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Distribution, occurrence and abundance of cobia (*Rachycentron canadum*) larvae captured in ichthyoplankton samples during National Marine Fisheries Service and Southeast Area Monitoring and Assessment Program fishery-independent resource surveys

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Introduction

Plankton survey activities were initiated in the Gulf of Mexico (GOM) by NMFS in 1977 as part of the Marine Resources Monitoring Assessment and Prediction program or MARMAP (Sherman et al. 1983 and Richards, 1987[1]). Most of the plankton sampling during those early annual surveys (1977 – 1981) was conducted in open GOM waters in April and May using essentially the same gear and methods as are in use today (see following sections for details). The success of these initial surveys in providing a useful fishery-independent index of the western Atlantic bluefin tuna spawning stock furnished the motivation and justification for all subsequent plankton survey activities in the GOM. Starting in 1982 resource surveys including plankton surveys carried out by the NMFS /Mississippi Laboratories were incorporated into the Southeast Area Monitoring and Assessment Program or SEAMAP (Sherman et al. 1983; Stuntz et al. 1983). Through this joint Federal-State program coordinated through the Gulf States Marine Fisheries Commission the NMFS and the states of Louisiana, Mississippi, Alabama and Florida conduct plankton sampling cooperatively during resource surveys in the GOM.

The goal of plankton surveys under SEAMAP has been to assemble a time series of data on the occurrence, abundance and geographical distribution of fish eggs and larvae, as well as, to collect data on selected physical properties of their pelagic habitat. These data can then be used to more precisely describe/define the spawning times and areas of GOM fishes and the relationship of their early life stages to environmental (abiotic) factors. Furthermore it was anticipated (and shown now to be true) that this time series of annual abundance estimates could eventually provide a valuable fishery-independent index of spawning stock size for additional GOM species as was first demonstrated for tuna

[1] Richards, W.J. 1987. MEXUS-Gulf ichthyoplankton research, 1977–84. Marine Fisheries Review 49:39–41, http://spo.nmfs.noaa.gov/mfr491/mfr4917.pdf.

from pre-SEAMAP plankton surveys. Larval indices of abundance based on SEAMAP plankton survey data have been developed for Atlantic bluefin tuna (Scott et al. 1993), king mackerel (Gledhill and Lyczkowski-Shultz 2000), red snapper (SEDAR52-WP-11[2]; Hanisko et al. 2007), vermilion snapper (SEDAR45-WP-05[3]) and gray triggerfish (SEDAR9-DW25[4]). After larval identifications have been verified (as necessary) nominal and model-generated indices of larval abundance over the SEAMAP time series are now routinely provided to SEFSC stock assessment scientists.

A review of historical literature, larval development and the distribution and ecology of cobia early plankton life stages in GOM was previously presented by Ditty and Shaw (1992). This report represents the first data summary for cobia larvae captured in GOM plankton samples during SEAMAP and NMFS resource surveys over the time period 1982 to 2016.

Methods

<u>Survey Design</u>

Area and station layout (spatial considerations)

The overall SEAMAP sampling area covers the entire northern GOM from the 10 m isobath out to the U.S. EEZ, and comprises approximately 300 designated sampling sites i.e. 'SEAMAP' stations. Most stations are located at 30-nautical mile or 0.5^{o} (~56 km) intervals in a fixed, systematic, 2-dimensional latitude-longitude grid of transects across the GOM. Some SEAMAP stations are located at < 56 km intervals especially along the continental shelf edge, while others have been moved to avoid obstructions, navigational hazards or shallow water. The majority of SEAMAP plankton samples have been taken during dedicated plankton surveys and groundfish (trawl) surveys at these stations but over the years additional samples were taken using SEAMAP gear and collection methods at locations other than designated SEAMAP stations and/or outside established SEAMAP surveys, e.g. during Louisiana seasonal trawl surveys, SEAMAP Squid/Butterfish survey; and other serendipitous or special projects/surveys.

Timeframe (temporal considerations)

The original plan for SEAMAP plankton surveys was for sampling to be conducted in both continental shelf (10-200 m depth range) and open GOM waters (shelf edge, i.e. 200 m to the limits of the EEZ) at least once during each season. This ambitious goal could not be achieved due to logistic constraints; neither all areas, nor all seasons, could be sampled every year Gulf-wide. As a result

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[2] Hanisko, D.S., AG. Pollack, D.M. Drass, P.J. Bond, C. Stepongzi, T. Wallace, A. Millet, C. Cowan, C.M. Jones, G. Zapfe and G.W. Ingram, Jr.. 2017. Red Snapper (Lutjanus campechanus) larval indices of relative abundance from SEAMAP Fall Plankton Surveys, 1986 to 2016. SEDAR52-WP-11. SEDAR, North Charleston, SC. 36 pp.
[3] Hanisko, D.S., A. Pollack and G. Zapfe. 2015. Vermilion snapper (Rhomboplites aurorubens) larval indices of relative abundance from SEAMAP Fall Plankton Surveys, 1986 to 2012 SEDAR45-WP-05. SEDAR, North Charleston, SC. 34 pp
[4] Lyczkowski-Shultz, J, D.S. Hanisko and G.A. Zapfe. 2005. Review of the early life history of gray triggerfish, Balistes capriscus, with a summary of data from SEAMAP plankton surveys in the Gulf of Mexico: 1982, 1984-2002. SEDAR, North Charleston, SC. 38 pp.

