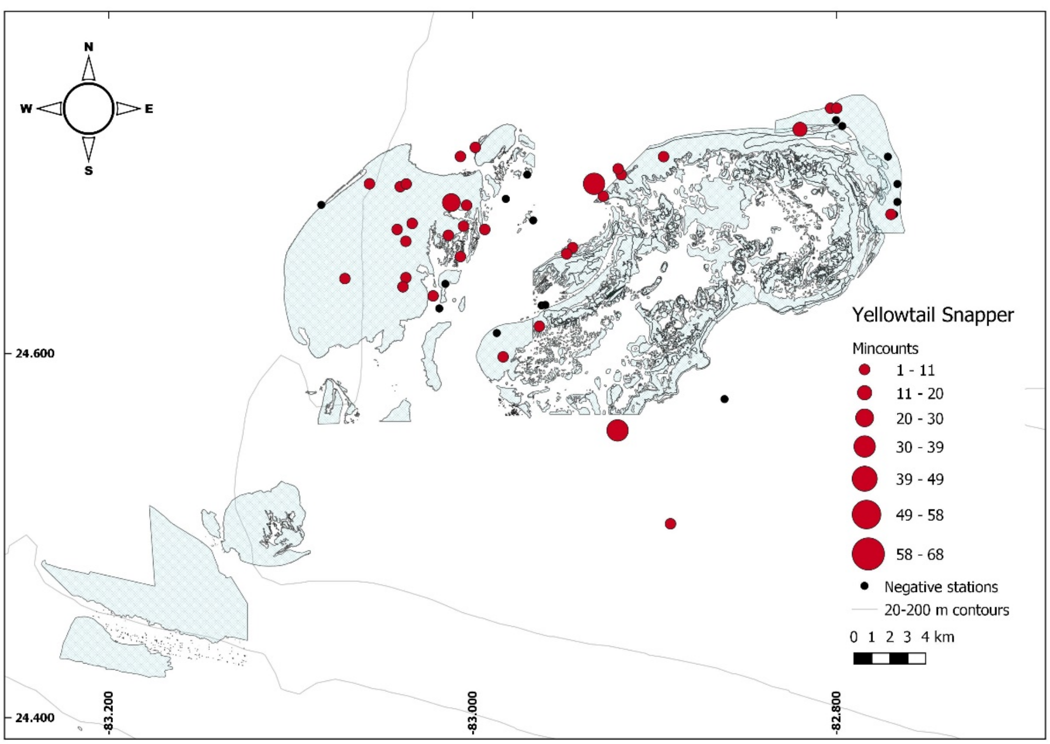


Figure 22. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2012b.

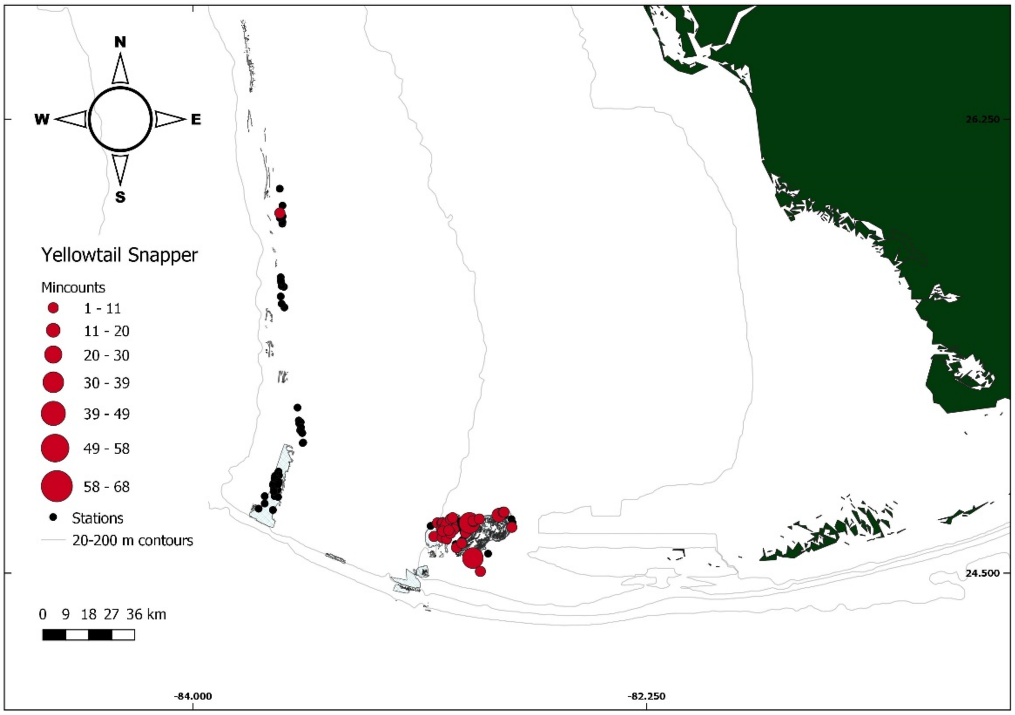


Figure 23. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2014.

