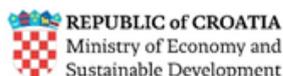


Map of distribution of boat traffic within and adjacent to the Natura 2000 SCI

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1. Introduction

The Soundscape project aims to investigate the behavioural response of the sensitive marine species to vessel traffic in the Cres-Lošinj archipelago. Therefore, a land-based survey was conducted, in which an electronic theodolite determined the positions of vessels.

A theodolite is a precision optical instrument for measuring angles between designated visible points in the horizontal and vertical planes. It consists of a mounted moveable telescope so it can rotate around horizontal and vertical axes and provide angular readouts. These indicate the orientation of the telescope and are used to relate the first point sighted through the telescope to subsequent sightings of other points from the same theodolite position. These angles can be measured with accuracies down to micro radians or seconds of arc. From these readings, a plan can be drawn, or objects can be positioned by an existing plan. The modern theodolite has evolved into what is known as a total station where angles and distances are measured electronically and are read directly into the computer memory.

A theodolite is a surveying instrument that is typically used in the field of geodesy. However, in the 1970s, Roger Payne and colleagues developed a method for collecting data on free-ranging marine mammals, which is non-invasive and shore-based (Piwetz et al., 2018). To examine how groups of bottlenose dolphins (*Tursiops truncatus*) and vessels interact around the Kvarnerić Sea, positions were measured by using an electronic theodolite “Sokkia SET500 Total Station”.

Noise generated by diverse human activities (anthropogenic noise) has altered the quality of the marine environment with consequences on physiology, communication, behaviour, and energetics of different marine species. Their responses to sound depend on characteristics such as sound levels and frequency, duration of exposure to it, animals’ state and distance from the sound source and they differ between species based on their hearing sensitivity. Anthropogenic sound in the sea is acknowledged as an important environmental stressor that can, in the long term, have detrimental consequences on the fitness, survival, and reproductive success of entire populations and species. (Rako Gospić et al, 2019)

The sole purpose of collecting data with theodolite is to prove that marine traffic can affect marine species in the Cres- Lošinj archipelago. This way allowed us to take real-time snapshots of specific time sessions of all vessels which were visible by the theodolite at that time, even including ones that did not have AIS (Automatic identification system).

2. Methods

2.1. Study area

The study site was located on the Kalvariija hill in Veli Lošinj, Lošinj island (Croatia). The theodolite tracking was conducted from a shore-based observation point “Sveti Ivan” 44.51° N, 14.50° E (source: Google Earth) on an elevation of 228.00 m above mean sea level overlooking the east side of the bay. The observation point was close to the sea (linear distance about 1.36 km) (source: Google Earth). Additionally, a second location was used for the west side of the bay, at Balvanida 44.50° N, 14.50° E (source: Google Earth) on an elevation of 184.00 m above mean sea level overlooking the west side of the bay.

This map shows the area of the Natura2000 areas, and it was focused on Cres- Lošinj archipelago. Also, the locations of theodolite were added to the map.

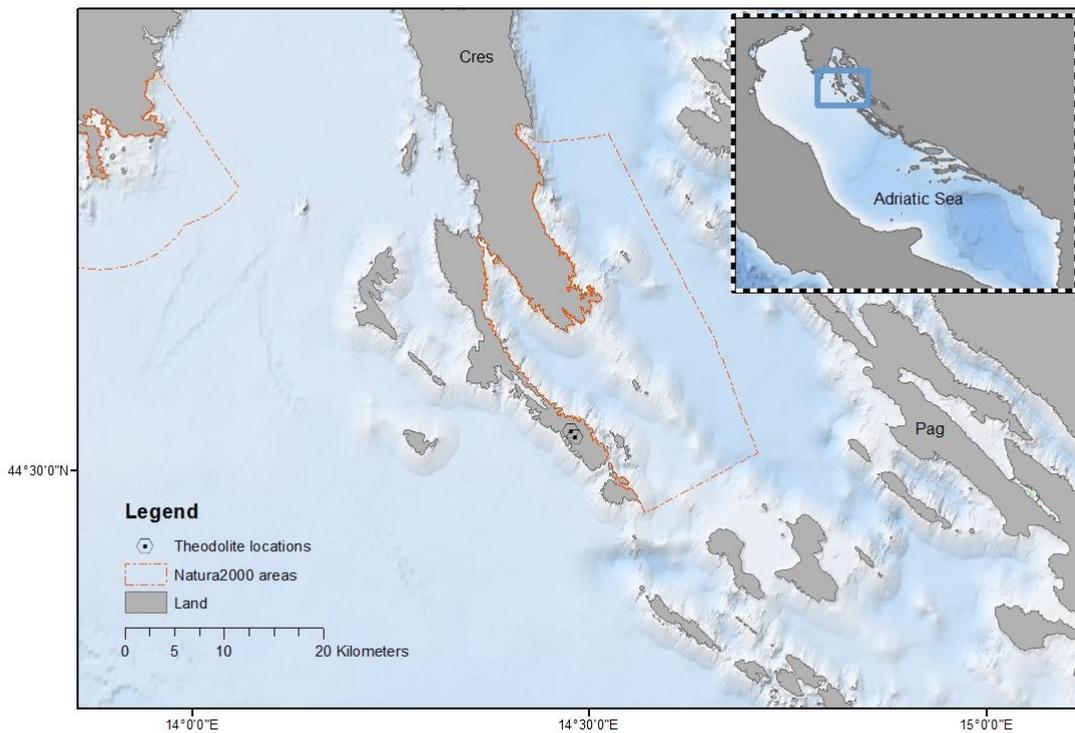


Figure 1. Natura2000 area around Cres - Lošinj archipelago

2.2. Time management

The survey was conducted in two seasons: summer 2020 and winter 2021. The summer season was from June until September 2020, a total of three months and the winter season was from October 2020 until March 2021, in the Cres- Lošinj archipelago.

In the summer season, the observation was performed with an alternating schedule at three set hours during the day. The late schedule was 09:30h, 13:30h, and 17:30h; the early schedule was at 8:30h, 12:30h, and 16:30h.

During the winter season, the observation was performed with an alternating schedule at two set hours during the day. The late schedule was 9:30h and 13:30h; the early schedule was at 8:30 and 13:30h.

2.3. Environmental conditions

For the observation period, the environmental conditions were considered. The wind intensity was no more than 4 on the Beaufort scale (Ribeiro et al, 2005). The visibility was 2 km or over (Papale et al., 2011). During the monitoring, data on environmental variables e.g. sea state, wind speed and direction, cloud cover, temperature, and tide height were collected at the beginning of every session. It is important to mention that it could not be rainy because the equipment could be short-circuited. The data were taken when weather conditions are favourable, which meant no wind over 4 on the Beaufort scale, no rain and the visibility has to be over 2 km.

2.4. Materials

- Electronic theodolite (Sokkia SET500)
- Field computer
- Magnification field scope/binoculars
- VADAR software (Visual Detection and Ranging at sea)
- ArcGIS software
- R software

2.5. Data collection

The survey was performed using an observation platform from fixed points on land to collect data on the positions and number of vessels according to different categories in the study area of the Kvarnerić Sea. It was important to mention that area where theodolite positions are is uneven and theodolite could not be exactly positioned every time, and there would be always an unnoticeable difference between

different measurements. Also, the nearby area was full of trees, which results in the not full-field view from theodolite positions.



Figure 2. Researcher with theodolite

2.6. Vessels categories

Data on marine vessels were collected during the theodolite survey. The vessels were divided into 9 different categories:

- research boat (RB)
- recreational boat (motor yachts; jet ski; military; police)
- Dolphin watching boat (DW)
- cargo ship (tugboat)
- fishing boat (FB) (trawler; trammel net boat; purse seiner)
- small local boat (LB - up to 6 m with no engine above 10 HP)
- sailing boat (sailB) (engine; sails; engine, catamaran; sails, catamaran; sails + engine; sails + engine, catamaran)
- tour boat (TourB – big excursion boats)
- ferry

2.7. Data analysis

Data were collected with a theodolite on the mentioned locations manually. Theodolite shows vertical and horizontal bearings of locations, and they were written in a predetermined form that is printed out.

Information on the form was:

Weather conditions

- Date
- Time
- Wind speed
- Wind direction
- Swell height
- Swell direction
- Beaufort
- Cloud coverage
- Glare
- Rain
- Fog

Sightings

- Observation number
- Category of the vessel
- Time
- Horizontal bearing
- Vertical bearing
- Subcategory of the vessel

The data were analysed with ArcGIS software, which could present locations of all vessels and their encounter rates.

For presenting relative density, or in other words encounter rates, it was decided to use a 2x2 km² grid layer, because it would not inflate the dataset with cells that have no value, and to have counteracted with errors.

Field of view was added to maps because it was noticed through analysis that the optimal distance to analyse vessels was 15 km, everything over 15 km wasn't very reliable to determine which kind of vessel there were. Cargo ships are very large vessels, and because of their routes they could not travel close to the coast, but yet again, they were detectible because of their size, so that was why they were spotted on bigger distances.

Relative density was shown on maps as an intersection of grid layer and point layer, and each grid cell was divided by the number of sessions in that interval of time.

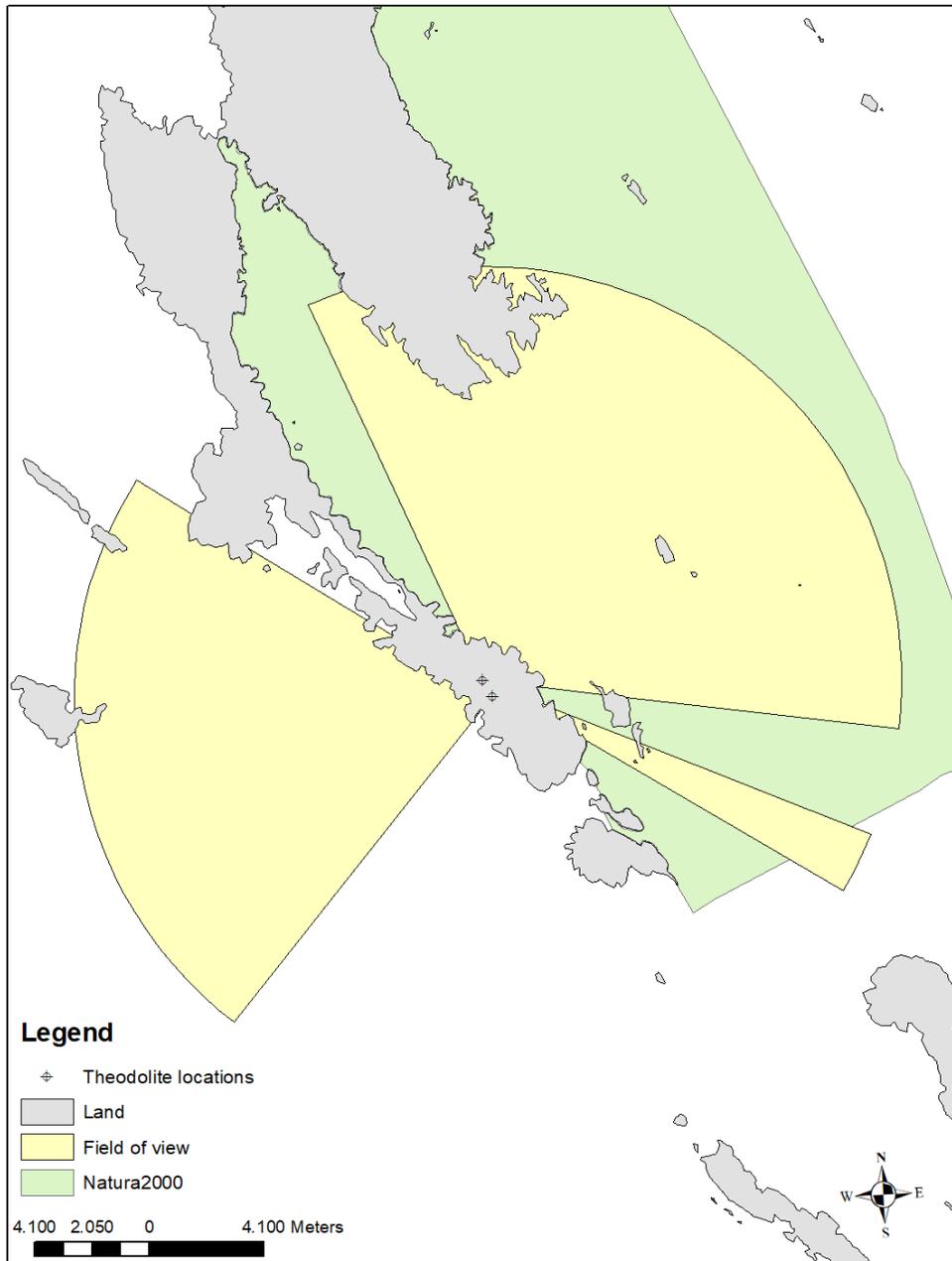


Figure 4. Field of view

3. Results

We have collected data on the number of overnight stays during the year 2020 in harbour Mali Lošinj, which was from January 3rd 2020 until December 31st 2020. The total number of overnight stays was 8971.

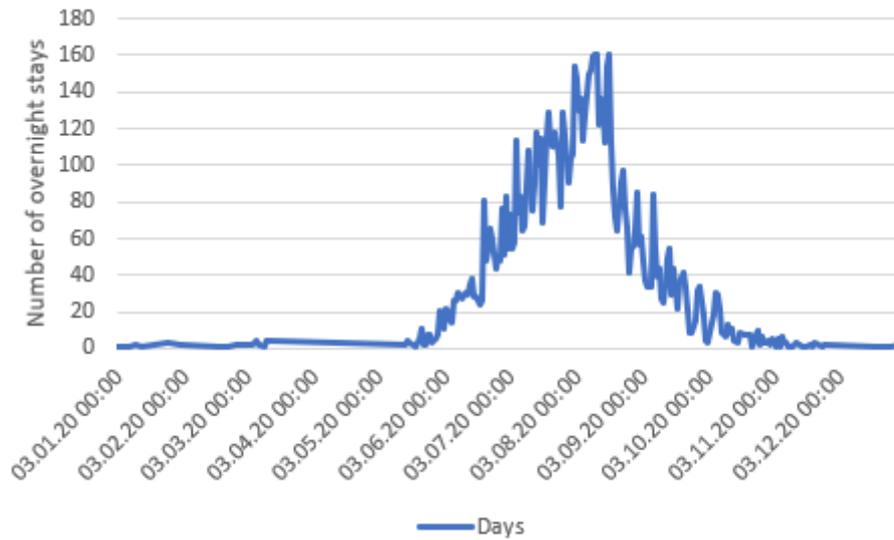


Figure 5. Histogram of overnight stays in Mali Lošinj harbour

3.1 Seasons

This section was divided into seasons, summer and winter. It has shown all data in the Cres- Lošinj archipelago through each season.

Summer

The next map shows the positions of all vessels during summer 2020, from June 6th 2020 until September 30th 2020. Each category has a different colour which represents a different category.

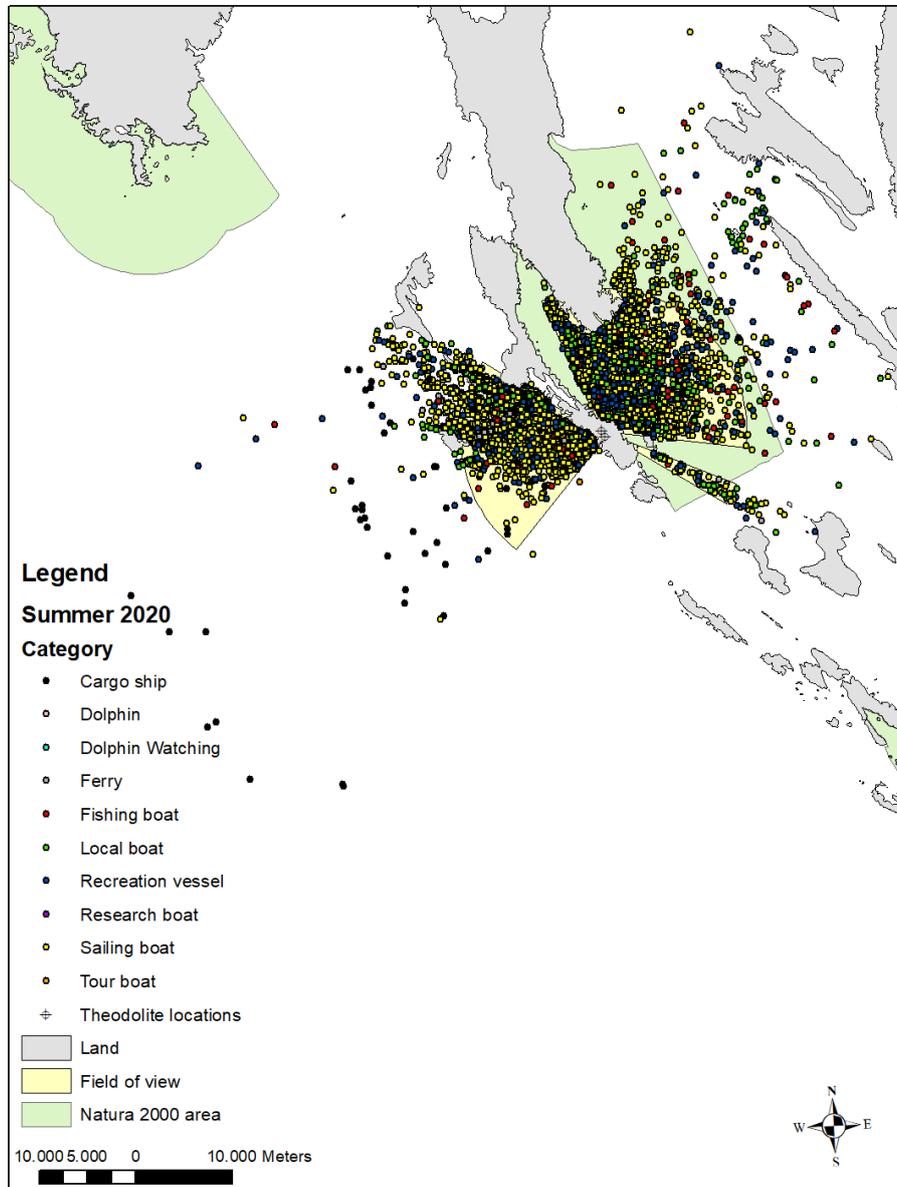


Figure 6. Locations of vessels - Summer 2020

The next map shows the relative density of vessels during summer 2020. Each grid cell was divided by a total number of sessions, from June 6th 2020 until September 30th 2020 (which were 222 sessions).