SEAMAP plankton surveys have yet to encompass the spawning seasons of all fish species; with a particular deficiency of sampling during winter months.

As a consequence SEAMAP plankton data have been collected primarily during four survey periods: spring (April to early June, annually, 1982 to present), summer (June and July, annually, 1982 to present), late summer/early fall (typically in September, annually, 1986 to present) and fall (October and November, annually, 1982 to 2014). The spring survey covers only open GOM waters (within the U.S. EEZ), while the summer and fall (trawl) surveys encompass only continental shelf waters from south Texas to Mobile Bay. The late summer/early fall survey encompasses the continental shelf waters from south Texas to south Florida. Analytical data is currently available for the spring and fall dedicated plankton surveys through 2016, and through 2012 for all other surveys.

Gear

The standard sampling gear and methodology used to collect plankton samples during SEAMAP surveys are similar to those recommended by Kramer et al. (1972), Smith and Richardson (1977) and Posgay and Marak (1980). Plankton sampling protocols and guidelines for the two standard SEAMAP gear using during resource surveys (bongo and neuston nets) are described in detail in the SEAMAP Field Operations manual (2007). A 61 cm (outside diameter) bongo net fitted with 0.335 mm mesh netting is fished in an oblique tow path from a maximum depth of 200 m or to 2-5 m off the bottom at station depths less than 200 m. A single or double, 2x1 m pipe frame neuston net fitted with 0.950 mm mesh netting is the other primary (standard) gear employed and it is towed at the surface with the frame half-submerged for 10 minutes.

Maximum bongo tow depth is calculated using the amount of wire paid out and the wire angle at the 'targeted' maximum tow depth or is directly observed using a SBE 19 or Seacat to view and record bongo net depth in real time throughout the tow. A mechanical flowmeter is mounted off-center in the mouth of each bongo net to record the volume of water filtered. During surveys in 1982 and 1983 (in part) a flowmeter was placed in only one side of the bongo gear. Water volume filtered during bongo net tows ranges from ~20 to 600 m^3 but is typically 30 to 40 m^3 at the shallowest stations and 300 to 400 m^3 at the deepest stations.

Catches of larvae in bongo net samples are standardized to account for sampling effort and typically expressed as number under 10 m^2 sea surface by dividing the number of larvae by volume filtered and then multiplying the resultant by the product of 10 and maximum depth of tow. This procedure results in a less biased estimate of abundance than number per unit of volume filtered alone and permits direct comparison of abundance estimates across samples taken over a wide range of water column depths (Smith and Richardson 1977). Catches of larvae in neuston net samples are standardized to account for tow time and expressed as the number of larvae per 10 minute tow.

Post Survey Data Collection (Plankton Sample Processing and Identification)

Essential elements of SEAMAP plankton survey activities include sample processing (sorting and identification), specimen archival and re-examination of selected taxa. Since the inception of the

SEAMAP program most plankton samples have been sorted for fish eggs and larvae, and specimens have been initially identified (mostly to the family level) at the Sea Fisheries Institute, Plankton Sorting and Identification Center (MIR ZSIOP), in Gdynia and Szczecin, Poland under a Joint Studies Agreement between the NMFS and the Sea Fisheries Institute. During the period 1989 to 2002 plankton samples collected by the Louisiana Department of Wildlife and Fisheries were processed by Louisiana state biologists following SEFSC/SEAMAP protocols in use at MIR ZSIOP.

Vials of eggs and identified larvae, plankton displacement volumes, total egg counts; and counts and body length measurements of identified larvae are sent to the SEAMAP Archive at the Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, FL. At the SEAMAP Archive data are entered into the SEAMAP database and specimens are curated and loaned to researchers upon request. Data files containing specimen identifications and lengths are sent to the NMFS Mississippi Laboratories where these data are combined with field collection data, edited and maintained in the SEAMAP data base. Examination and re-identification of the larvae of selected taxa by SEFSC ichthyoplankton specialists are routinely undertaken in order to assure accurate and consistent identifications over the time series. A full re-examination of all cobia larvae has not been undertaken for this summary. However, re-examination of a random subset of 43 samples consisting of 419 larvae indicated no misidentifications.

Analysis and Summary

A total of 11,514 bongo and 13,138 neuston net collections taken during NMFS and SEAMAP fishery - independent resource surveys in the GOM and South Atlantic (SA) were used to examine the distribution, occurrence and abundance of the larval stages of cobia. Limited sampling effort has been conducted by NMFS and SEAMAP outside of the U.S Exclusive Economic Zone in the northern GOM. The southern GOM accounts for 1.8 % of bongo and neuston net samples and the South Atlantic 0.5%. Maps depicting the relative sampling effort of bongo and neuston net collections and the presence/absence of cobia larvae by 0.5 degree longitude by latitude grid cells are shown in Figures 1 and 2.