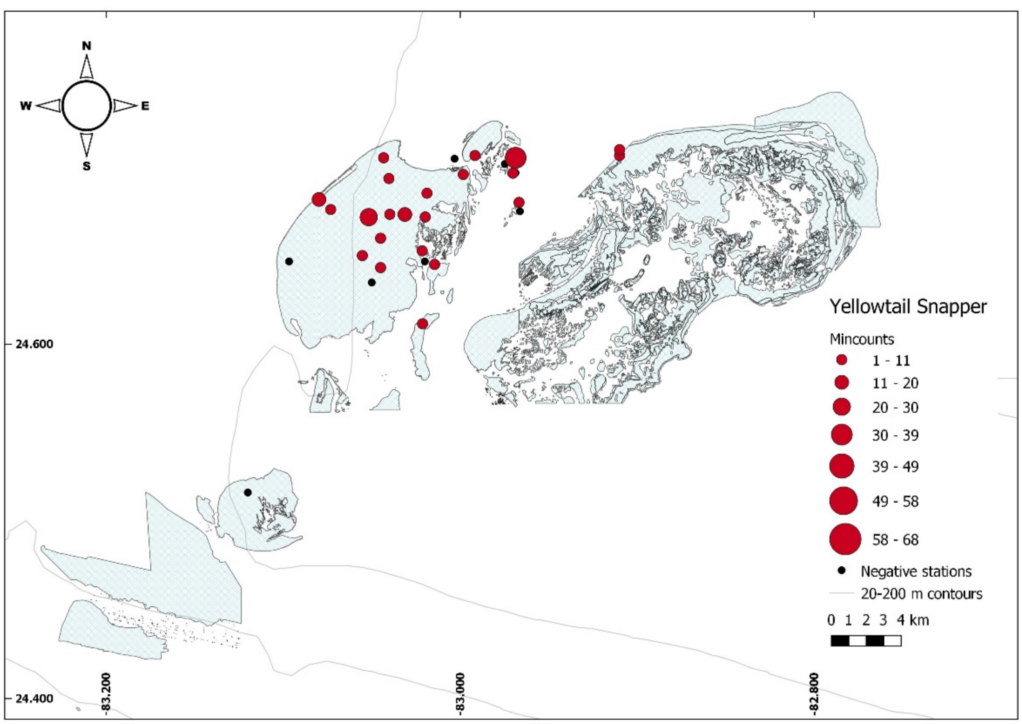


Figure 24. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2016.