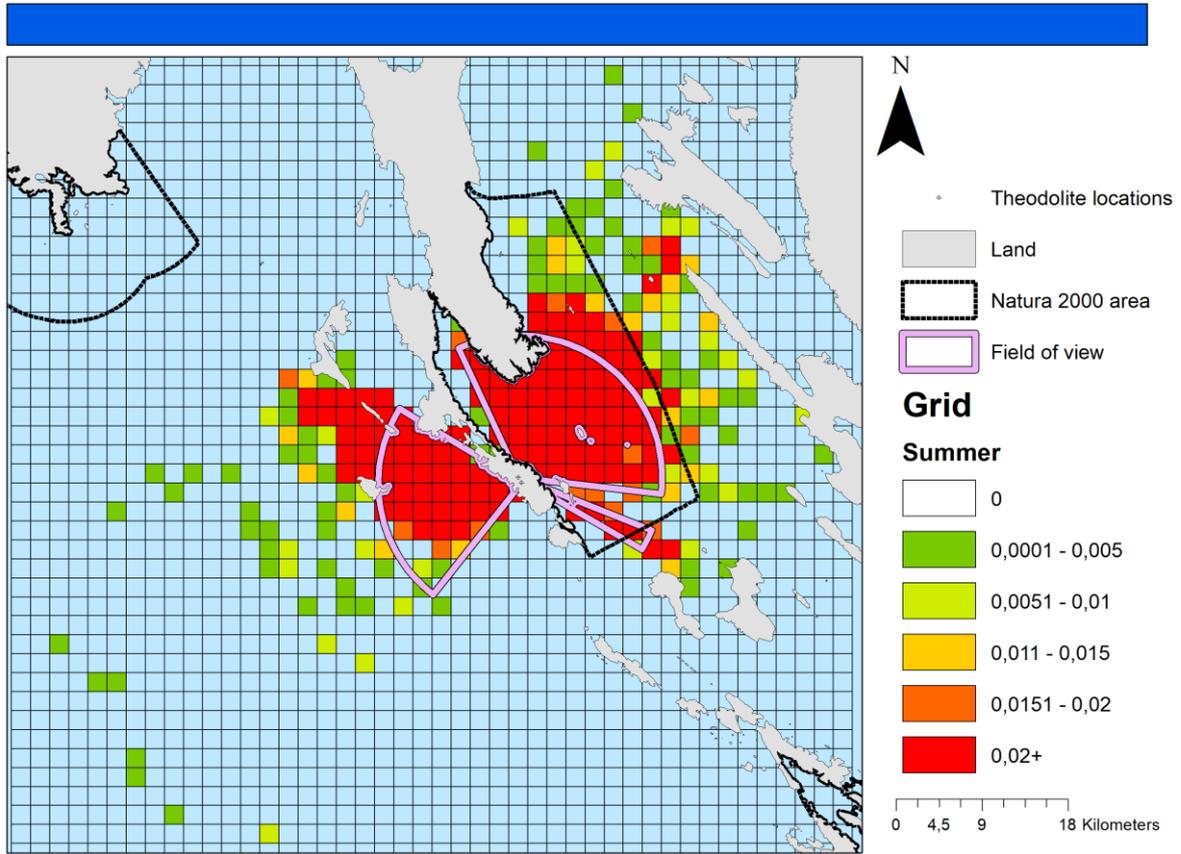


Figure 7. Relative density - Summer 2020

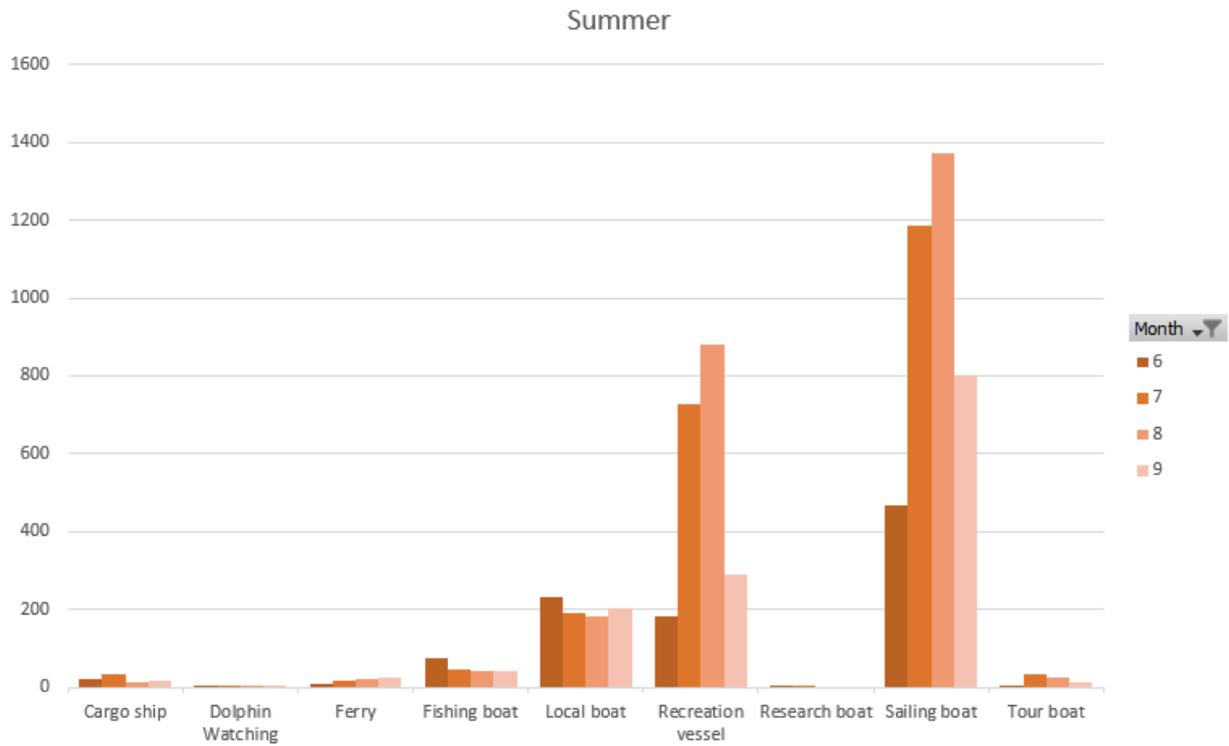


Figure 8. Number of vessels by categories - Summer 2020

Winter

The next map shows the positions of all vessels during winter 2021, from October 1st 2020 until March 31st 2021. Each category has a different colour which represents a different category.

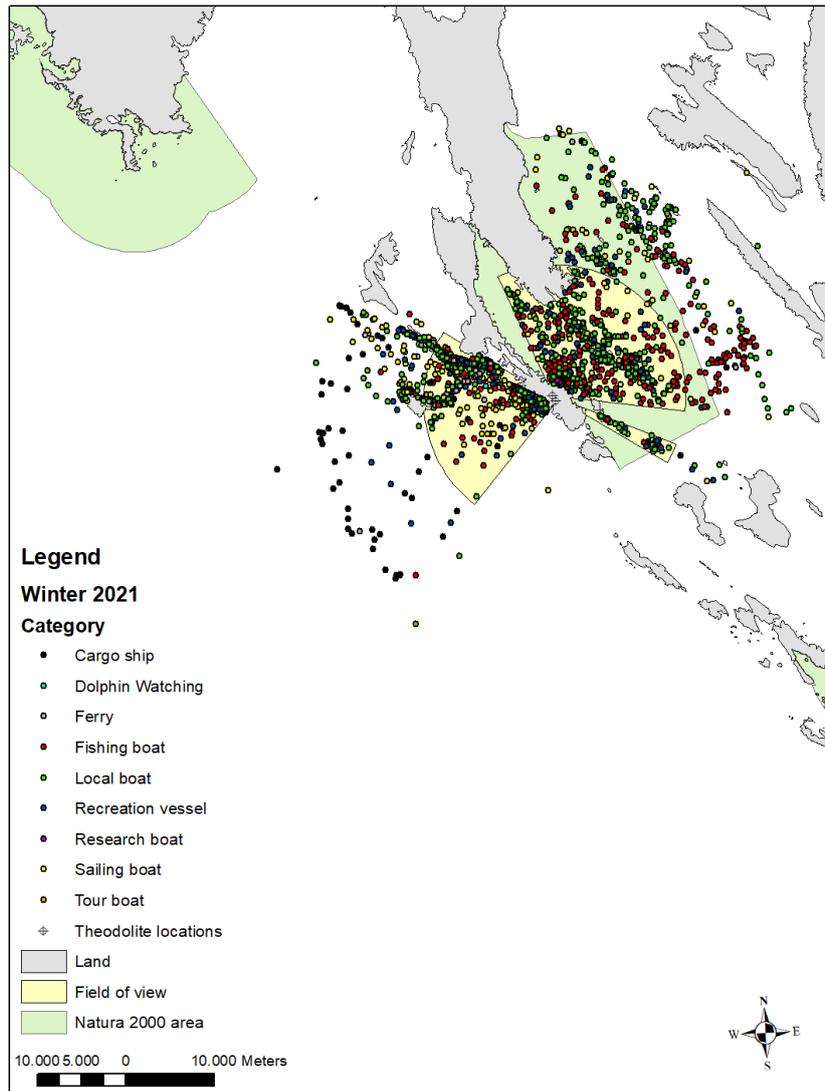


Figure 9. Locations of vessels - Winter 2020

The next map shows the relative density of vessels during winter 2021. Each grid cell was divided by a total number of sessions, from October 1st 2020 until March 31st 2021 (which were 183 sessions).

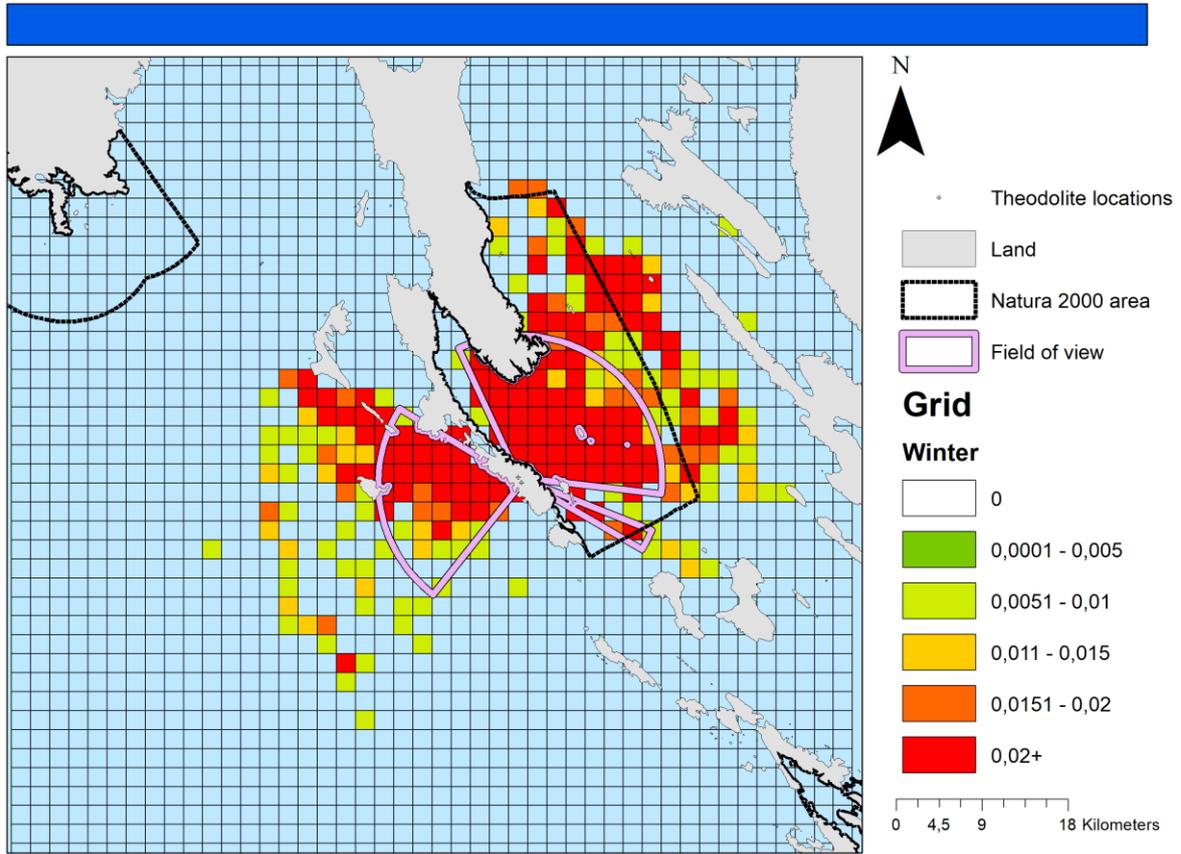


Figure 10. Relative density - Winter 2020

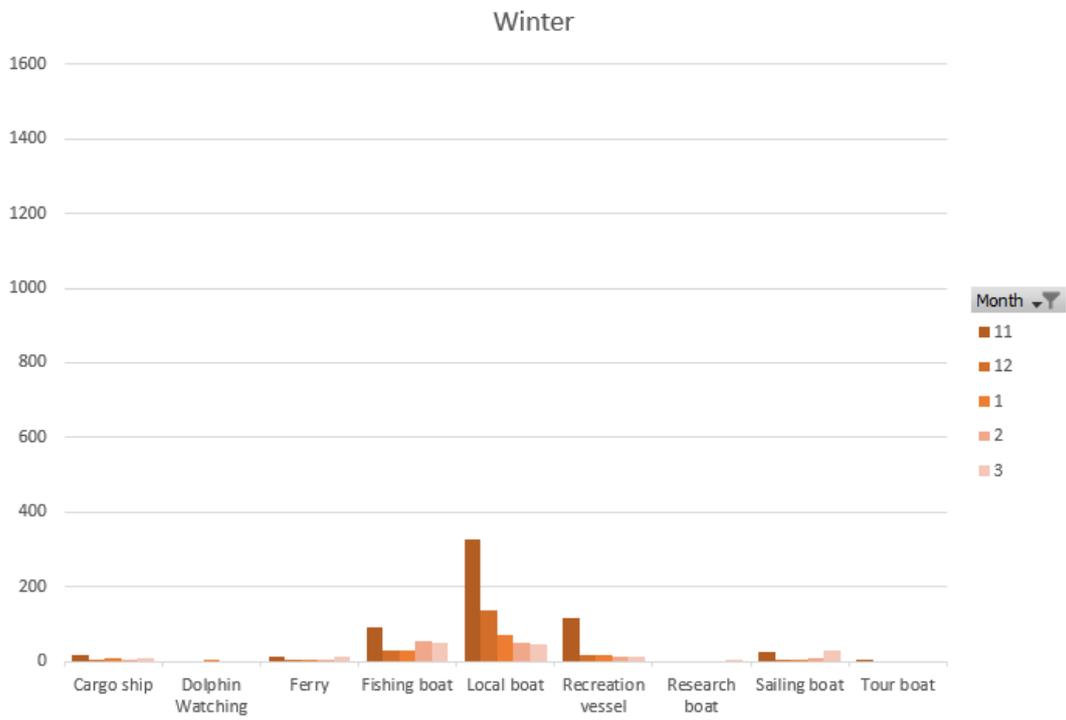


Figure 11. Number of vessels by categories - Winter 2020

3.2 Sessions

This section was divided into sessions, divided by year and seasons. It has shown all data in the Cres- Lošinj archipelago through each season and year.

2020 1st sessions

The next map shows the positions of all vessels during the year 2020 1st sessions of each day, from June 6th 2020 until December 20th 2020. Each category has a different colour which represents a different category.

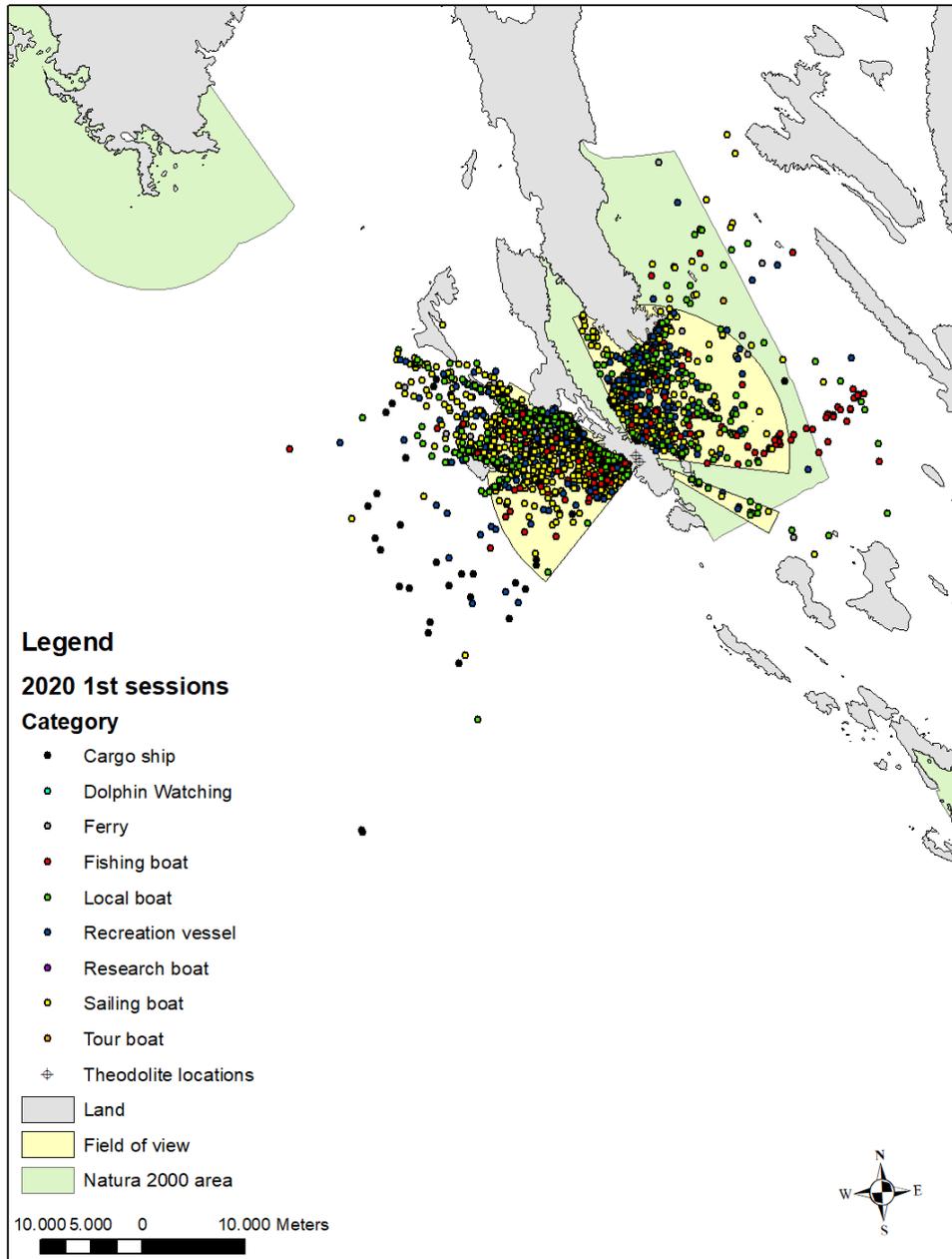


Figure 12. Locations of vessels - 2020 1st sessions

The next map shows the relative density of vessels during the year 2020 1st sessions of each day. Each grid cell was divided by a total number of sessions, from June 6th 2020 until December 20th 2020 (which were 125 sessions).