Cobia larvae were rarely taken in bongo and neuston net collections (Table 1). Only 107 larvae were taken in bongo net samples, and 978 larvae taken in neuston samples. A single anomalous catch of 231 larvae (Sample 43814) accounted for 24 % all larvae captured in neuston samples. Only 2 larvae were taken in neuston samples (Samples 24589 and 24636) from the SA, and 12 larvae were taken in a single bongo sample (Sample 37520) in the southern GOM. The proportion of positive occurrence of cobia larvae was 0.007 for bongo samples and 0.025 for nueston samples. Overall, the proportion of positive occurrence of cobia larvae in neuston collections was 3.6 times greater than for bongo collections. Bongo and nueston net abundances reflected similar patterns as proportion of positive occurrence.

The occurrence of cobia larvae from NMFS and SEAMAP bongo and nueston net collections by month was consistent with the known spawning season of adult cobia in the GOM and SA (Table 1, Franks and Brown-Peterson, 2002 and Ditty and Shaw, 1992). Larvae in bongo net collections were taken primarily from April through September. However, a single specimen was identified in a December bongo net sample. This specimen may represent a misidentification and will be further examined. Larvae in neuston net collections were taken during the months of May through September. The proportion of positive occurrence of cobia larvae peaked in July for both bongo and neuston nets.

The SEAMAP spring plankton (April to early June), SEAMAP summer groundfish (June and July) and the SEAMAP fall plankton survey (Late August to Early October) are conducted during the months when cobia are known to spawn. Bongo and neuston samples from these surveys are used to examine the occurrence and distribution of cobia larvae in further detail. The analysis utilizes only samples from core SEAMAP systematic grids (B-Numbers) at which greater than 5 bongo or nueston samples were taken for each times series. These core B-Number stations are typically sample each year allowing for the determination of occurrence rates at individual systematic grid stations. Combined, these core stations accounted for 65.5% of bongo samples, 73.8% of bongo caught larvae, 71.6% of neuston samples and 71.9% of neuston caught larvae examined for this report.

Core stations sampled during the SEAMAP spring plankton survey were collected Gulfwide primarily during the months of April and May from the edge of the U.S continental shelf to the limits of the U.S. EEZ.boundary (Figure 3). Cobia larvae were primarily taken in a narrow band of stations along the shelf edge in the northwestern and northcentral GOM in both bongo and nueston collections. Cobia larvae occurred less frequently at stations located in the open GOM. These occurrences most likely represent larvae that have been entrained by the Loop Current and/or associated warm and cold core eddy interaction with the outer continental shelf. Proportion of positive occurrence and abundance were higher at station located near the shelf break than in the open GOM for bongo and nueston net (Table 2).

Unlike the spring survey, core stations sampled during the SEAMAP summer groundfish and fall plankton surveys are collected over the U.S. continental shelf (Figures 4 and 5). The summer groundfish survey has consistently covered the continental shelf from Brownsville, TX to Mobile Bay, AL during June and July. Cobia larvae taken in summer groundfish neuston samples were distributed throughout the survey area with higher proportion of positive occurrence at core stations east of 96 degrees west. In contrast, cobia larvae taken in summer groundfish bongo samples were only found at higher proportion of positive occurrence at core stations over the mid to outer shelf. The fall plankton survey has consistently sampled the continental shelf from Brownsville, TX to Key West, FL primarily during the month of September. Cobia larvae from fall nueston samples in the northwestern and northcentral GOM exhibited distribution and occurrence patterns at core stations similar to those of summer groundfish survey. Cobia larvae in fall plankton bongo nets were distributed throughout the northwestern and northcentral GOM. However, their highest proportions of positive occurrence were over the middle shelf as opposed to middle and outer shelf for summer groundfish survyes. Cobia larvae were only taken over the West Florida shelf in fall plankton nueston net collections. Distribution of larvae on the West Florida shelf was patchy and did not exhibit any clear pattern.

The proportion of positive occurrence and abundance of cobia taken over the U.S. continental shelf varied greatly between surveys, regions and gears (Table 2). The highest occurrence of cobia larvae was seen for neuston samples taken in the northwestern and northcentral GOM. Cobia larvae in this region were 2.1 times greater than for fall plankton nueston samples taken in the same area. Proportion of positive occurrence from bongo samples was also highest in the northwestern and northcentral GOM, but never exceeded 1% during fall plankton surveys. Larval abundance in nueston samples was highest in the northwestern and northcentral GOM with catch rates 2.7 times greater than for fall plankon neuston samples taken in the same area. No cobia larvae were taken in core bongo net samples over the West Florida shelf.

The spatial distribution of cobia larvae from the SEAMAP spring plankton, summer groudnfish and fall plankton surveys place the center of larval occurrence and abundance over the continental shelf of the northwest and northcentral GOM. The appearance of larvae coincides with the annual migration of adult fish into the northern GOM during the spring and the onset and duration of the spawning season (Dippold et al., 2017, Franks and Brown-Peterson, 2002 and Ditty and Shaw, 1992). Cobia larvae rarely occurred in open GOM waters during spring plankton surveys suggesting that spawning occurs primarily shoreward of the shelf break. However, sampling during this survey overlaps only with the early months of the spawning season, and it is unknown whether larval distributions may extend further offshore during months at which peak spawning occurs. Cobia larvae also occurred infrequently in fall plankton survey samples over the West Florida shelf in the late summer and early fall. The timing of survey occurs at the end of the spawning season making it unclear as the extent of larval distribution in the eastern GOM. Several years of sampling conducted during the summer months over the West Florida shelf will be available in the near future, and may be able to help clarify larval distribution and occurrence in the eastern GOM.