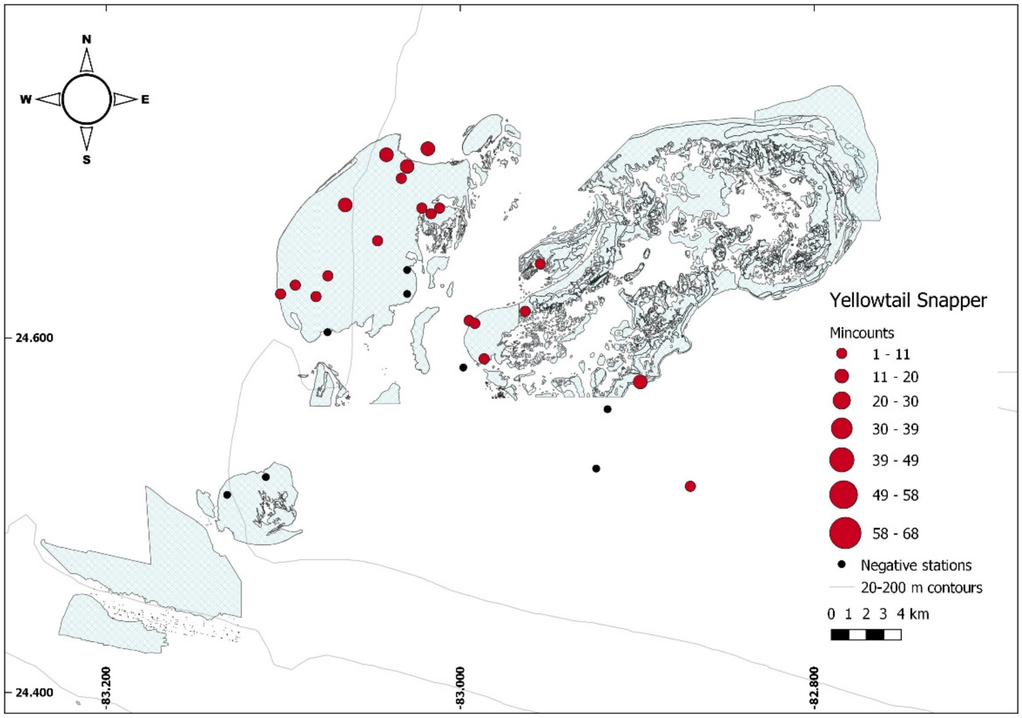


Figure 25. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2016b.

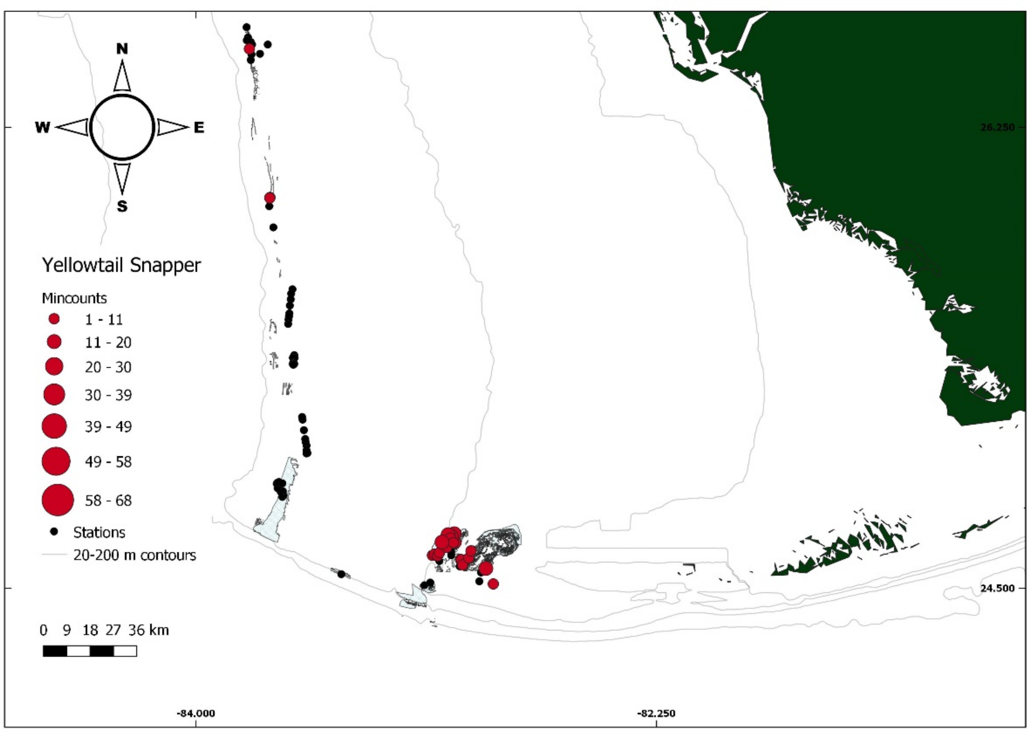


Figure 26. Yellowtail snapper mincounts during the SEAMAP reef fish video cruise in 2017.