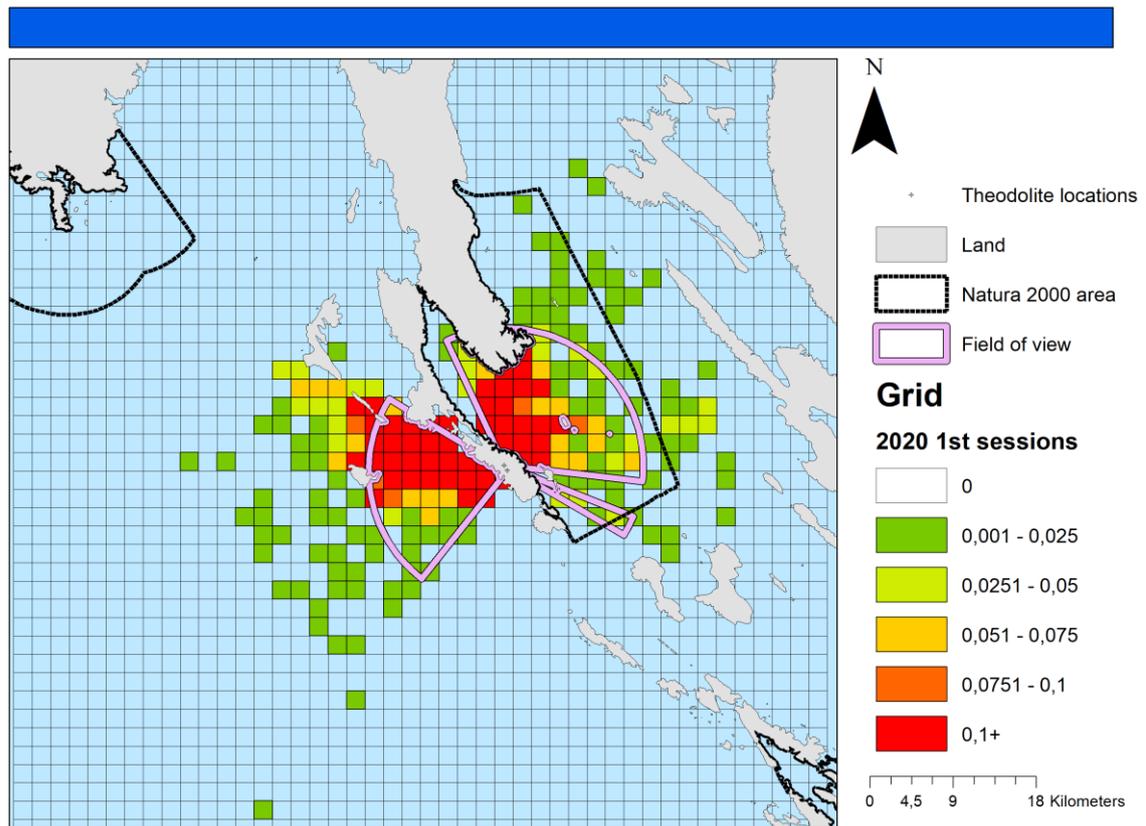


Figure 13. Relative density - 2020 1st sessions

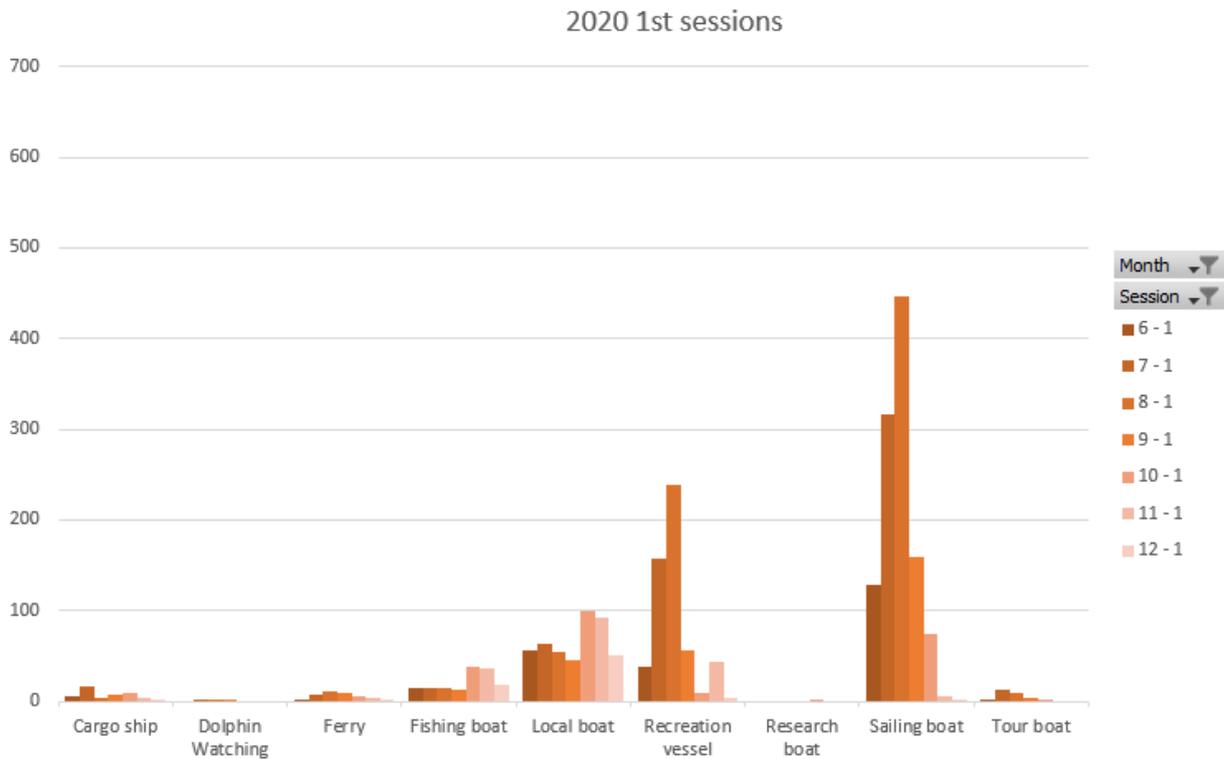


Figure 14. Number of vessels by categories - 2020 1st sessions

2020 2nd sessions

The next map shows the positions of all vessels during the year 2020 2nd sessions of each day, from June 6th 2020 until December 20th 2020. Each category has a different colour which represents a different category.

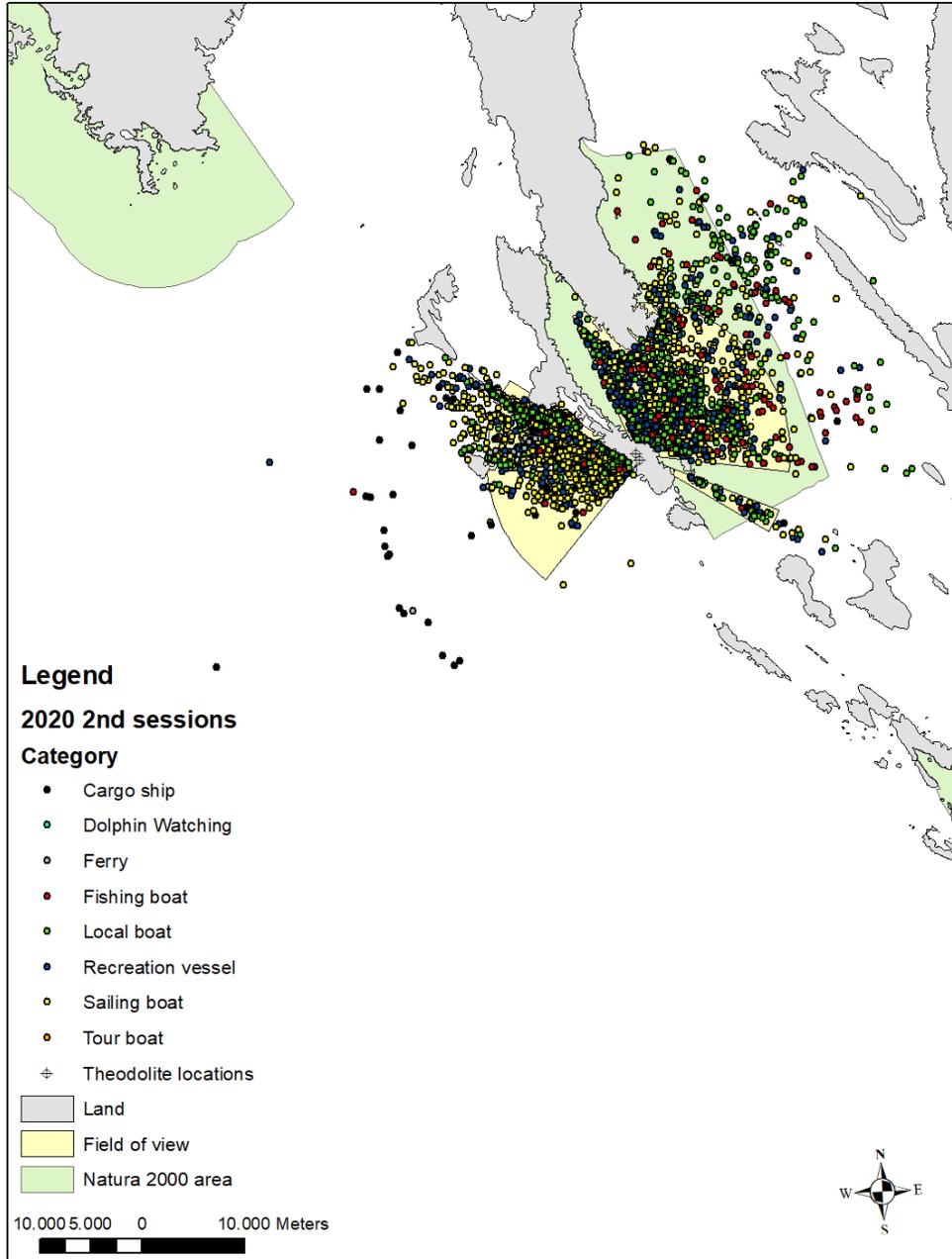


Figure 15. Locations of vessels - 2020 2nd sessions

The next map shows the relative density of vessels during the year 2020 2nd sessions of each day. Each grid cell was divided by a total number of sessions, from June 6th 2020 until December 20th 2020 (which were 120 sessions).

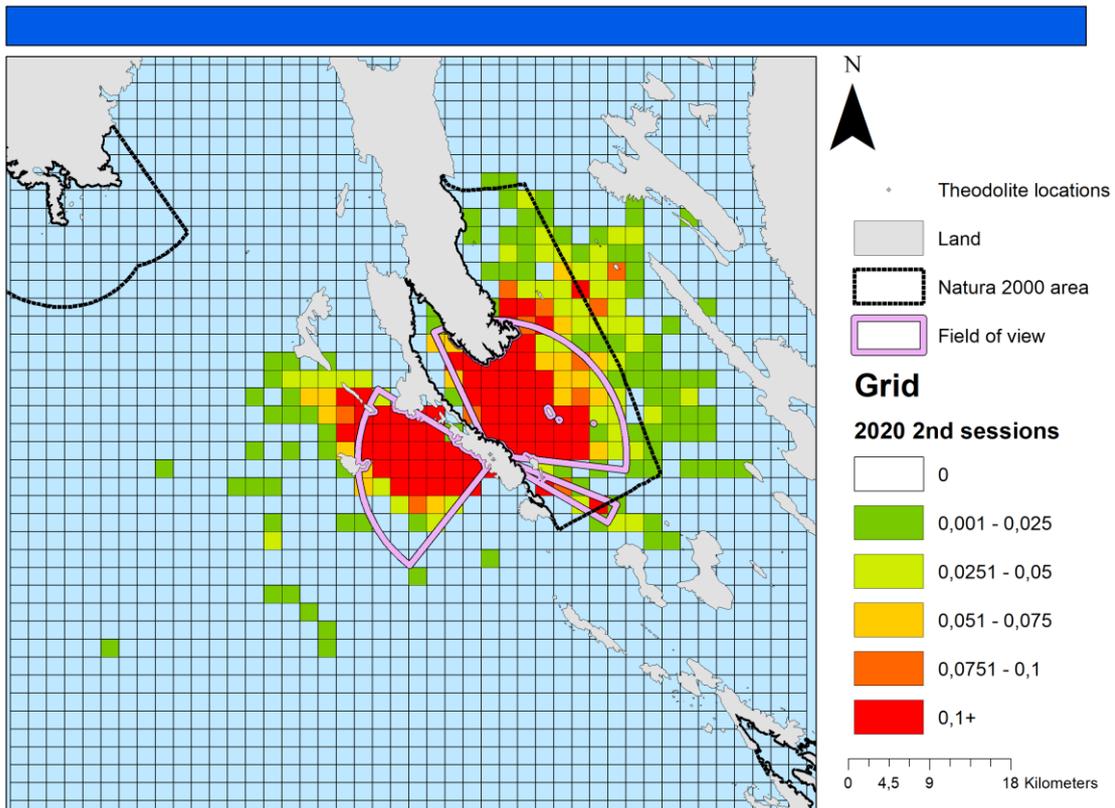


Figure 16. Relative density - 2020 2nd sessions

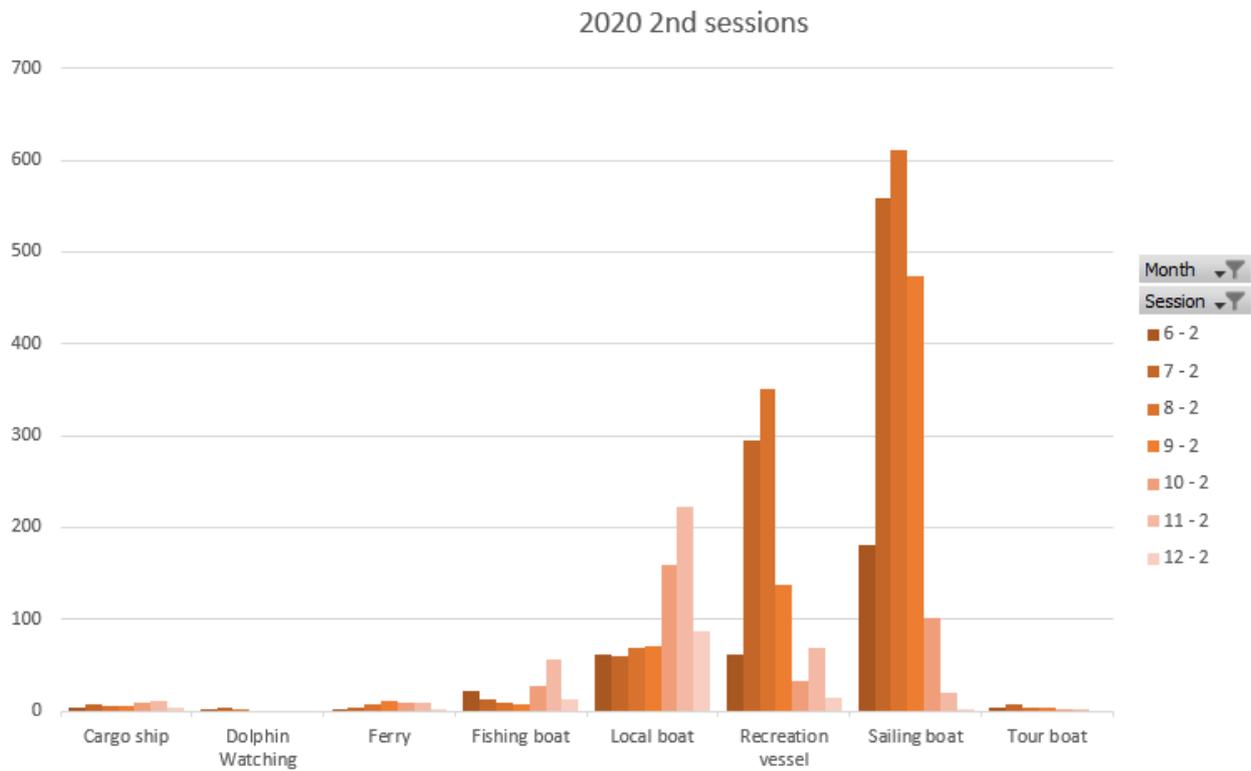


Figure 17. Number of vessels by categories - 2020 2nd sessions

2020 3rd sessions

The next map shows the positions of all vessels during the year 2020 3rd sessions of each day, from June 6th 2020 until December 20th 2020. Each category has a different colour which represents a different category.

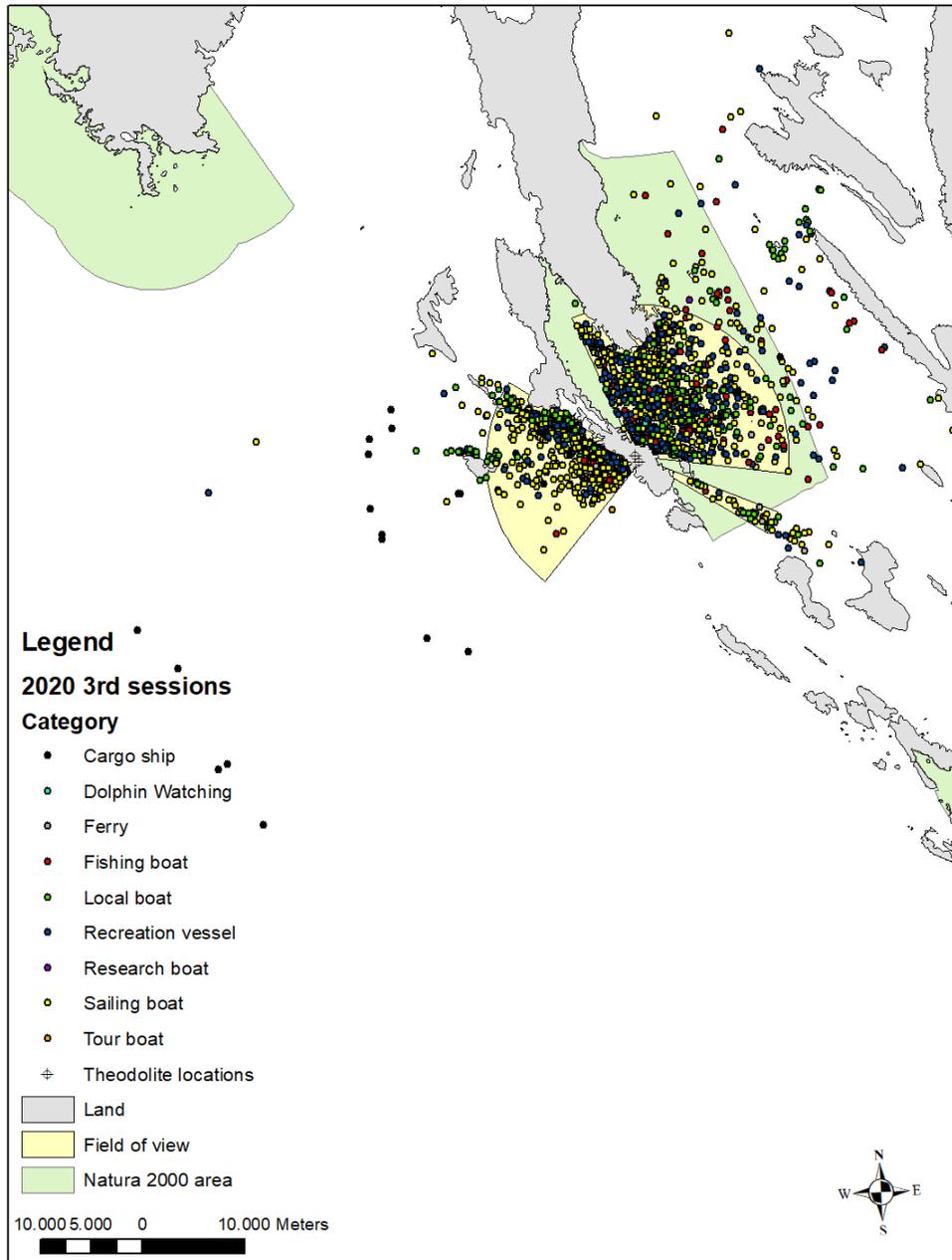


Figure 18. Locations of vessels - 2020 3rd sessions

The next map shows the relative density of vessels during the year 2020 3rd sessions of each day. Each grid cell was divided by a total number of sessions, from June 6th 2020 until December 20th 2020 (which were 70 sessions).