Future work will focus on examining relationships between larval occurrence, abundance and environmental data to further elucidate the factors driving their distributions. In addition, the potential for annual indices of relative abundance will also be explored based on SEAMAP summer groundfish and fall plankton surveys. These two surveys represent relative long time series with sampling coverage in spatial areas where cobia larvae frequently occur, at least in the northwestern and northcentral GOM.

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Table 1. Total samples, total larvae, samples with larvae, proportion of positive occurrence (PPO), standard error of proportion of positive occurrence (PPO SE), mean standardized catch (Catch) and standard error of catch of cobia larvae by month from bongo and nueston net samples. Catch is standardized to the number of larvae under 10 m^2 sea surface for bongo nets and number per 10 minute tow for neuston nets.

Bongo

Month	Total Samples	Total Larvae	Samples with Larvae	PPO	PPO SE	Catch	Catch SE
1	151	0	0	0.000	0.000	0.000	0.000
2	265	0	0	0.000	0.000	0.000	0.000
3	331	0	0	0.000	0.000	0.000	0.000
4	857	17	6	0.007	0.003	0.119	0.078
5	2249	17	17	0.008	0.002	0.044	0.011
6	979	17	12	0.012	0.004	0.064	0.020
7	869	20	16	0.018	0.005	0.114	0.031
8	662	9	5	0.008	0.003	0.044	0.022
9	3063	26	19	0.006	0.001	0.034	0.009
10	1053	0	0	0.000	0.000	0.000	0.000
11	771	0	0	0.000	0.000	0.000	0.000
12	264	1	1	0.004	0.004	0.024	0.024
Total	11514	107	76	0.007	0.001	0.044	0.007

Nueston

Month	Total Samples	Total Larvae	Samples with Larvae	PPO	PPO SE	Catch	Catch SE
1	181	0	0	0.000	0.000	0.000	0.000
2	244	0	0	0.000	0.000	0.000	0.000
3	215	0	0	0.000	0.000	0.000	0.000
4	1266	0	0	0.000	0.000	0.000	0.000
5	3254	40	33	0.010	0.002	0.012	0.002
6	1057	431	69	0.065	0.008	0.403	0.219
7	856	232	89	0.104	0.010	0.280	0.046
8	632	38	21	0.033	0.007	0.065	0.019
9	3439	236	111	0.032	0.003	0.069	0.009
10	1064	1	1	0.001	0.001	0.001	0.001
11	712	0	0	0.000	0.000	0.000	0.000
12	218	0	0	0.000	0.000	0.000	0.000
Total	13138	978	324	0.025	0.001	0.075	0.018

Table 2. Total samples, total larvae, samples with larvae, proportion of positive occurrence (PPO), standard error of proportion of positive occurrence (PPO SE), mean standardized catch (Catch) and standard error of catch of cobia larvae by region from bongo and nueston net samples collected at core stations during SEAMAP Spring Plankton, Summer Groundfish and Fall Plankton surveys. Catch is standardized to the number of larvae under 10 m^2 sea surface for bongo nets and number per 10 minute tow for neuston nets.

SEAMAP Spring Plankton

Gear	Region	Total Samples	Total Larvae	Samples with Larvae	PPO	PPO SE	Catch	Catch SE
Bongo	Shelf Break	1069	9	9	0.008	0.003	0.054	0.018
	Open GOM	1576	11	11	0.007	0.002	0.046	0.014
	All	2645	20	20	0.008	0.002	0.049	0.011
Neuston	Shelf Break	1578	42	25	0.016	0.003	0.028	0.009
	Open GOM	2601	14	11	0.004	0.001	0.005	0.002
	All	4179	56	36	0.009	0.001	0.014	0.004

SEAMAP Summer Groundfish

Gear	Region	Total Samples	Total Larvae	Samples with Larvae	PPO	PPO SE	Catch	Catch SE
Bongo	Northwestern and Northcentral GOM	1387	35	26	0.019	0.004	0.110	0.024
Neuston	Northwestern and Northcentral GOM	1364	398	142	0.104	0.008	0.297	0.044

SEAMAP Fall Plankton

Gear	Region	Total Samples	Total Larvae	Samples with Larvae	PPO	PPO SE	Catch	Catch SE
Bongo	Northwestern and Northcentral GOM	1960	24	19	0.010	0.002	0.049	0.013
	West Florida Shelf	1550	0	0	0.000	0.000	0.000	0.000
	All	3510	24	19	0.005	0.001	0.028	0.007
Neuston	Northwestern and Northcentral GOM	2295	236	110	0.048	0.004	0.104	0.013
	West Florida Shelf	1572	7	7	0.004	0.002	0.005	0.002
	All	3867	243	117	0.030	0.003	0.064	0.008