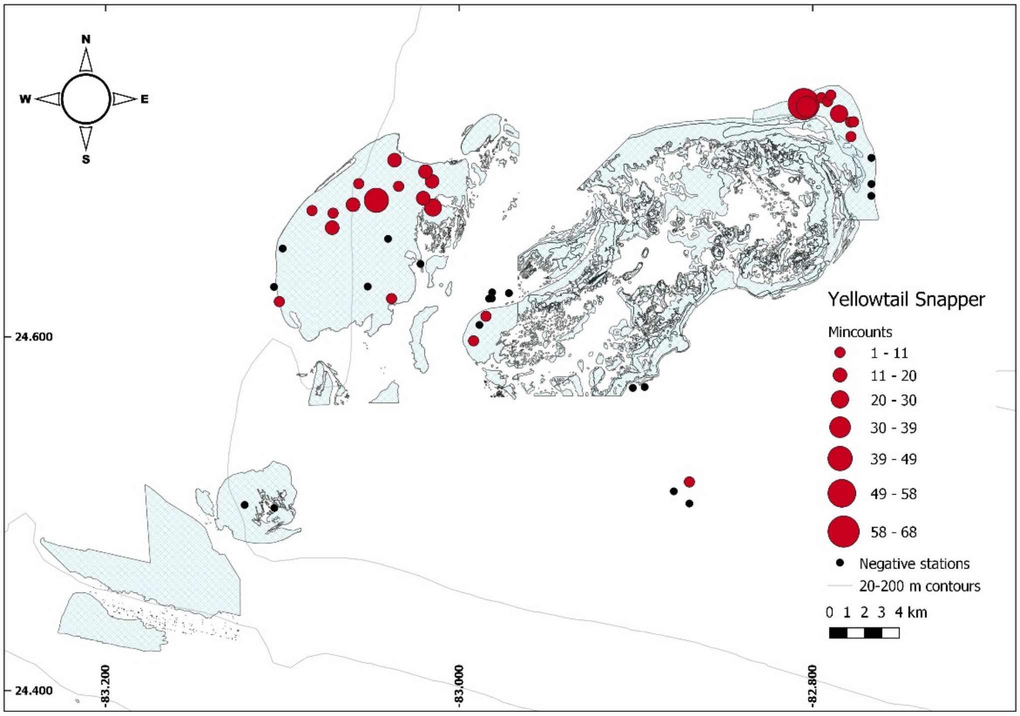
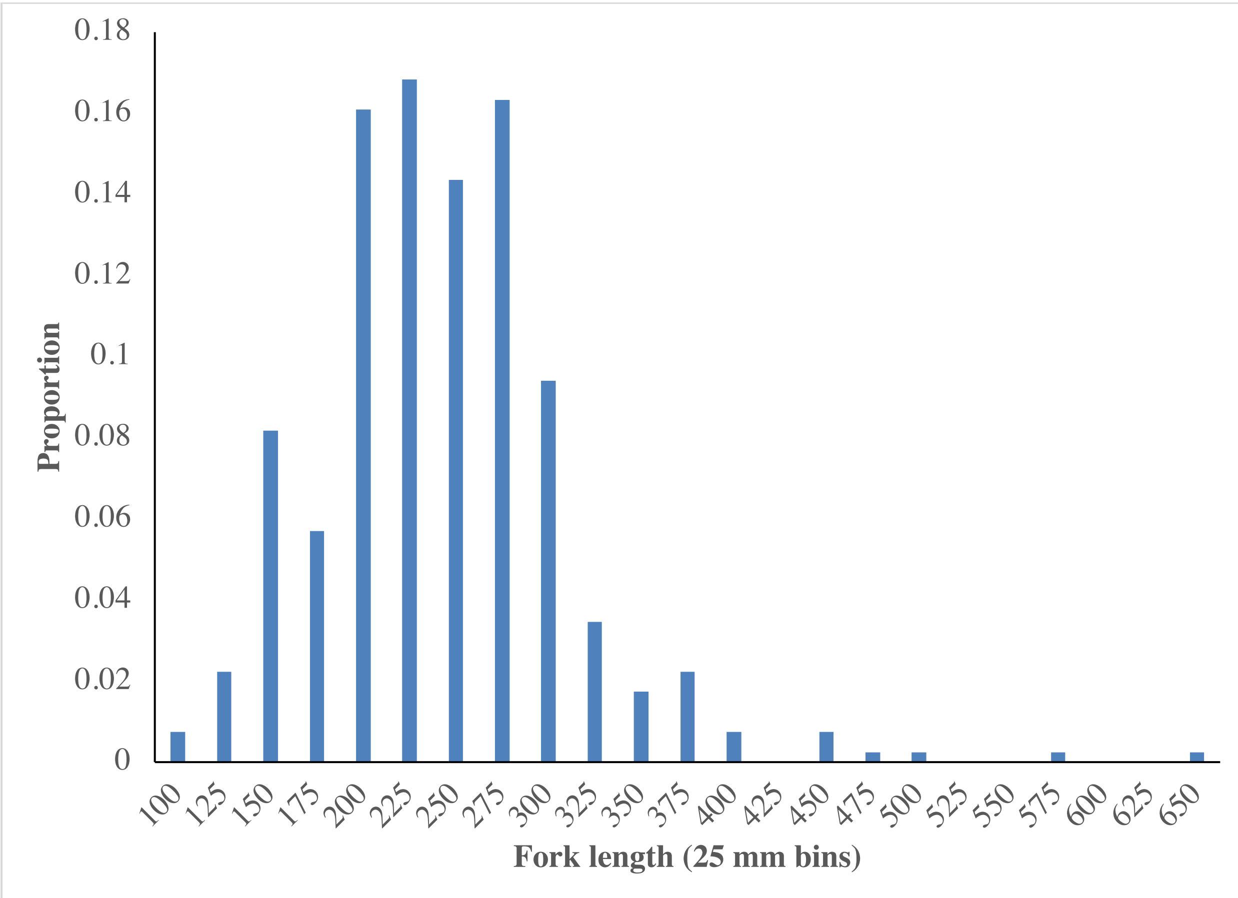