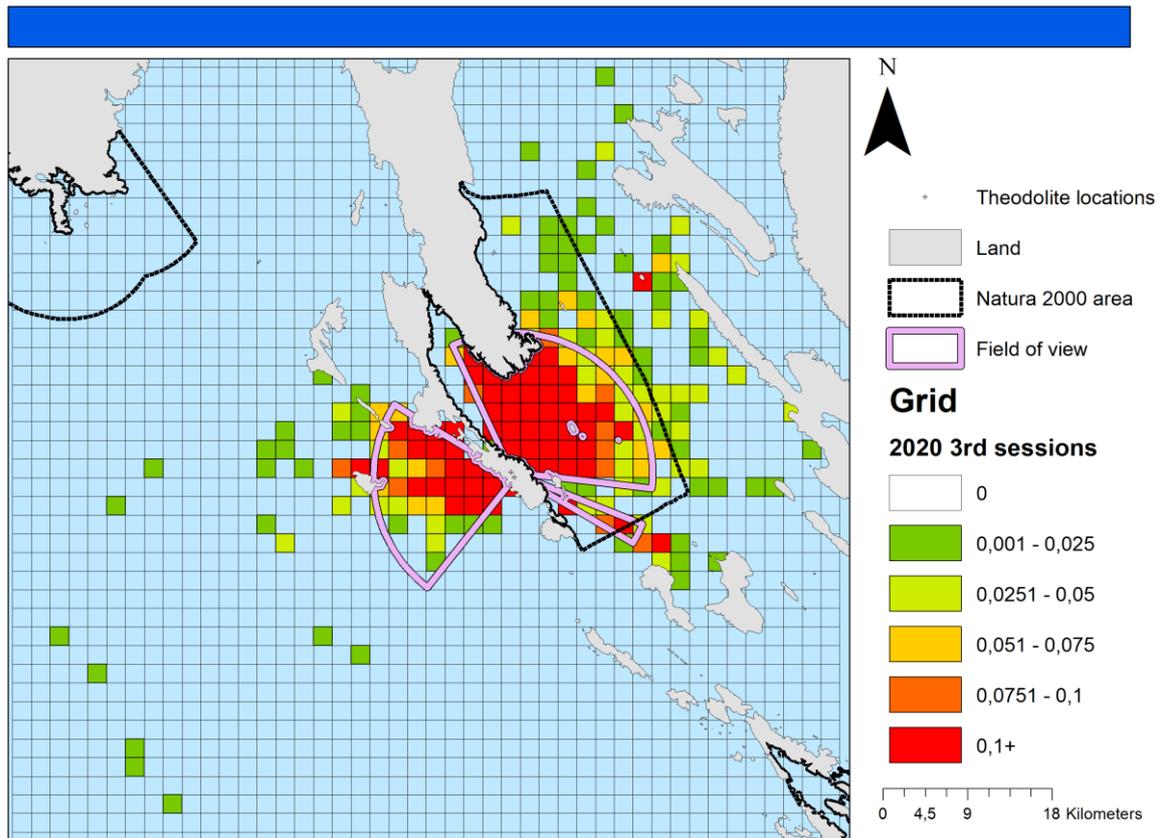


Figure 19. Relative density - 2020 3rd sessions

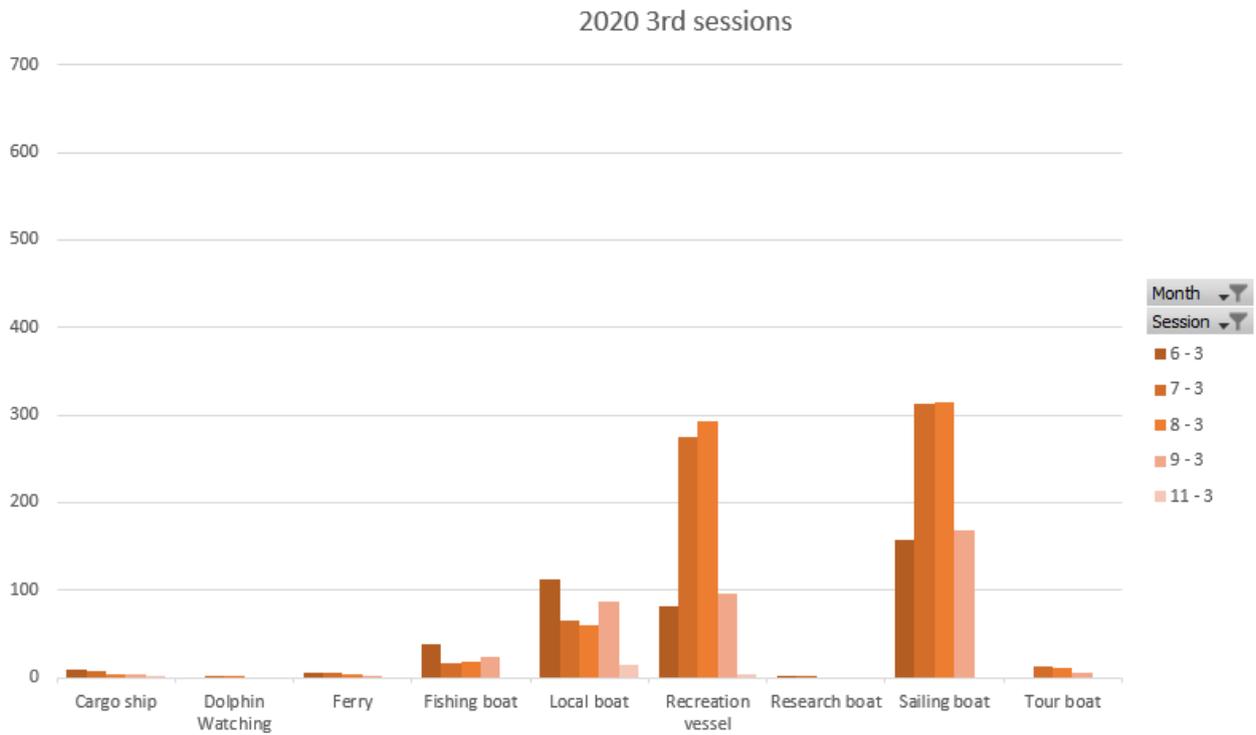


Figure 20. Number of vessels by categories - 2020 3rd sessions

2021 1st sessions

The next map shows the positions of all vessels during the year 2021 1st sessions of each day, from January 4th 2021 until March 31st 2021. Each category has a different colour which represents a different category.

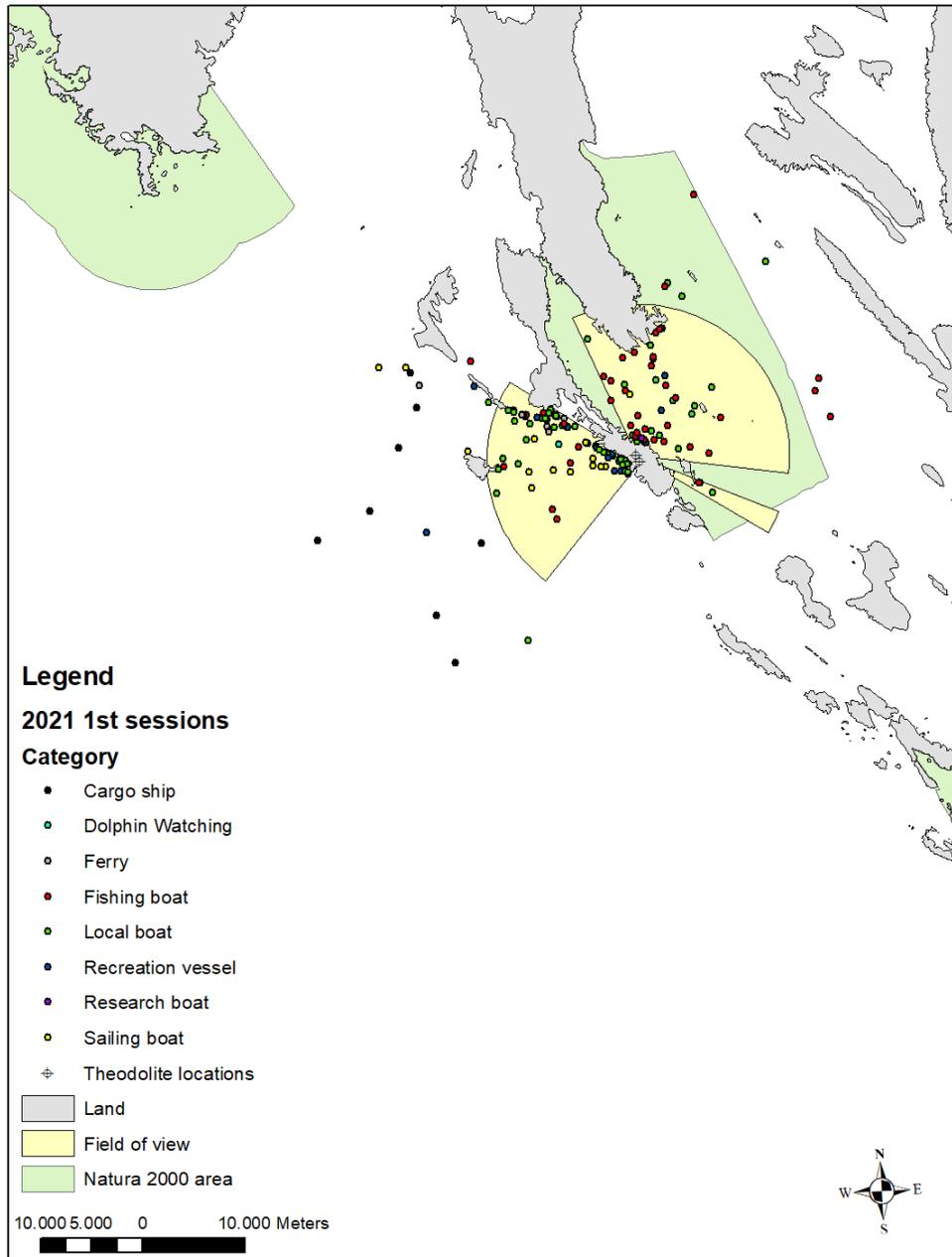


Figure 21. Locations of vessels - 2021 1st sessions

The next map shows the relative density of vessels during the year 2021 1st sessions of each day. Each grid cell was divided by a total number of sessions, from January 4th 2021 until March 31st 2021 (which were 51 sessions).

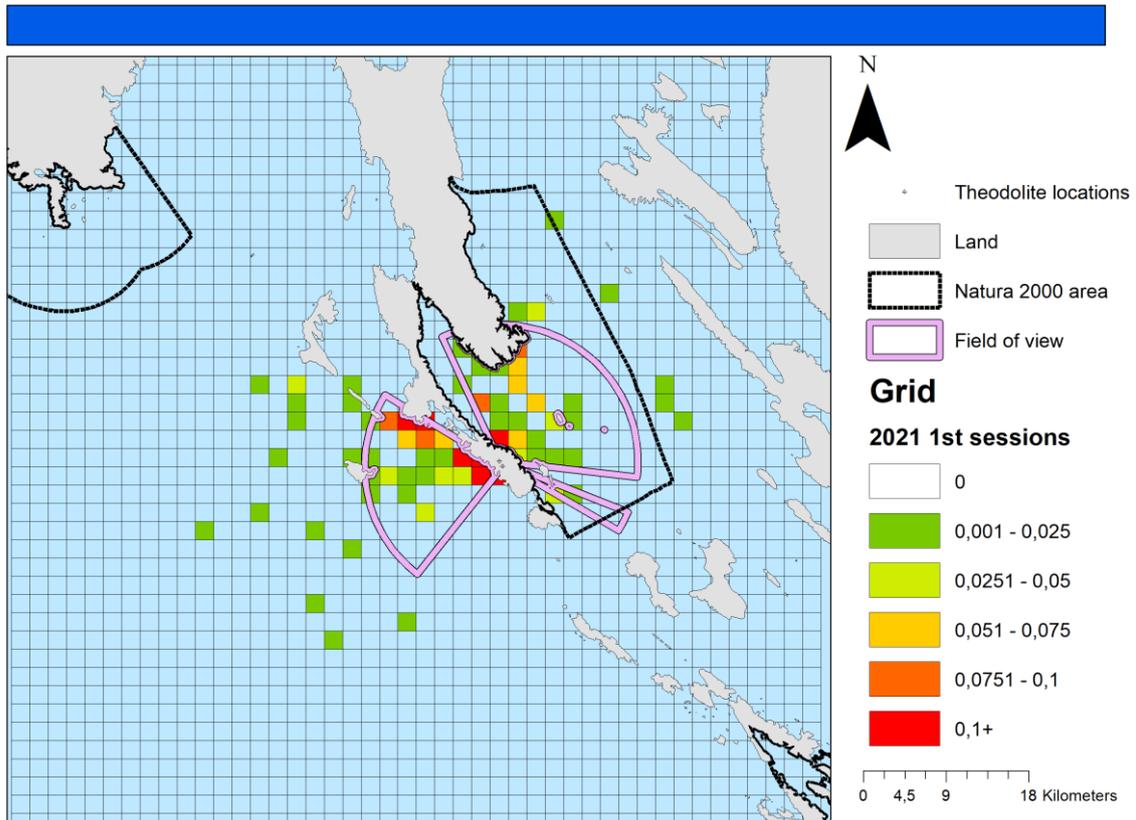


Figure 22. Relative density – 2021 1st sessions

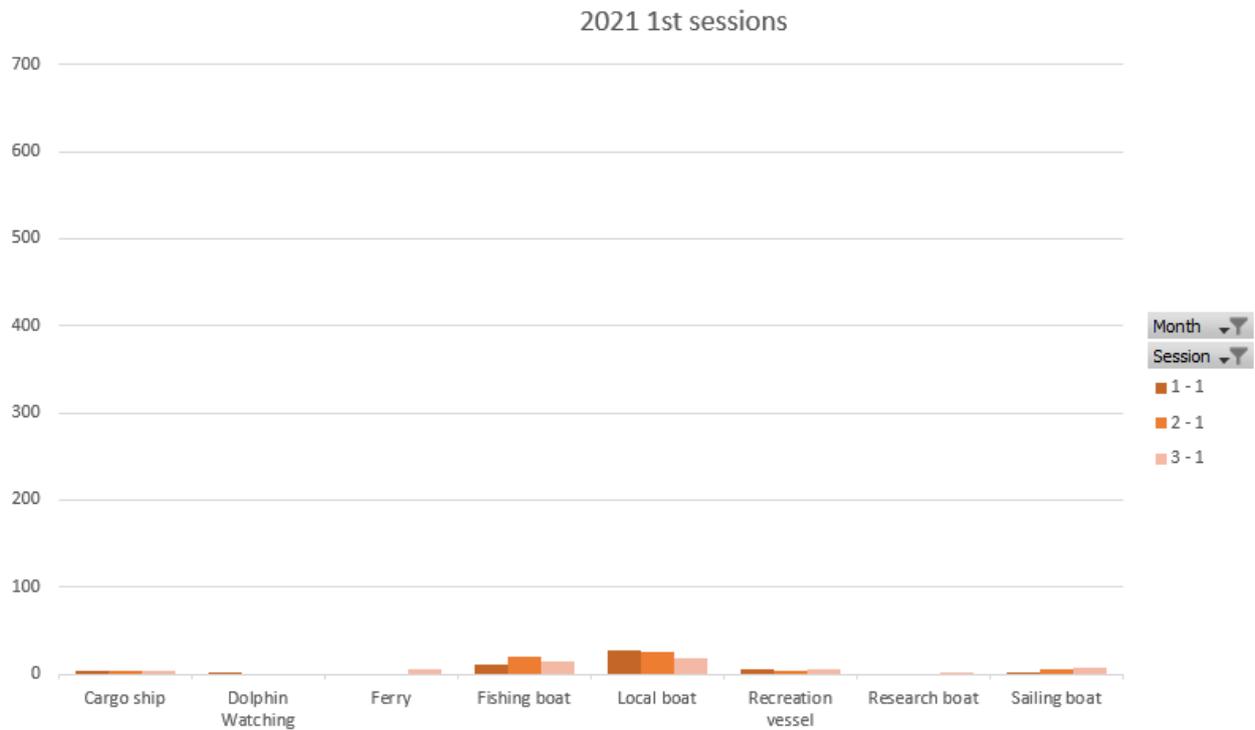


Figure 23. Number of vessels by categories - 2021 1st sessions

2021 2nd sessions

The next map shows the positions of all vessels during the year 2021 2nd sessions of each day, from January 4th 2021 until March 31st 2021. Each category has a different colour which represents a different category.

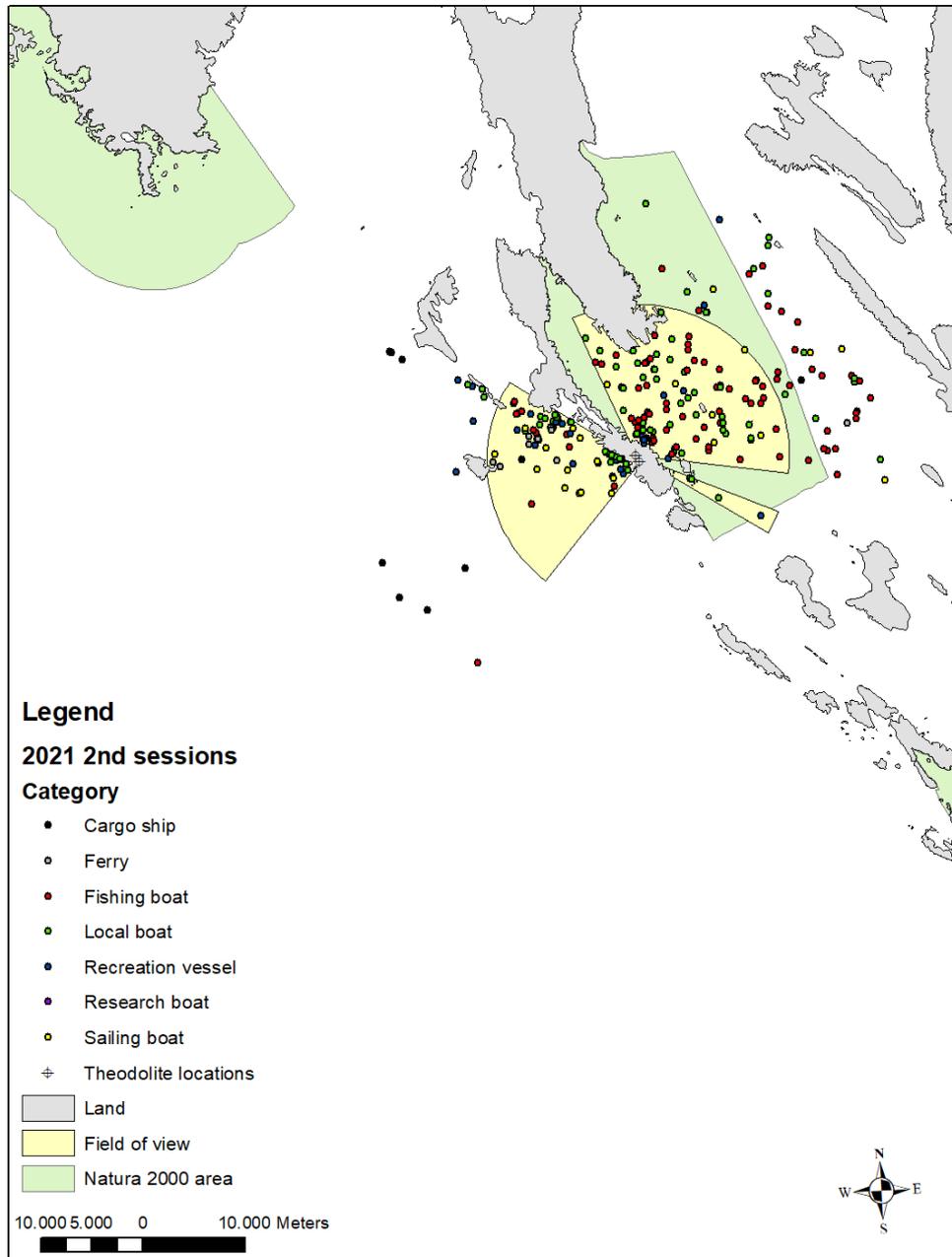


Figure 24. Locations of vessels - 2021 2nd sessions

The next map shows the relative density of vessels during the year 2021 2nd sessions of each day. Each grid cell was divided by a total number of sessions, from January 4th 2021 until March 31st 2021 (which were 40 sessions).