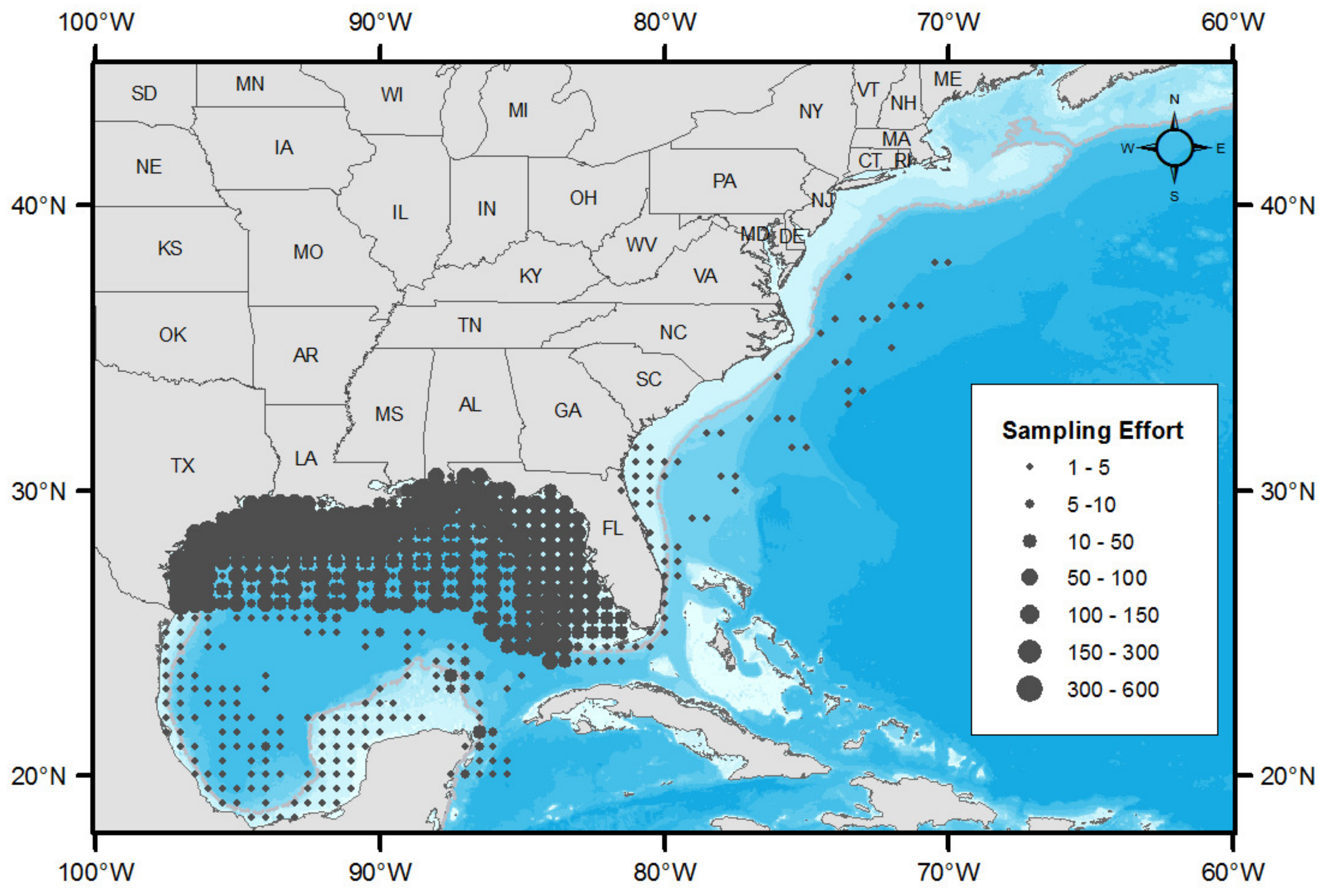


Figure 1. Relative sampling effort of NMFS and SEAMAP bongo and nueston nets tows by 0.5 degree longitude by latitude grid cells.