Table 4. Yellowtail snapper mean fork lengths (FL) from the SEAMAP reef fish video cruise from 2002 – 2017.

Year	**Mean**	**STD**
2002	257.00	165.59
2003	268.50	122.33
2004	244.84	33.84
2005	227.80	53.96
2006	231.12	60.04
2007	187.29	30.26
2008	206.42	67.41
2009	245.86	57.95
2010	309.91	49.47
2011	221.88	67.29
2012	244.65	58.83
2014	219.24	65.58
2016	259.79	65.36
2017	220.93	35.89
Total	231.59	71.58

Figure 27. Length frequency histograms of yellowtail snapper observed during the SEAMAP reef fish video cruise from 1993 - 2017.



Appendix 1. Explanatory variables and definitions

Year (Y) = The survey is conducted on an annual basis during the spring and the objective is to calculate standardized observation rates by year. Years included 1993-1997, 2001-2002, and 2004-2014.

Region (R) = The survey is conducted throughout the northern Gulf of Mexico, however historically the SEDAR data workshop has requested separate indices for the western and eastern Gulf which is divided at 89° west longitude. This variable is not included in the model itself.

Block (B) = The first stage of the random site selection process is selected from 10' latitude x 10' longitude blocks. Only blocks containing known reef are eligible for selection. Ten sites are randomly selected from within the blocks. Initial models always include a random block factor to test for autocorrelation among sites within a block.

Strata (ST) = Strata are defined by geographic region (4 regions: South Florida, Northeast Gulf, Louisiana-Texas Shelf, and South Texas), and by total reef habitat area contained in the block (blocks ≤ 20 km^2 reef, block > 20 km^2 reef). There are a total of 7 strata.

Depth (D) = Water depth at the lat-lon where the camera was deployed via TDR placed on the array.

Temperature (T) = Water temperature on the bottom (C°) taken during camera deployment via TDR placed on the camera array.

Dissolved oxygen (DO) = Dissolved oxygen (mg/l) taken via CTD cast slightly away from where the camera is deployed.

Salinity (S) = Salinity (ppt) taken via CTD cast slightly away from where the camera is deployed.

Silt sand clay (SSC) = Percent bottom cover of silt, sand, or clay substrates.

Shell gravel (SG) = Percent bottom cover of shell or gravel substrates.

Rock (RK) = Percent bottom cover of rock substrates.

Attached epifauna (AE) = Percent bottom cover of attached epifauna on top of substrate.

Grass (G) = Percent bottom covered by grass.

Sponge (SP) = Percent bottom covered by sponge.

Unknown sessiles (US) = Percent bottom covered by unknown sessile organisms.

Algae (AL) = Percent bottom covered by algae.

Hardcoral (HC) = Percent bottom covered by hard coral.

Softcoral (SC) = Percent bottom covered by soft coral.

Seawhips (SW) = Percent bottom covered by seawhips.

Relief Maximum (RM) = Maximum relief measured from substrate to highest point.

Relief Average (RA) = Average relief measured from substrate to all measurable points.

Reef (RF) = Boolean variable indicating whether or not a station landed on reef or missed reef. It is a composite variable where positive reef stations area identified as having one of the following: > 5% hard coral or >5% rock or >5% soft coral

Diversity (Hperc) = Shannon weiner diversity index. We calculated Hperc using the percent coverage data associated with the habitat variables (SSC, SG, RK, AE, G, SP, US, AL, HC, SC, and SW).

Diversity (Hbin) = Shannon weiner diversity index. We calculated Hbin using the percent coverage data transformed to binary (presence/absence) values and which are associated with the habitat variables (SSC, SG, RK, AE, G, SP, US, AL, HC, SC, and SW).

Evenness (Jperc) = Pielou's evenness. $J' = H'/H'max$. Evenness is calculation of how equal a community is across species/groups. We calculated Jperc using the percent coverage data associated with the habitat variables (SSC, SG, RK, AE, G, SP, US, AL, HC, SC, and SW).