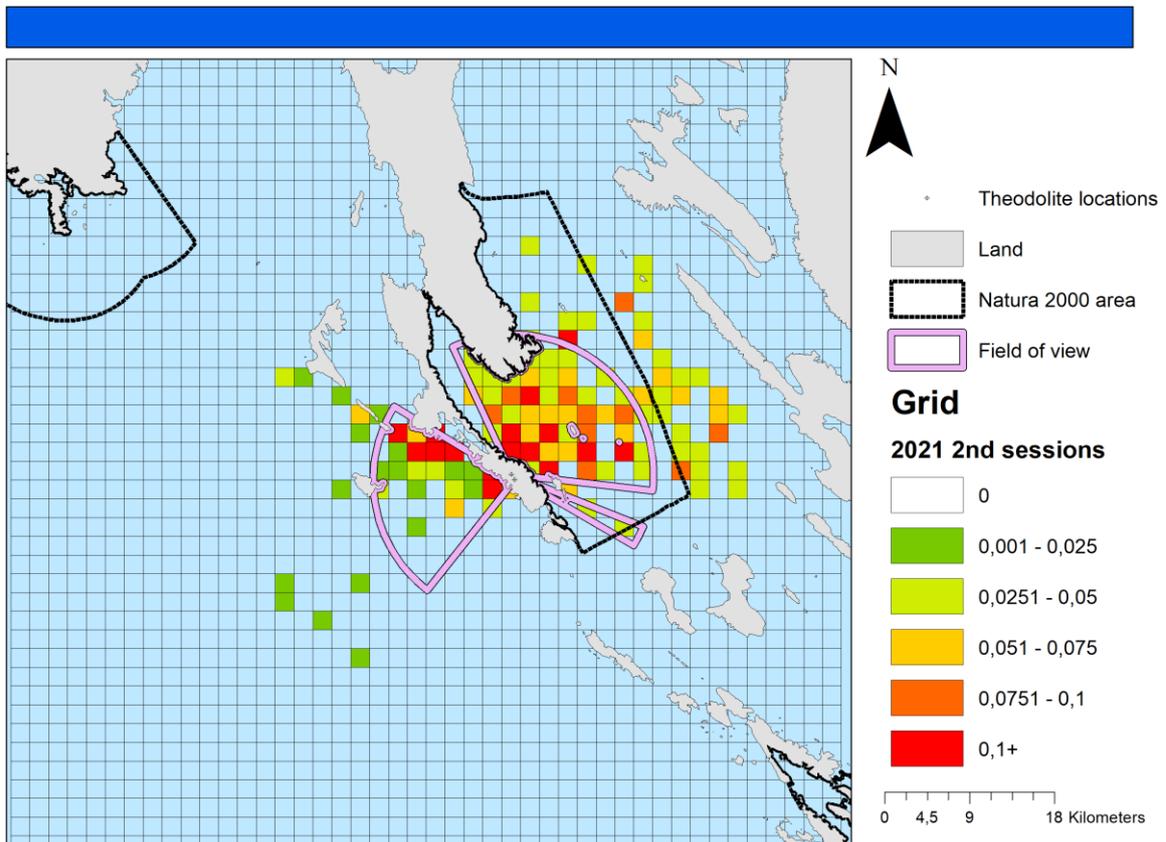


Figure 25. Relative density – 2021 2nd sessions

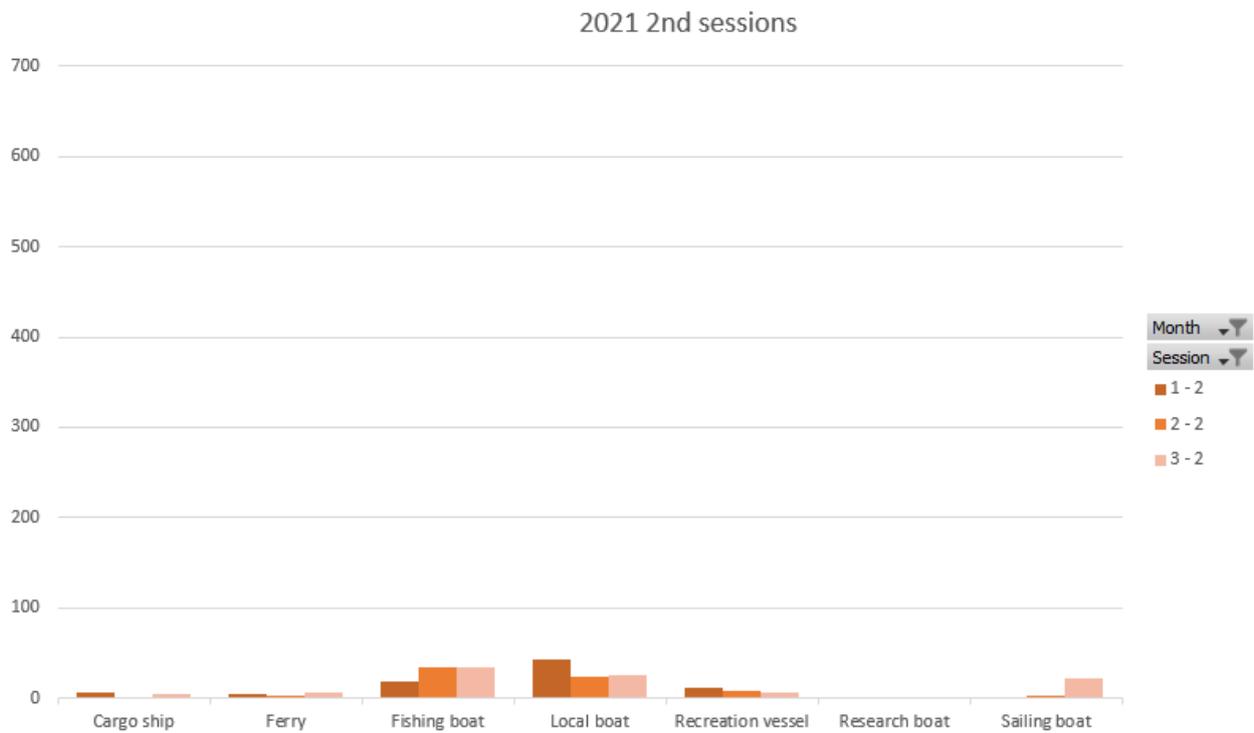


Figure 26. Number of vessels by categories - 2021 2nd sessions

Summer 1st sessions

The next map shows the positions of all vessels during the summer 2020 1st sessions of each day, from June 6th 2020 until September 30th 2020. Each category has a different colour which represents a different category.

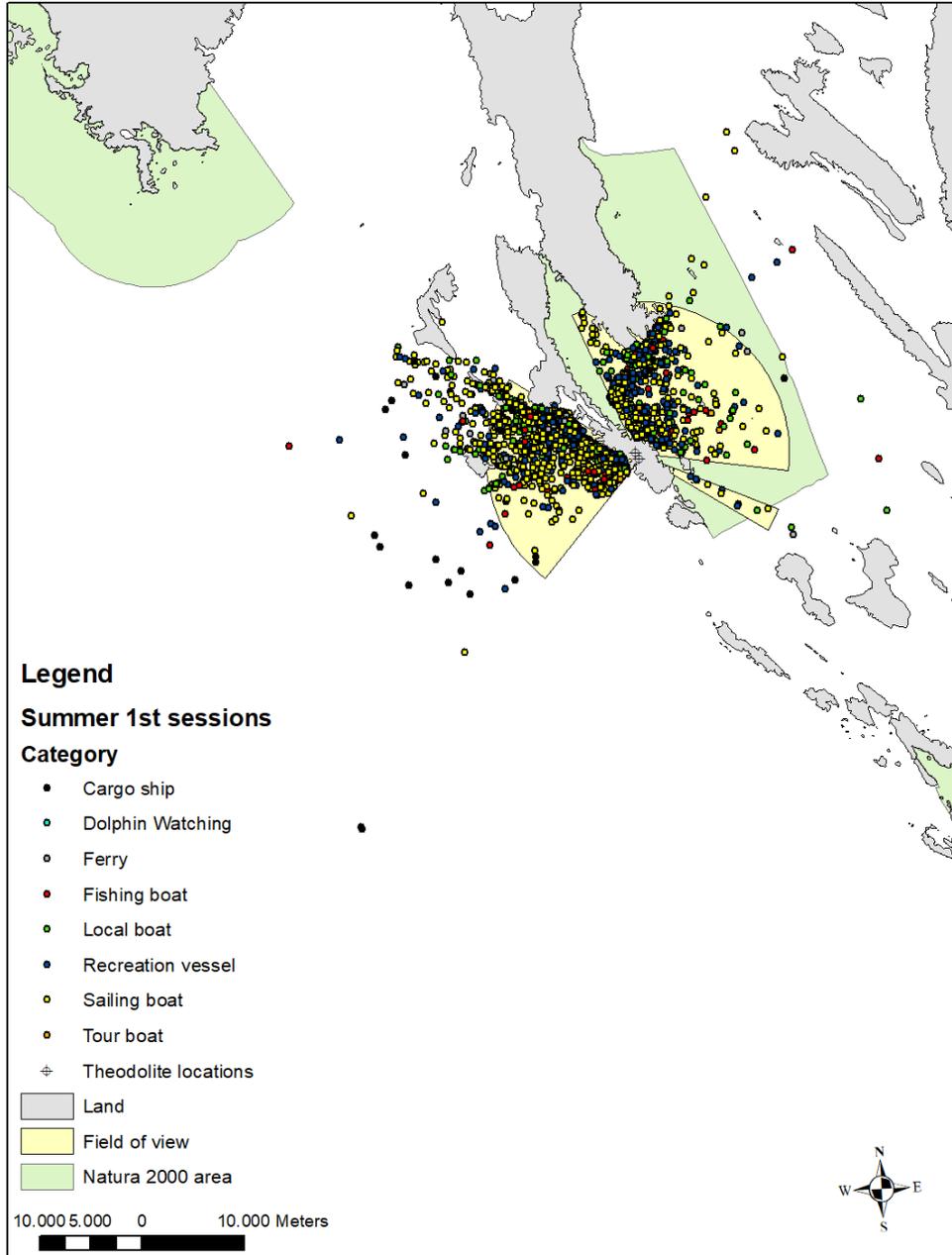


Figure 27. Locations of vessels - Summer 1st sessions

The next map shows the relative density of vessels during the summer 2020 1st sessions of each day. Each grid cell was divided by a total number of sessions, from June 6th 2020 until September 30th 2020 (which were 77 sessions).

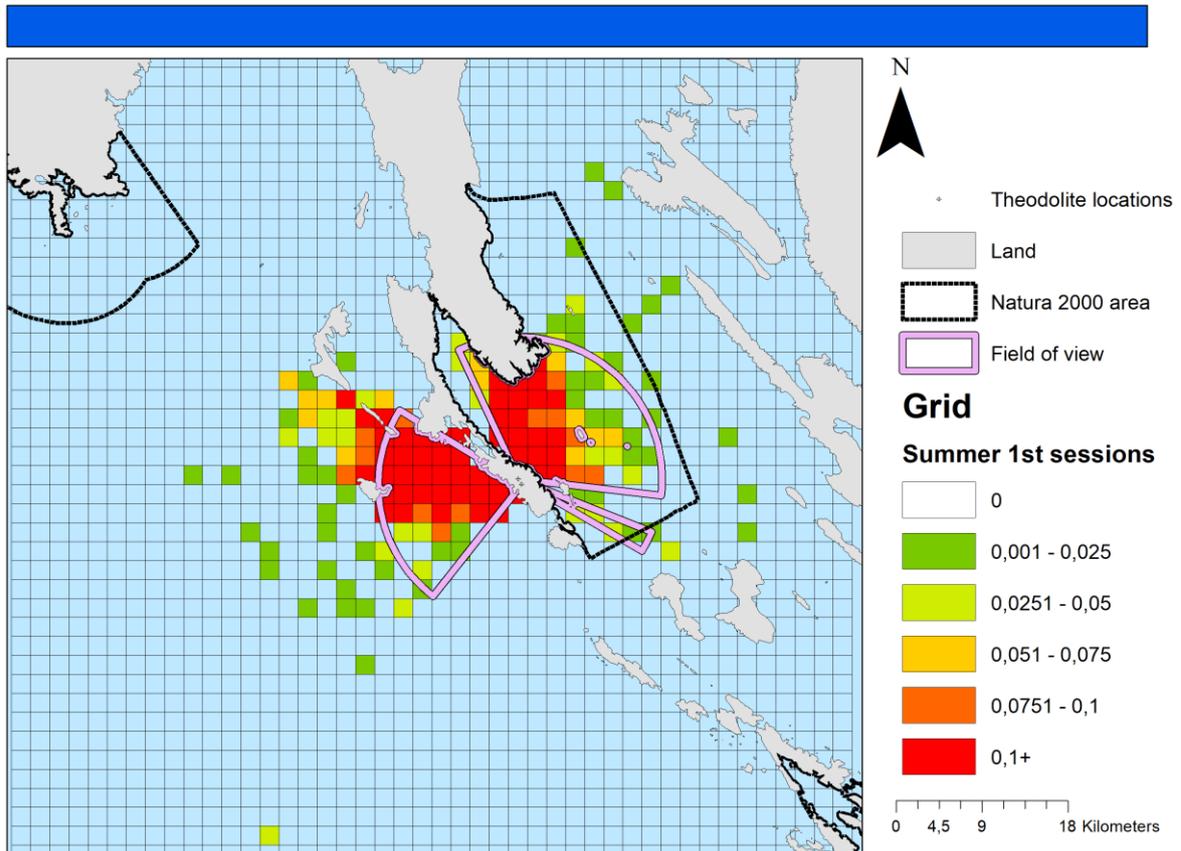


Figure 28. Relative density – Summer 1st sessions

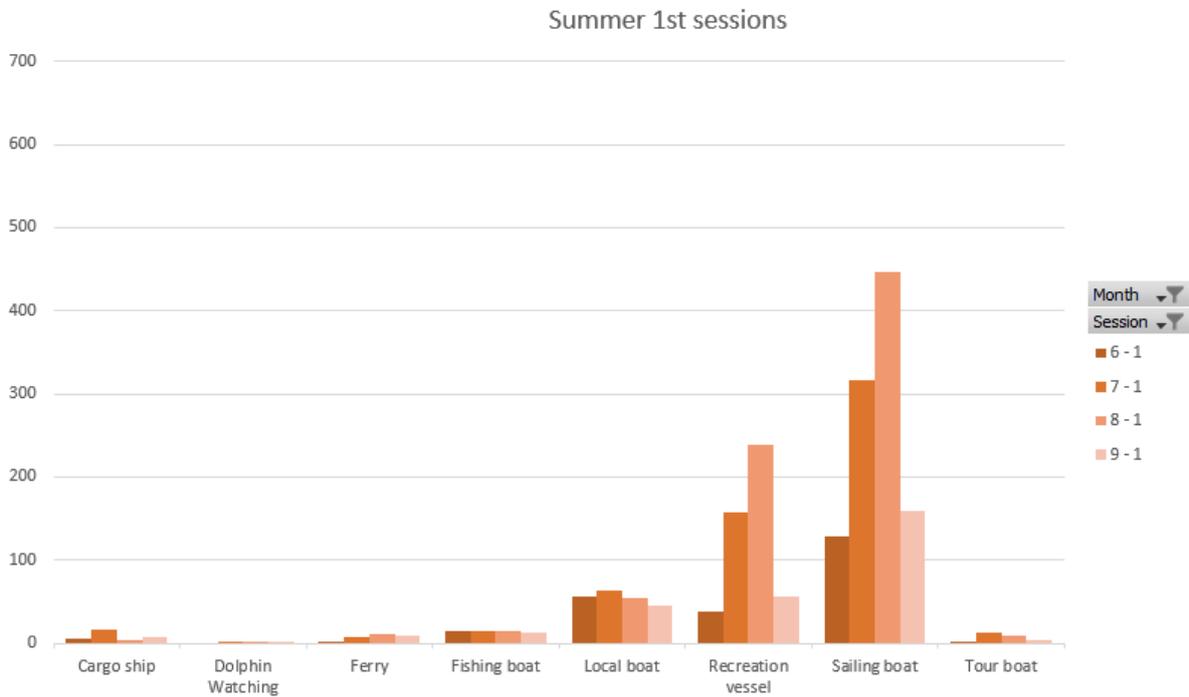


Figure 29. Number of vessels by categories - Summer 1st sessions

Summer 2nd sessions

The next map shows the positions of all vessels during the summer 2020 2nd sessions of each day, from June 6th 2020 until September 30th 2020. Each category has a different colour which represents a different category.

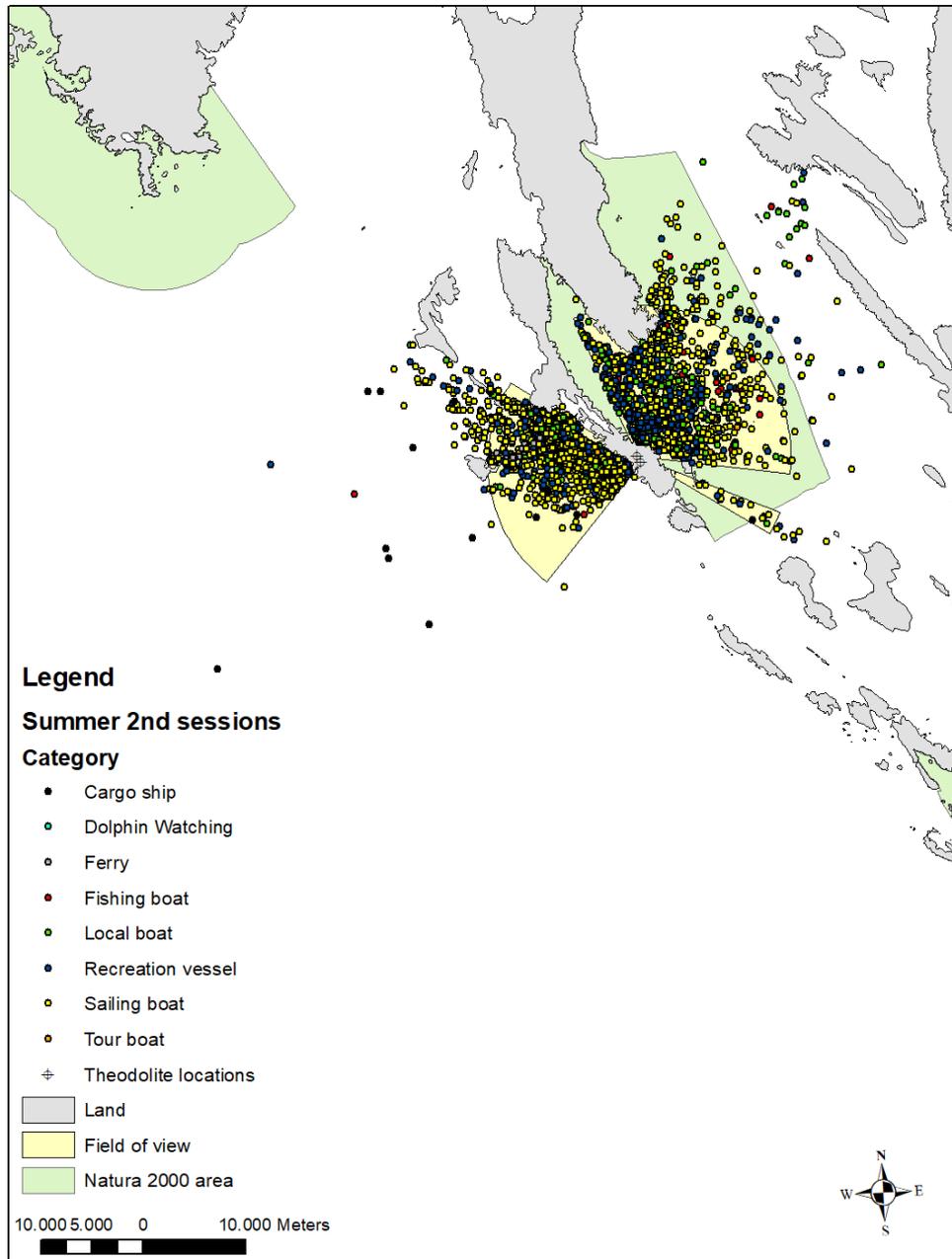


Figure 30. Locations of vessels - Summer 2nd sessions

The next map shows the relative density of vessels during the summer 2020 2nd sessions of each day. Each grid cell was divided by a total number of sessions, from June 6th 2020 until September 30th 2020 (which were 75 sessions).