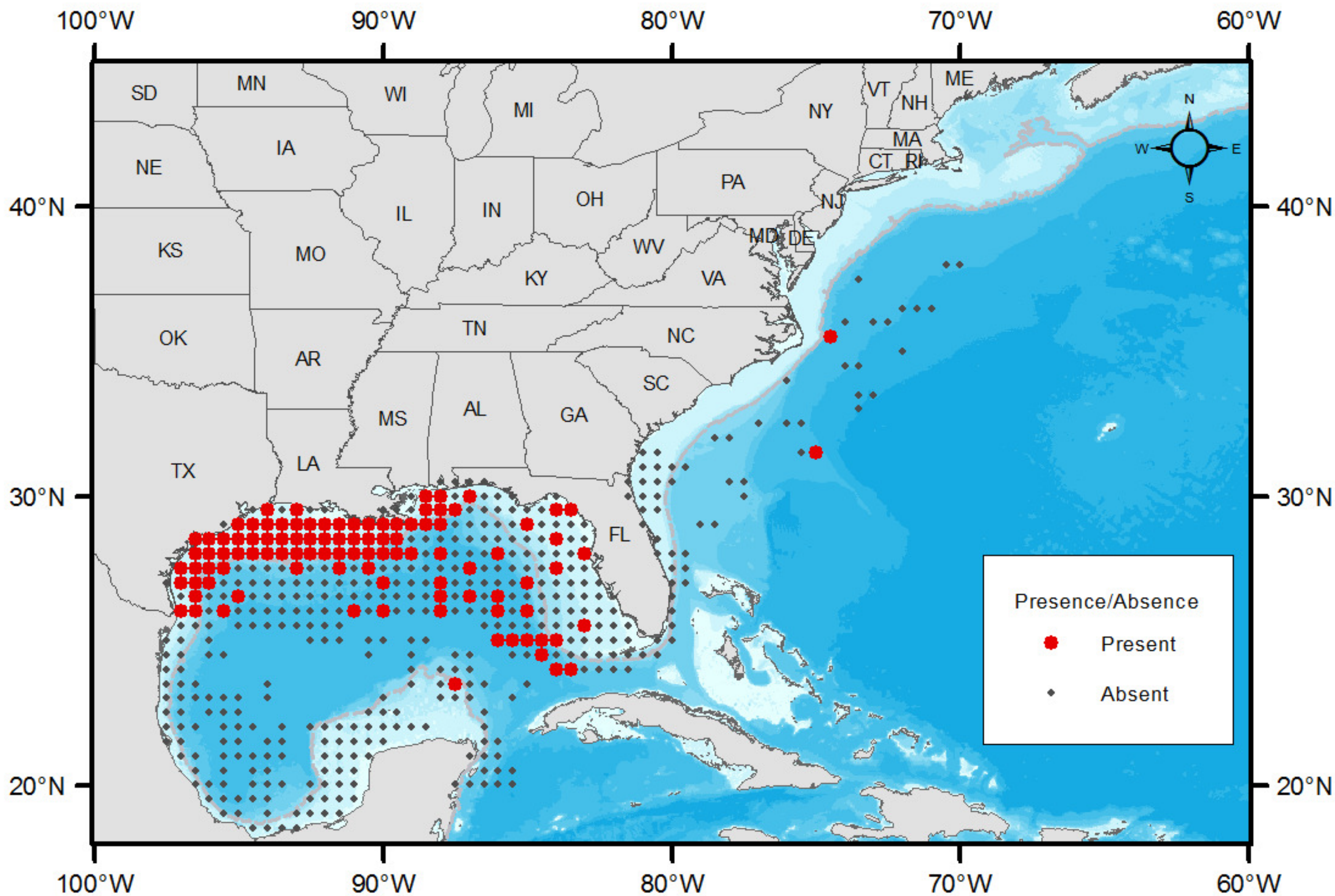
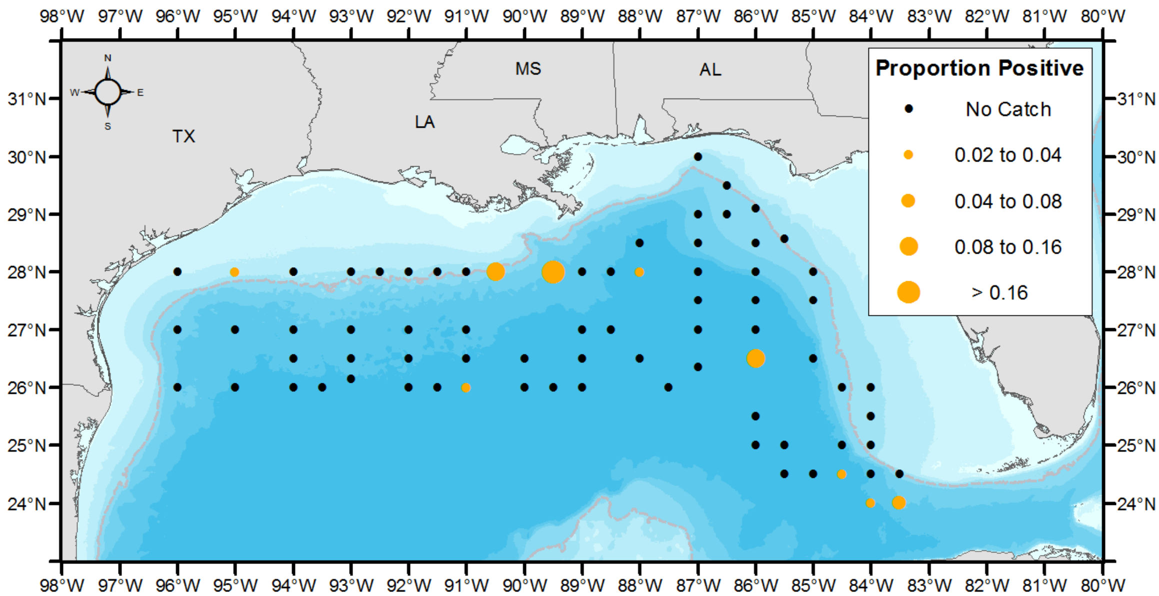


Figure 2. Presence/Absence of cobia larvae taken during NMFS and SEAMAP bongo and nueston nets tows by 0.5 degree longitude by latitude grid cells.