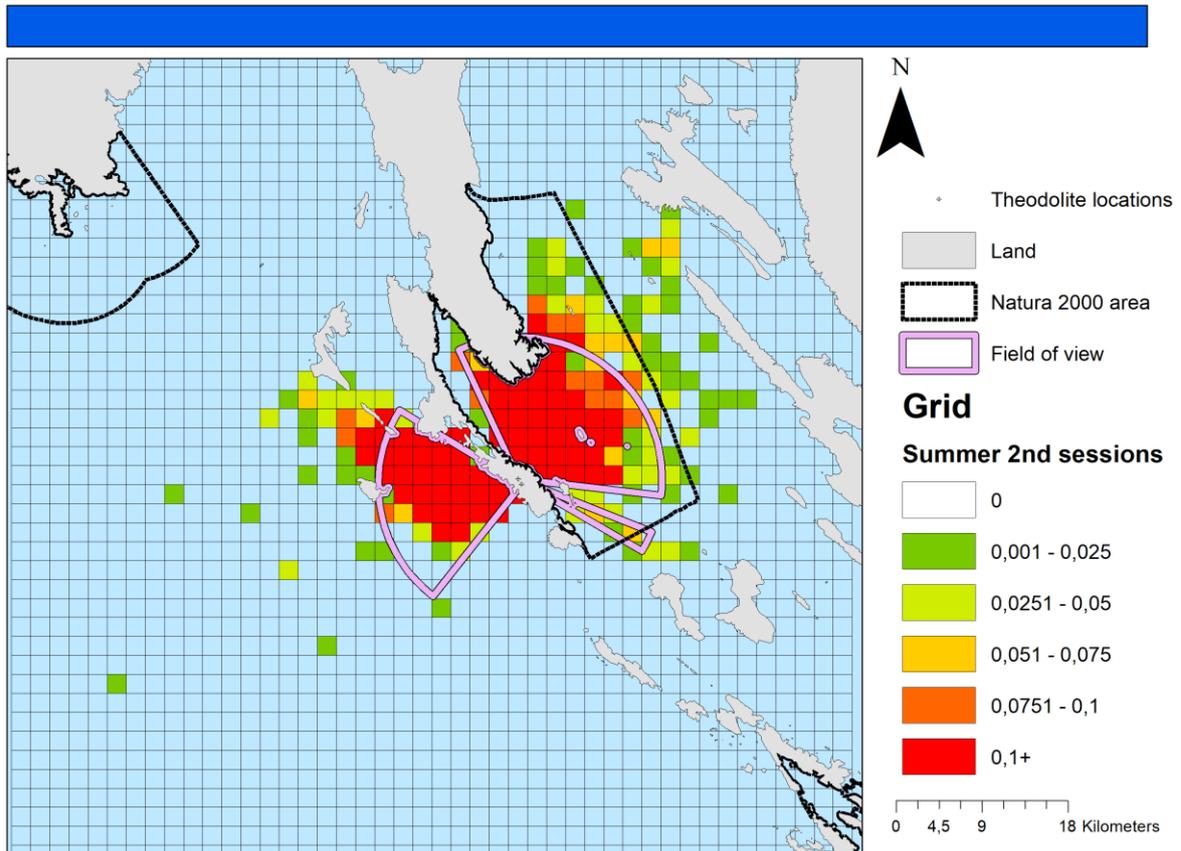


Figure 31. Relative density – Summer 2nd sessions

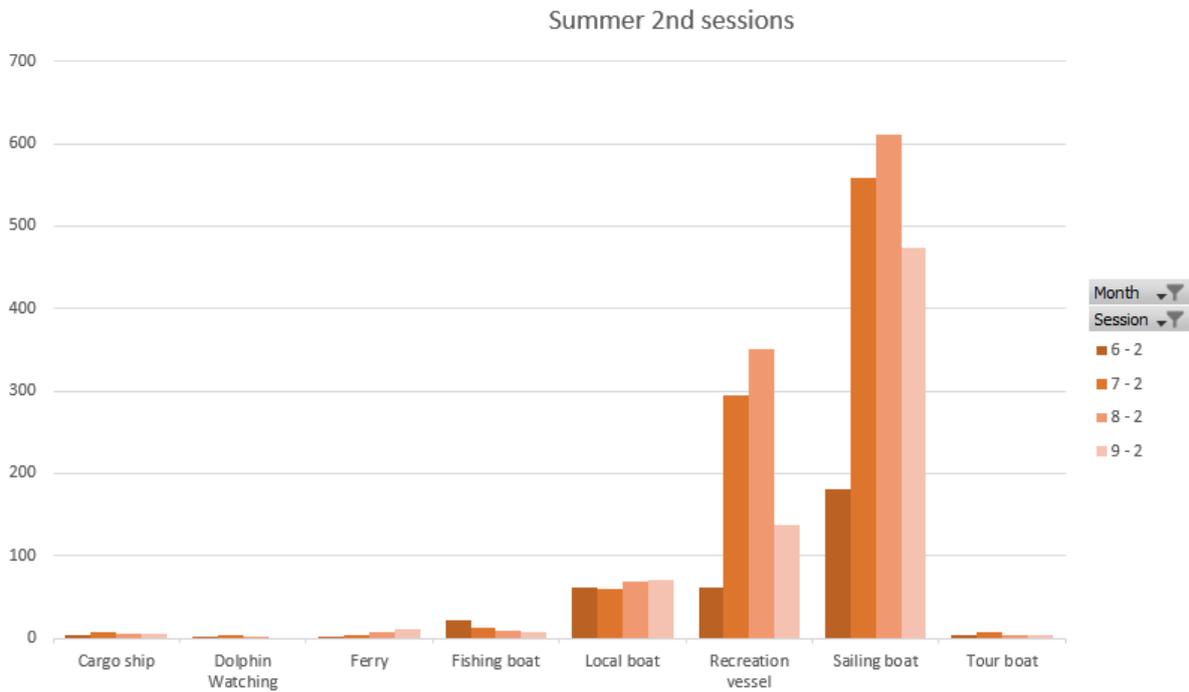


Figure 32. Number of vessels by categories - Summer 2nd sessions

Summer 3rd sessions

The next map shows the positions of all vessels during the summer 2020 3rd sessions of each day, from June 6th 2020 until September 30th 2020. Each category has a different colour which represents a different category.

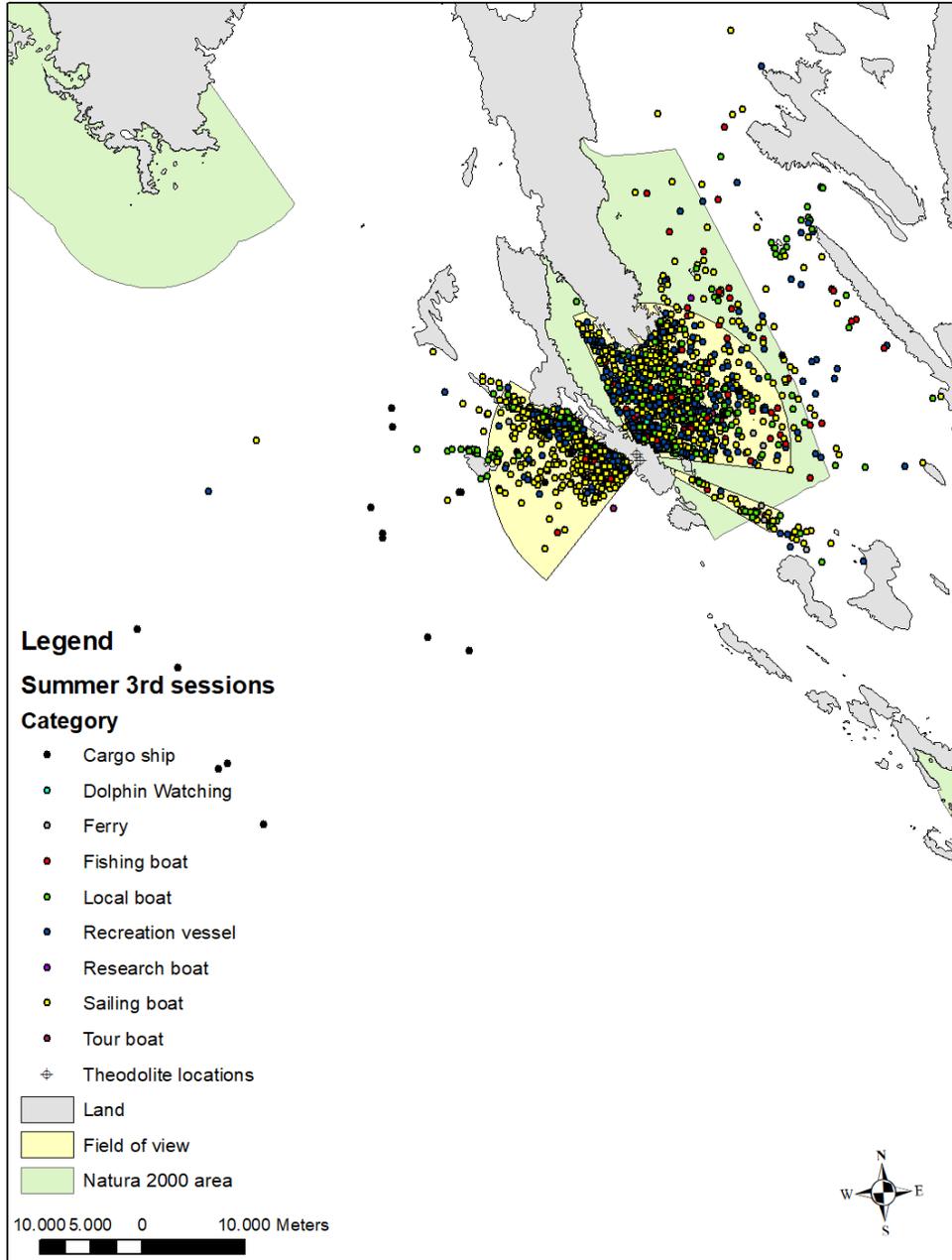


Figure 33. Locations of vessels - Summer 3rd sessions

The next map shows the relative density of vessels during the summer 2020 3rd sessions of each day. Each grid cell was divided by a total number of sessions, from June 6th 2020 until September 30th 2020 (which were 70 sessions).

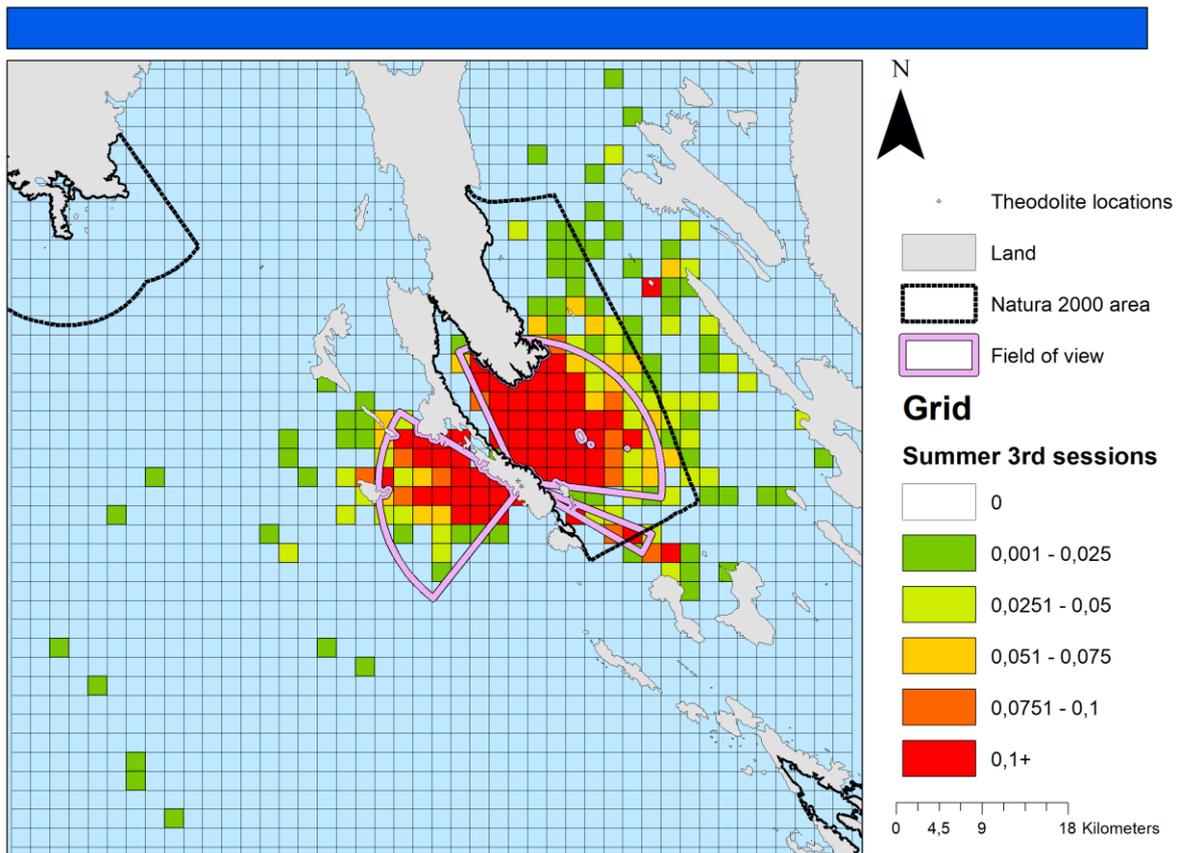


Figure 34. Relative density – Summer 3rd sessions

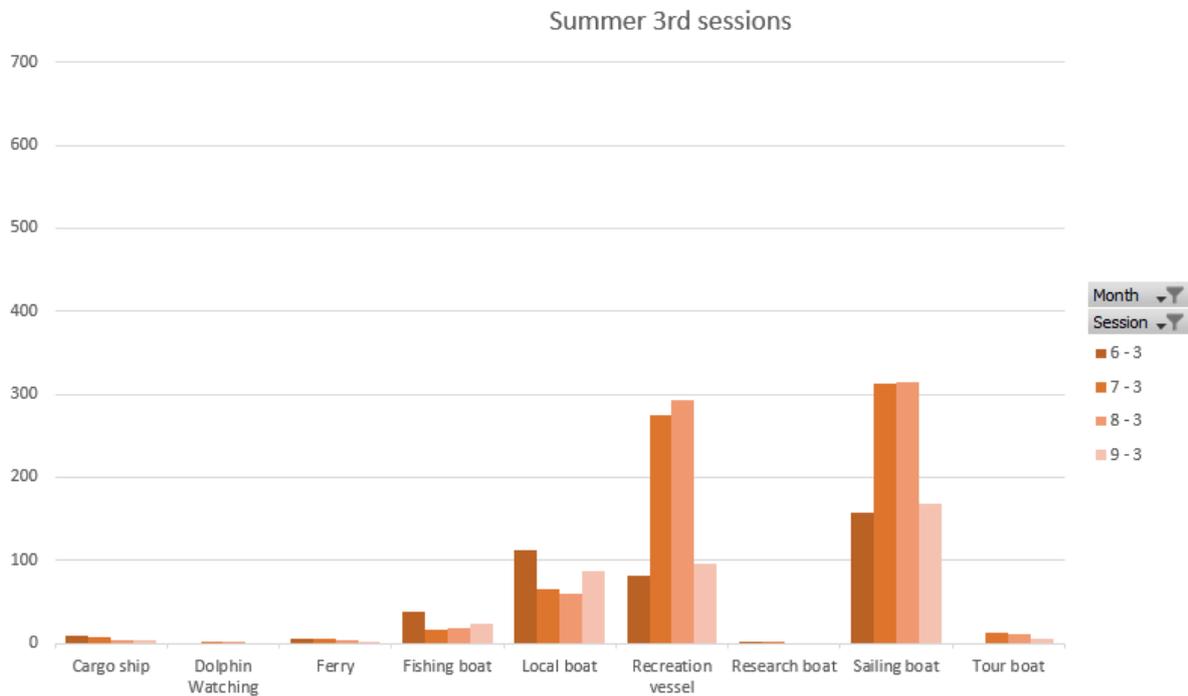


Figure 35. Number of vessels by categories - Summer 3rd sessions

Winter 1st sessions

The next map shows the positions of all vessels during winter 2021 1st sessions of each day, from October 1st 2020 until March 31st 2021. Each category has a different colour which represents a different category.

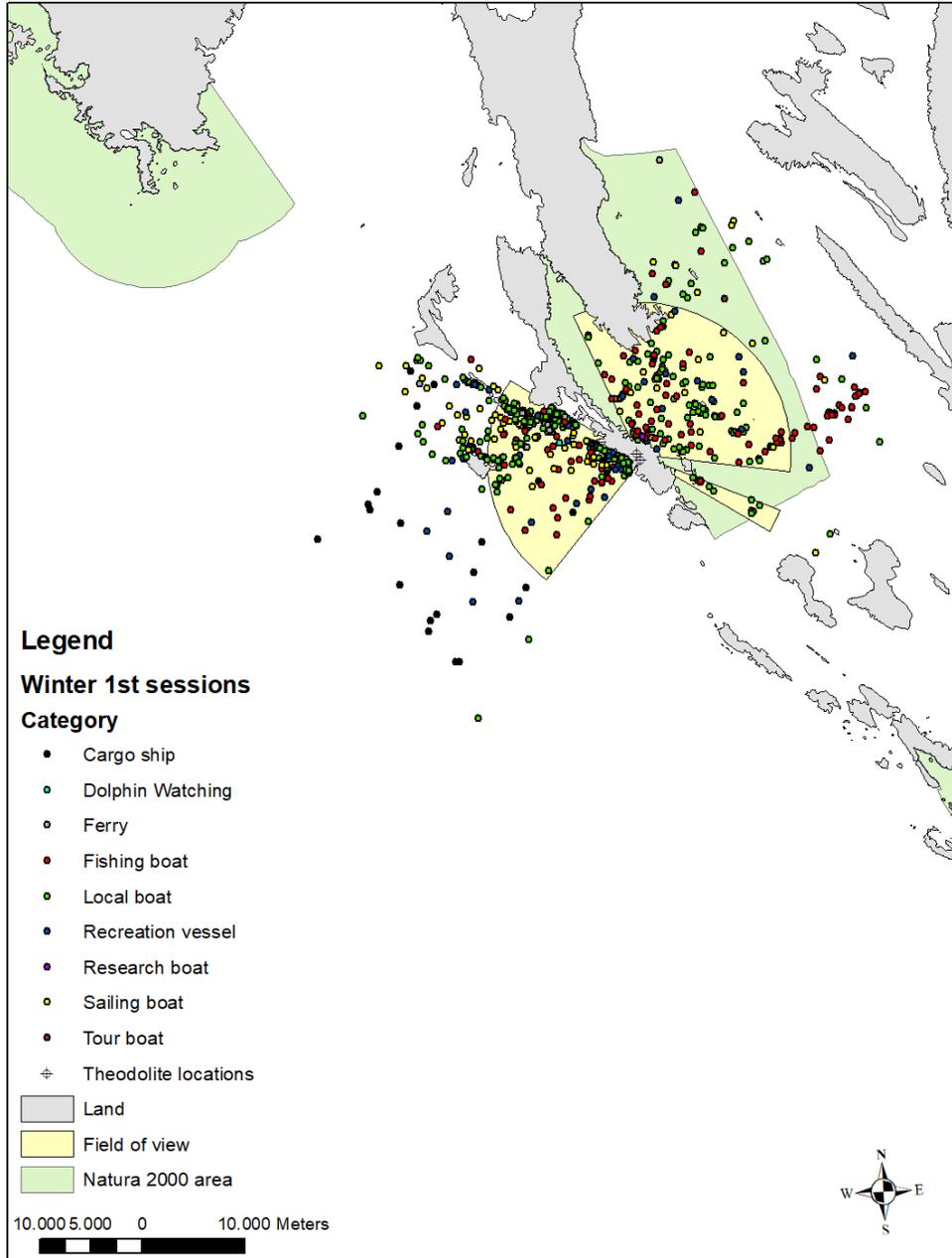


Figure 36. Locations of vessels - Winter 1st sessions

The next map shows the relative density of vessels during winter 2021 1st sessions of each day. Each grid cell was divided by a total number of sessions, from October 1st 2020 until March 31st 2021 (which were 99 sessions).

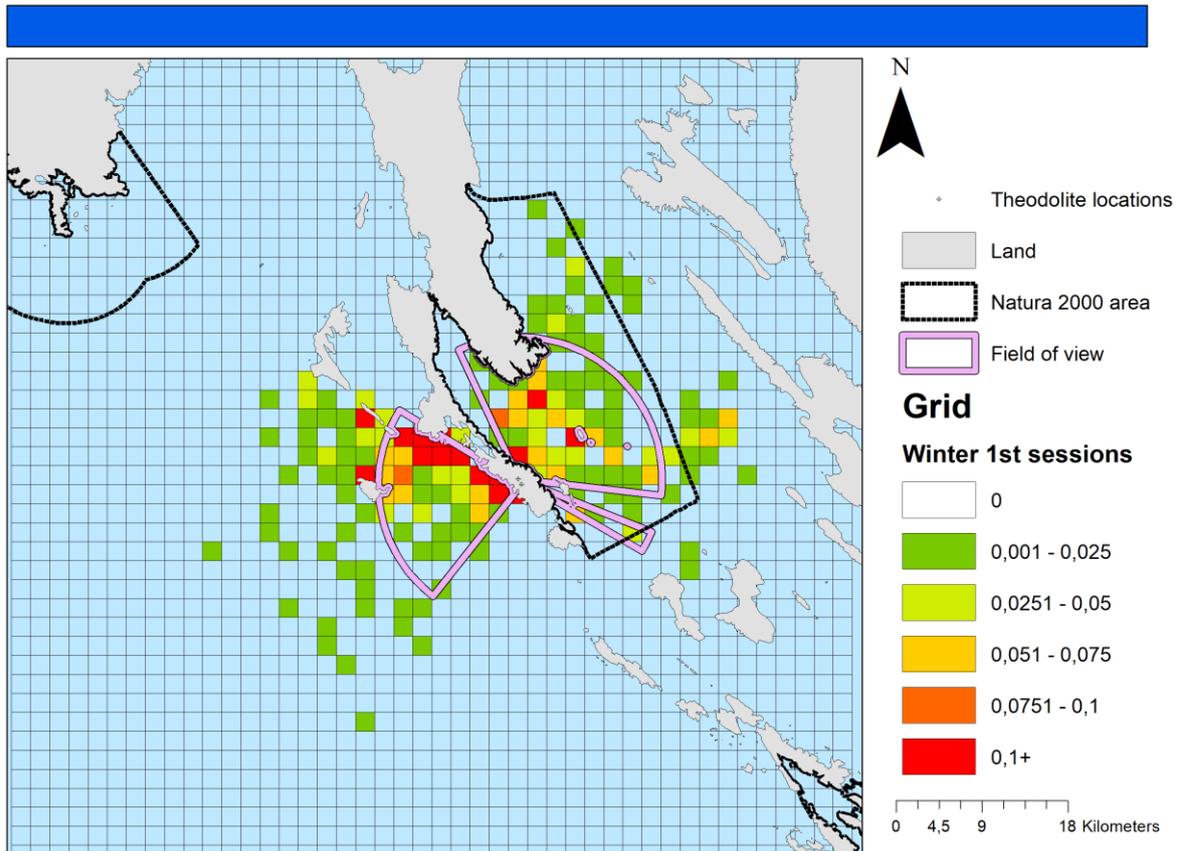


Figure 37. Relative density – Winter 1st sessions

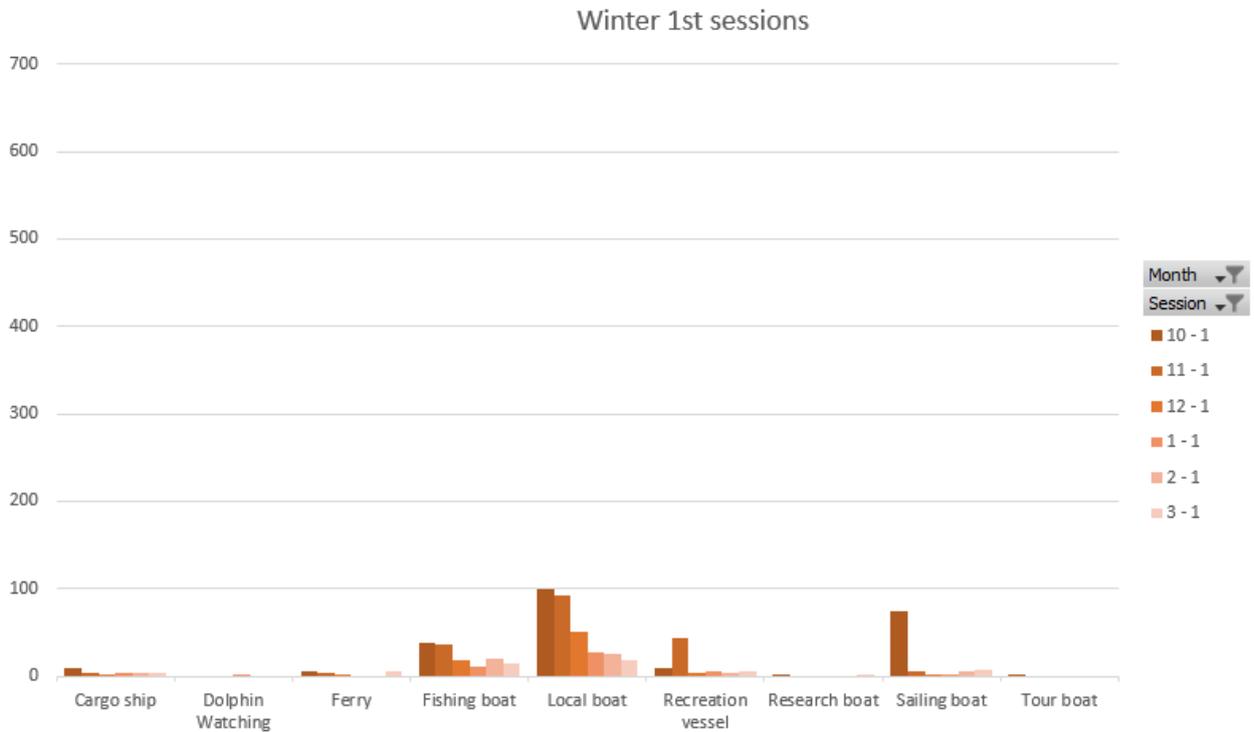


Figure 38. Number of vessels by categories - Winter 1st sessions

Winter 2nd sessions

The next map shows the positions of all vessels during winter 2021 2nd sessions of each day, from October 1st 2020 until March 31st 2021. Each category has a different colour which represents a different category.

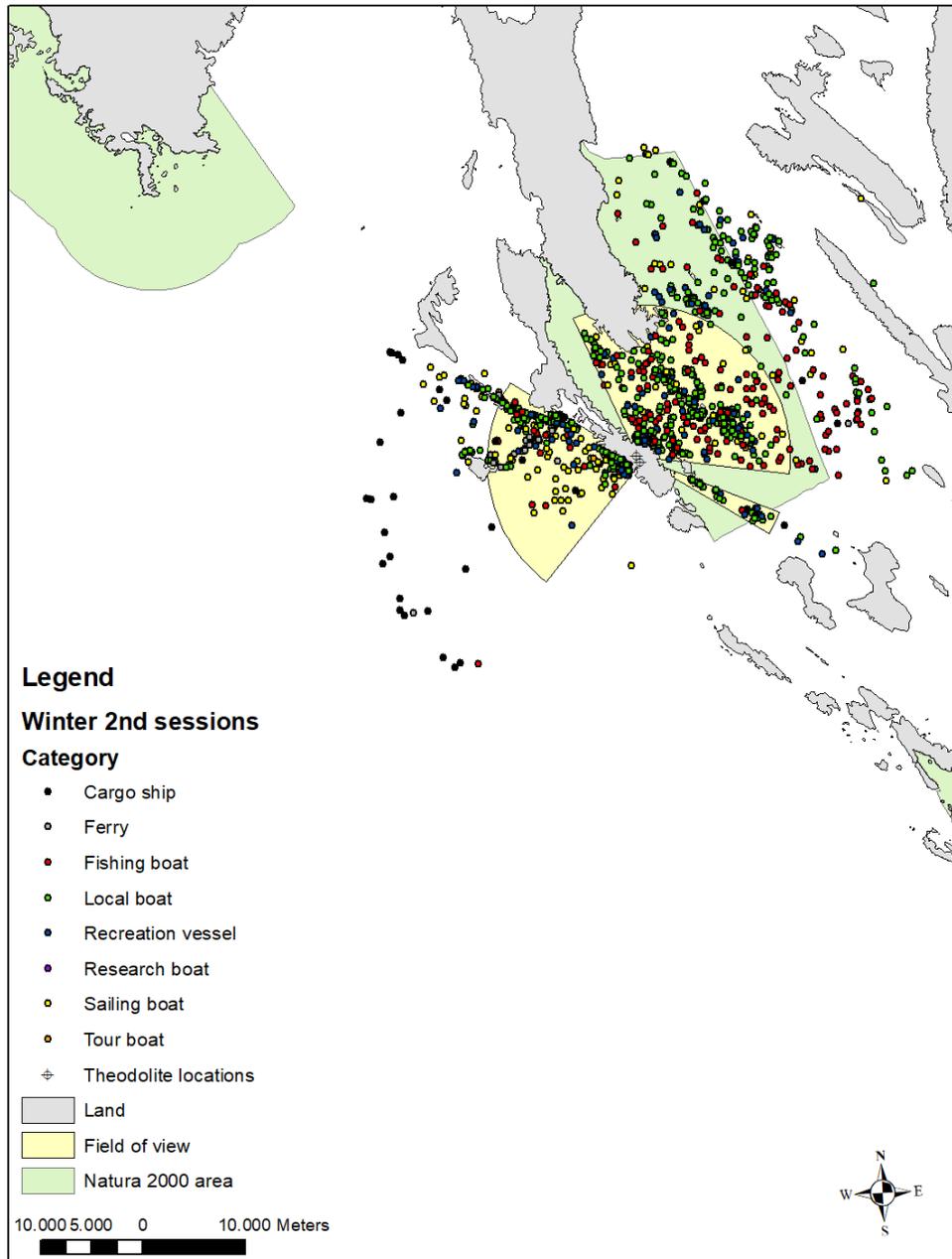


Figure 39. Locations of vessels - Winter 2nd sessions

The next map shows the relative density of vessels during winter 2021 2nd sessions of each day. Each grid cell was divided by a total number of sessions, from October 1st 2020 until March 31st 2021 (which were 84 sessions).

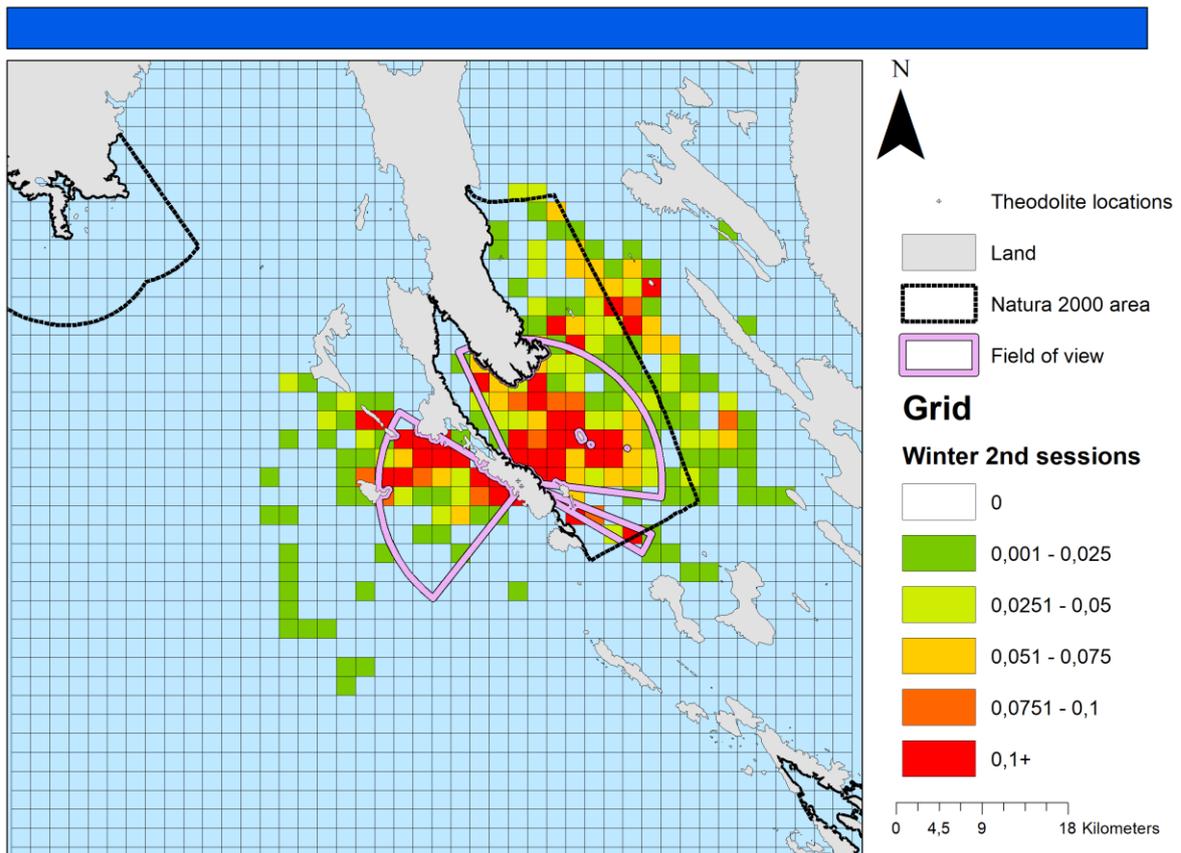


Figure 40. Relative density – Winter 2nd sessions

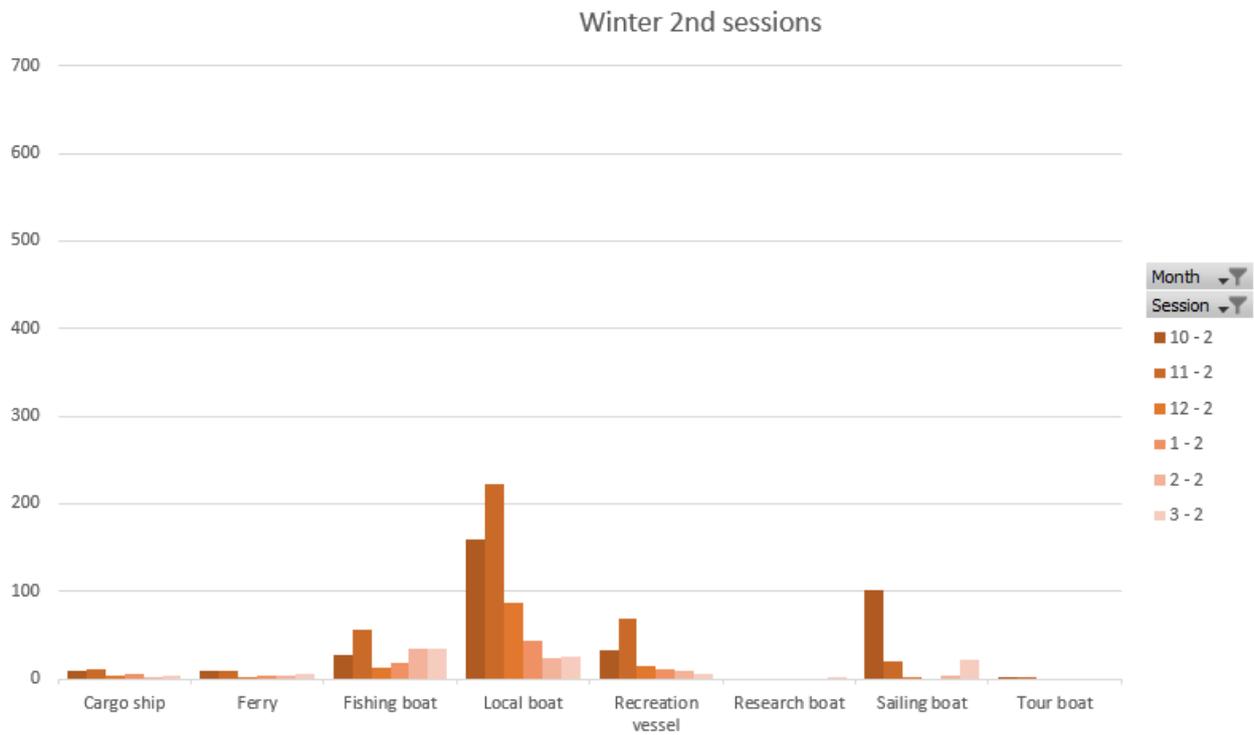


Figure 41. Number of vessels by categories - Winter 2nd sessions

Winter 3rd sessions

The next map shows the positions of all vessels during winter 2021 3rd sessions of each day, from October 1st 2020 until March 31st 2021. Each category has a different colour which represents a different category.

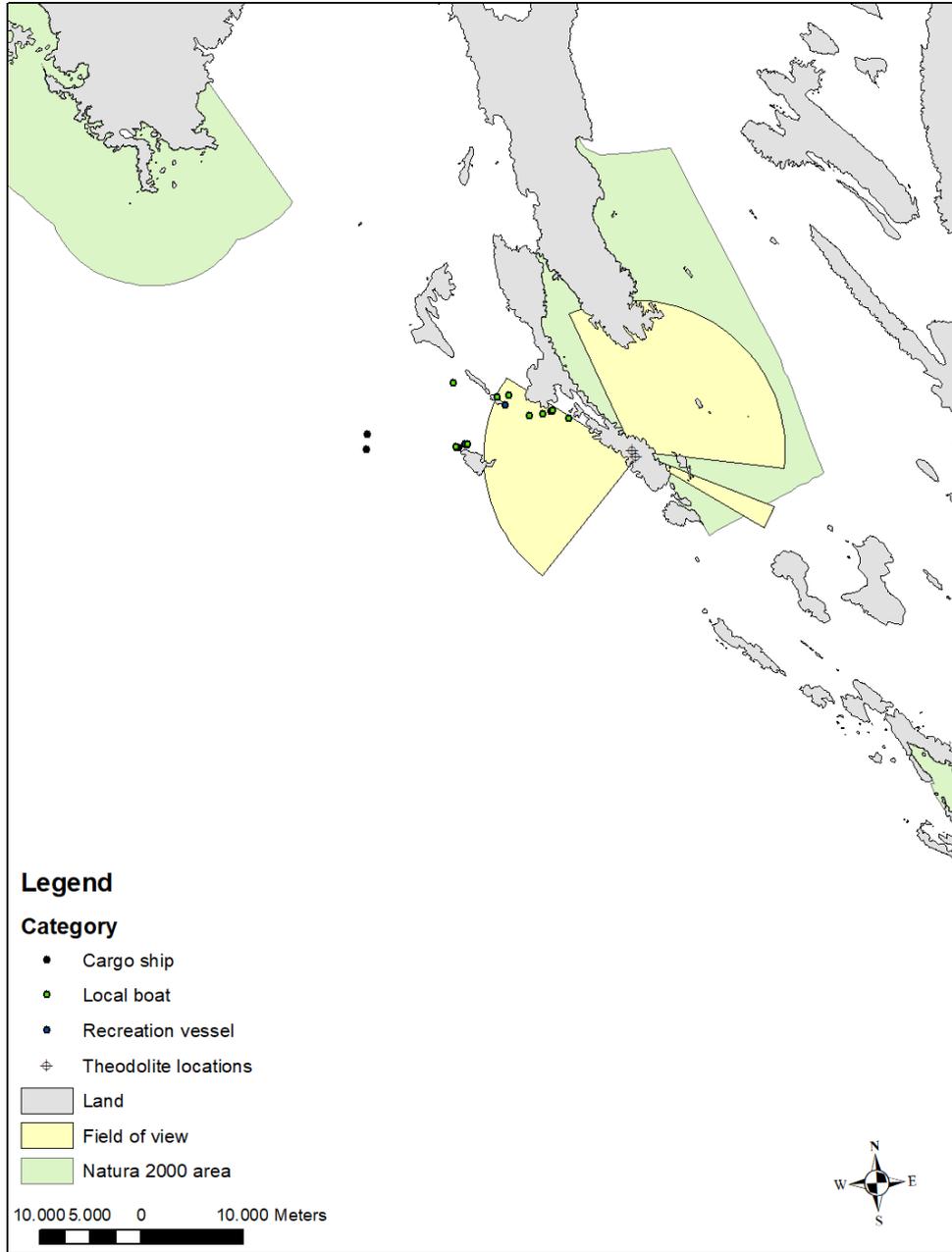


Figure 42. Locations of vessels - Winter 3rd sessions

The next map shows the relative density of vessels during winter 2021 3rd sessions of each day. Each grid cell was divided by a total number of sessions, from October 1st 2020 until March 31st 2021 (which was only one session).