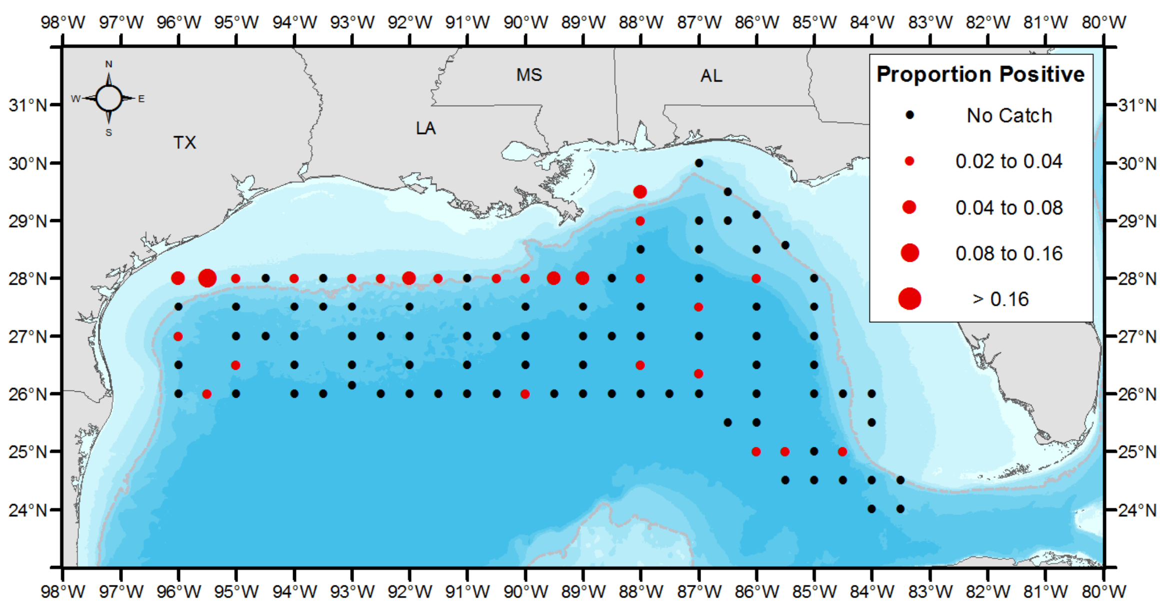


Figure 3. SEAMAP Spring Plankton survey proportion of positive occurrence at core B-Number stations for bongo (top) and neuston (bottom) nets.

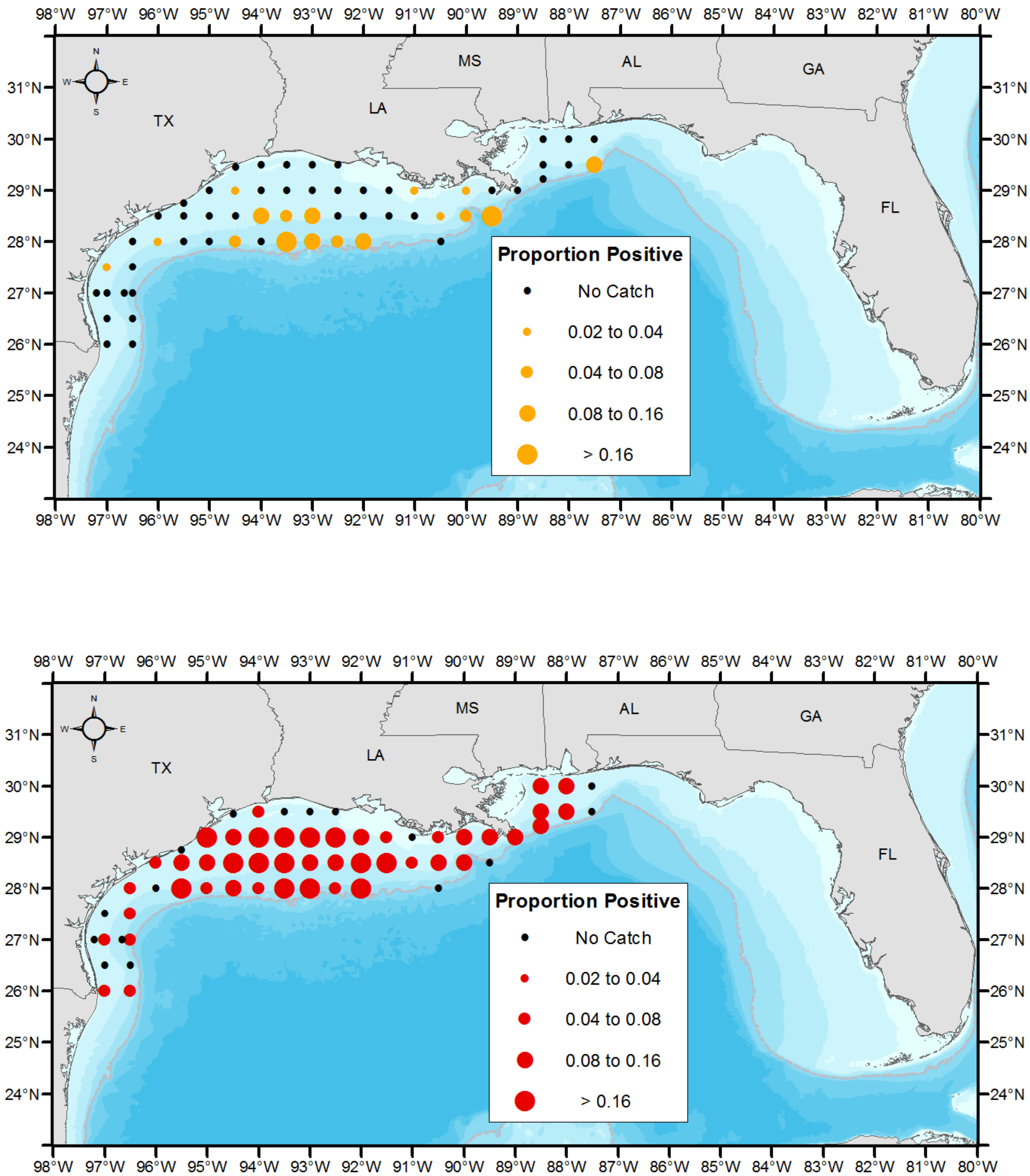


Figure 4. SEAMAP Summer Groundfish survey proportion of positive occurrence at core B-Number stations for bongo (top) and neuston (bottom) nets.

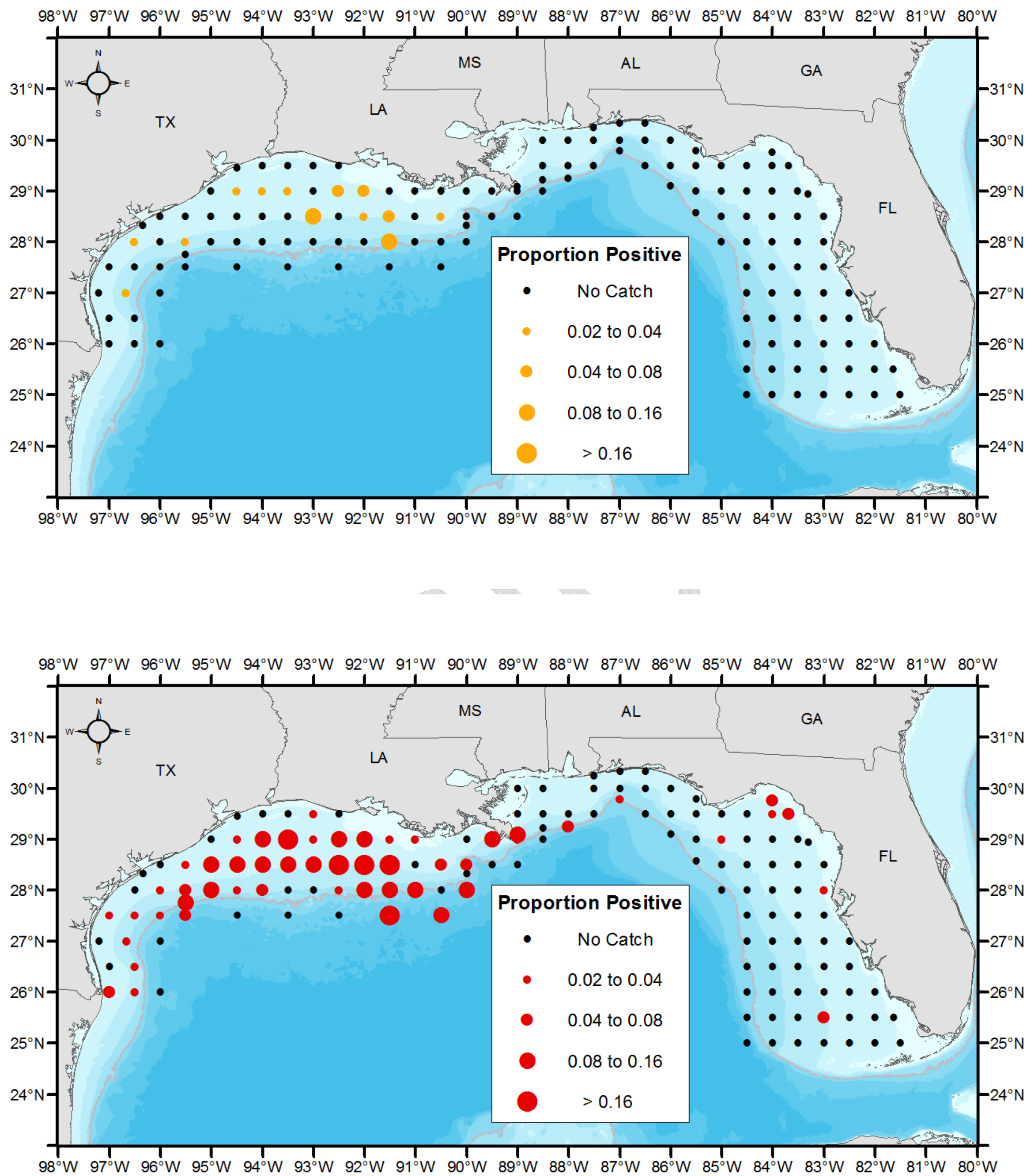


Figure 5. SEAMAP Fall Plankton survey proportion of positive occurrence at core B-Number stations for bongo (top) and neuston (bottom) nets.