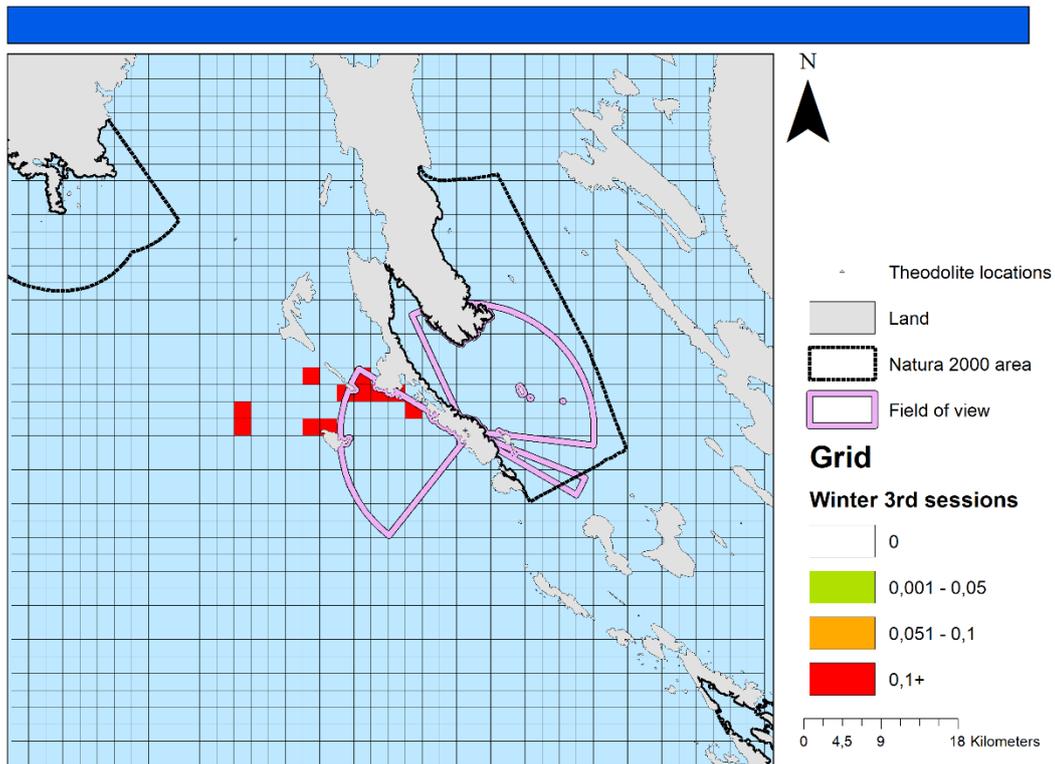


Figure 43. Relative density – Winter 3rd sessions

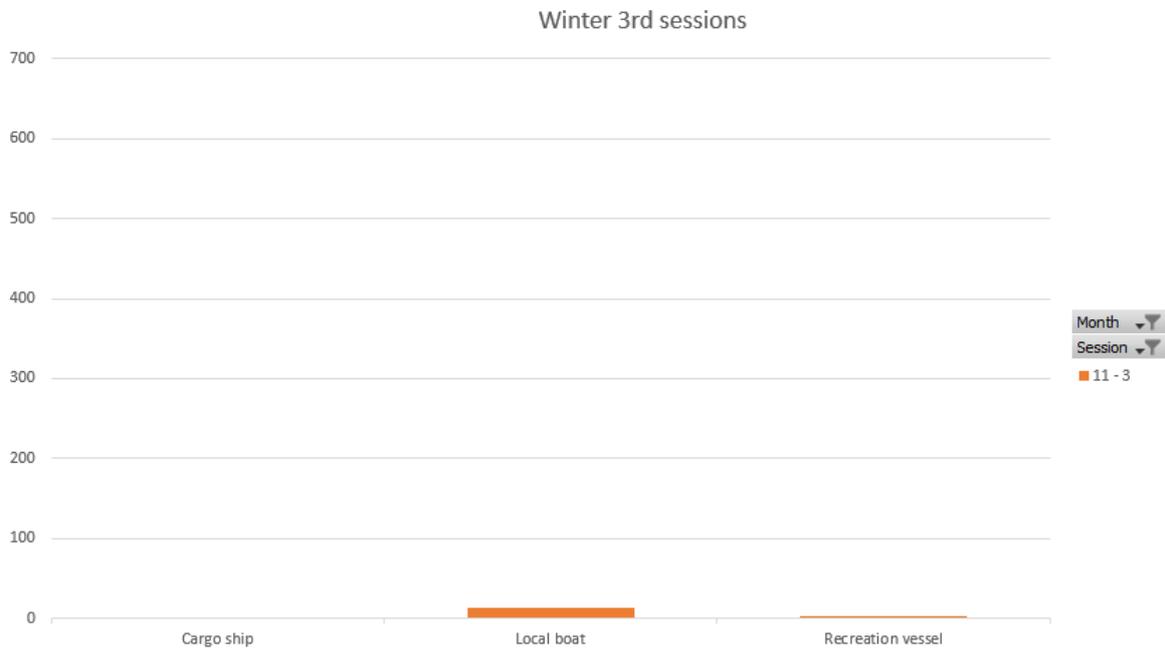


Figure 44. Number of vessels by categories - Winter 3rd sessions

Usually, the winter season doesn't have three sessions, but this specific case was so large in the number of vessels at the moment, that it became 3rd session.

3.3 Months

This section was divided into months. It has shown all data in the Cres- Lošinj archipelago through each month.

June

The next map shows the positions of all vessels during June 2020, from June 6th 2020 until June 19th 2020. Each category has a different colour which represents a different category.

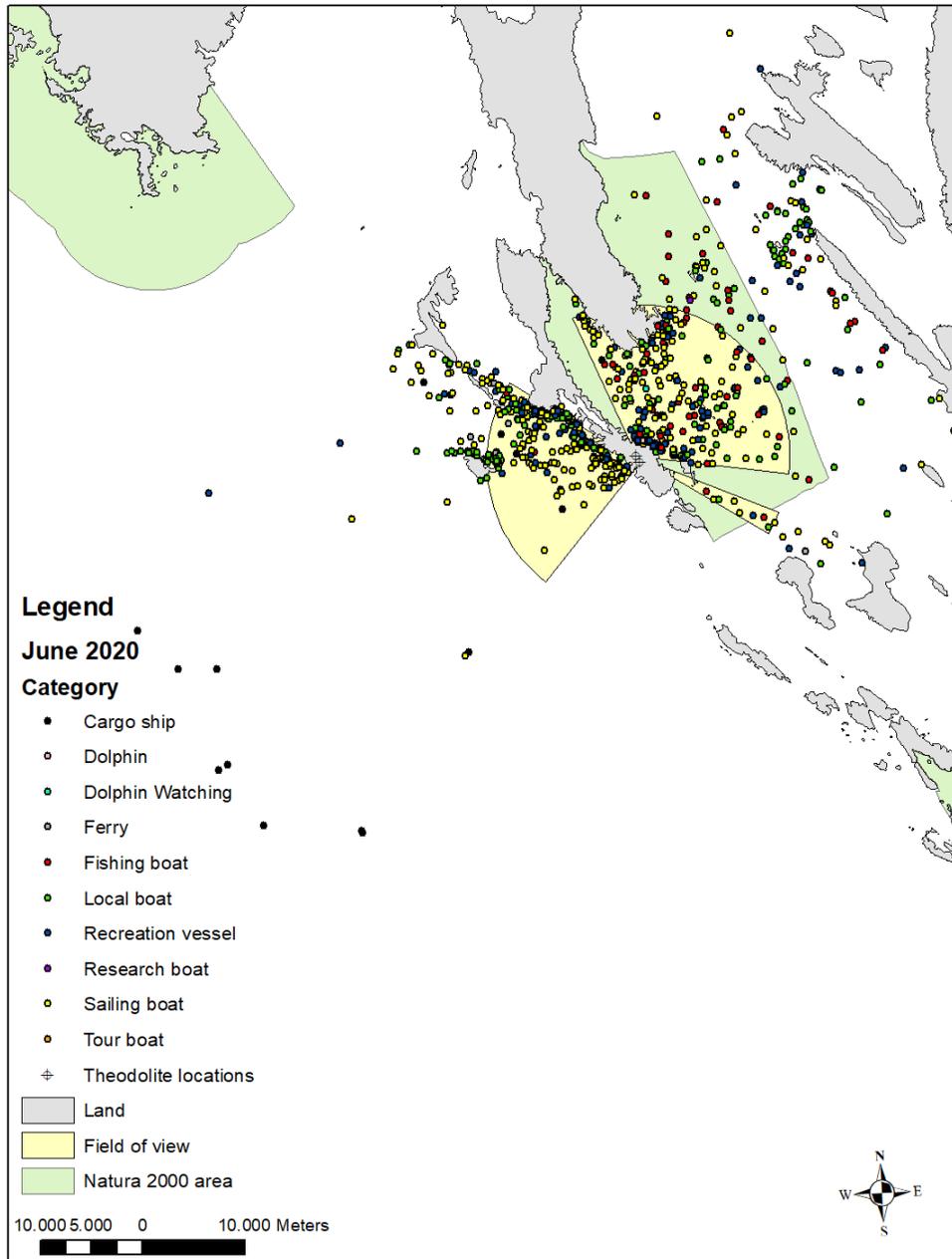


Figure 45. Locations of vessels - June

The next map shows the relative density of vessels during June 2020. Each grid cell was divided by a total number of sessions, from June 6th 2020 until June 19th 2020 (which were 34 sessions).

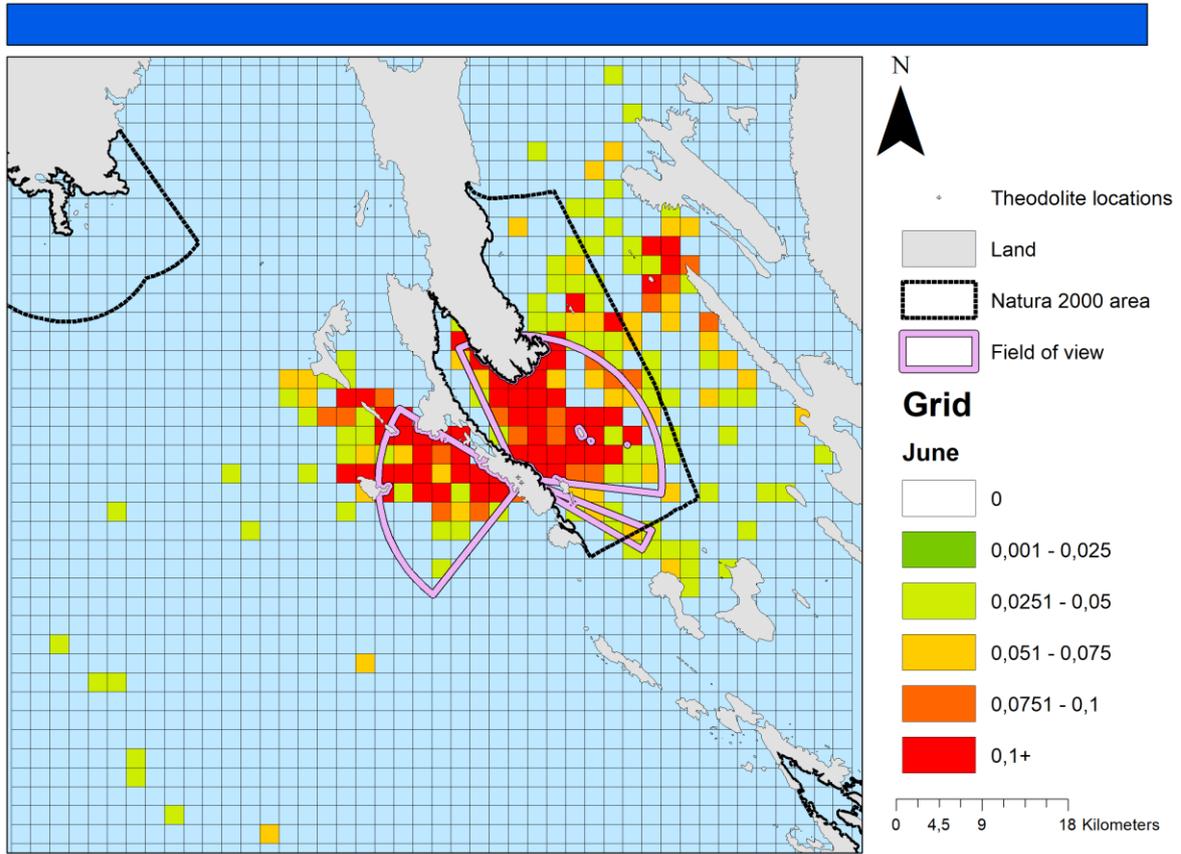


Figure 46. Relative density – June

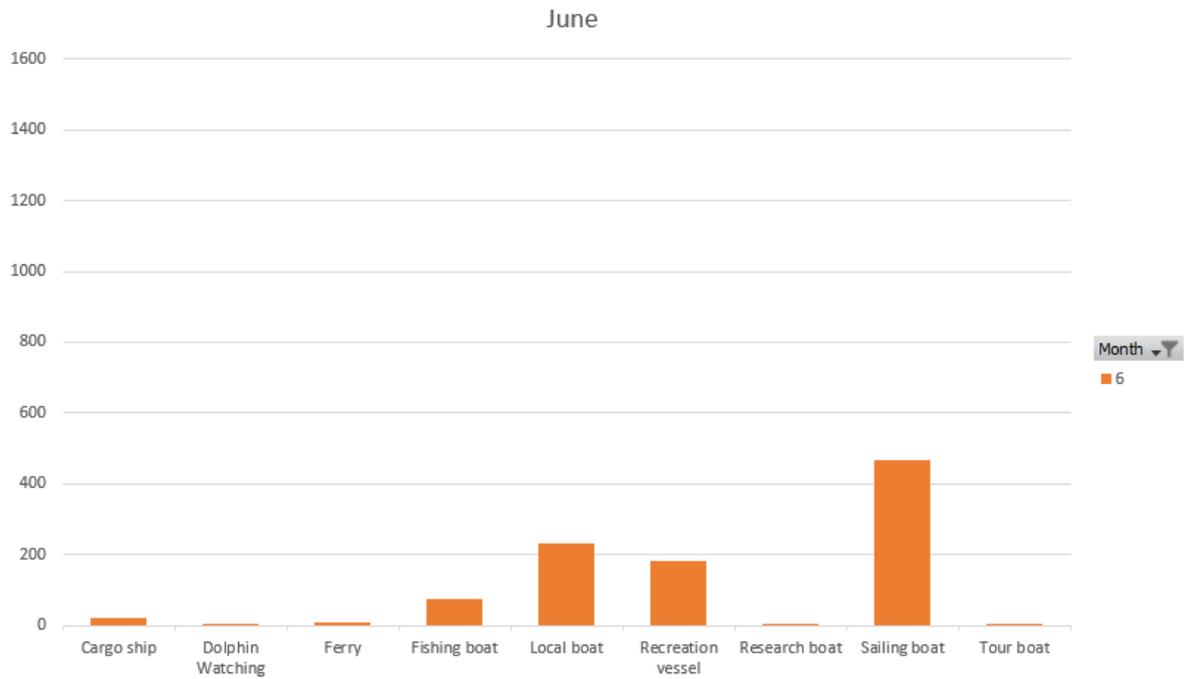


Figure 47. Number of vessels by categories - June

July

The next map shows the positions of all vessels during July 2020, from July 10th 2020 until July 30th 2020. Each category has a different colour which represents a different category.

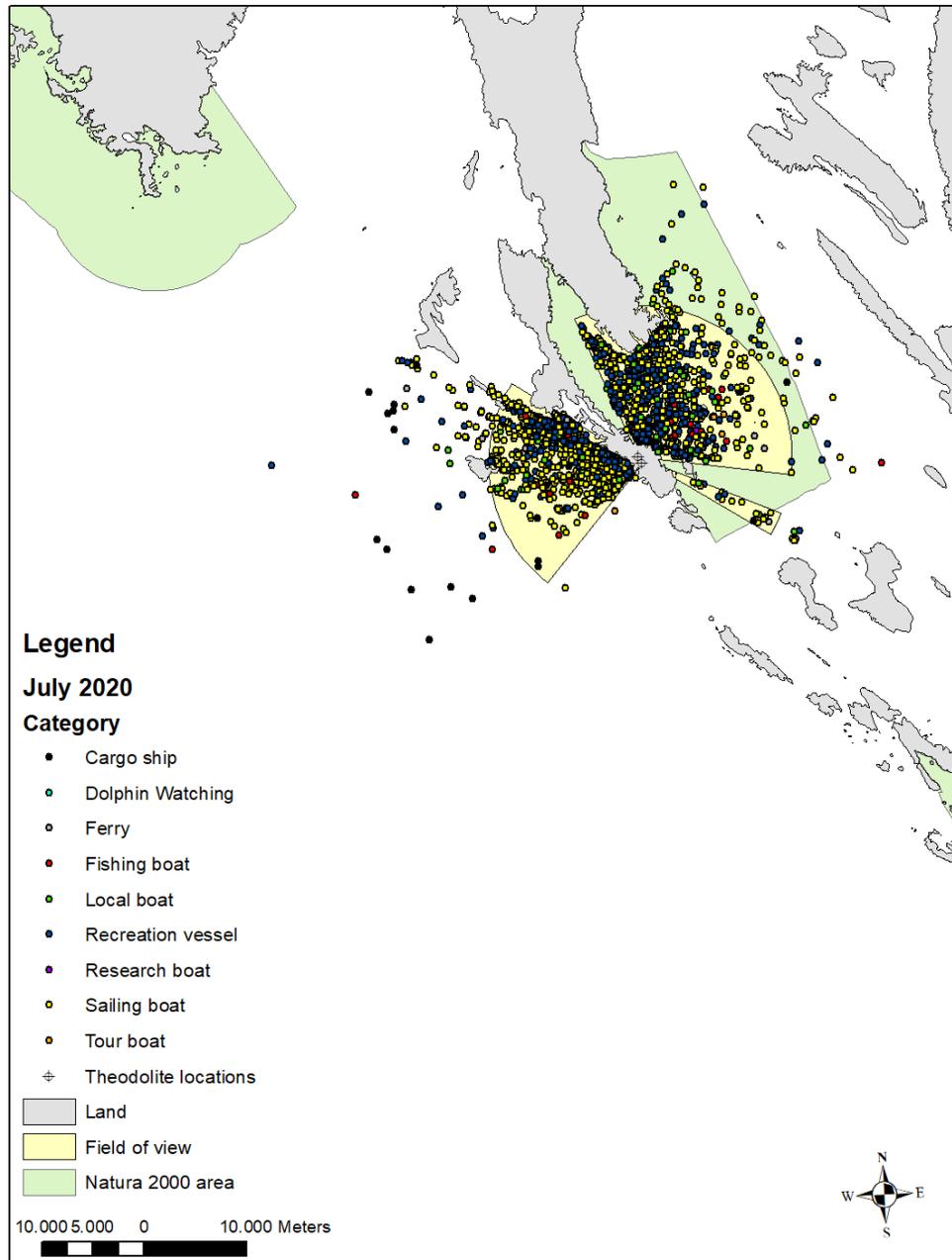


Figure 48. Locations of vessels - July

The next map shows the relative density of vessels during July 2020. Each grid cell was divided by a total number of sessions, from July 10th 2020 until July 30th 2020 (which were 58 sessions).

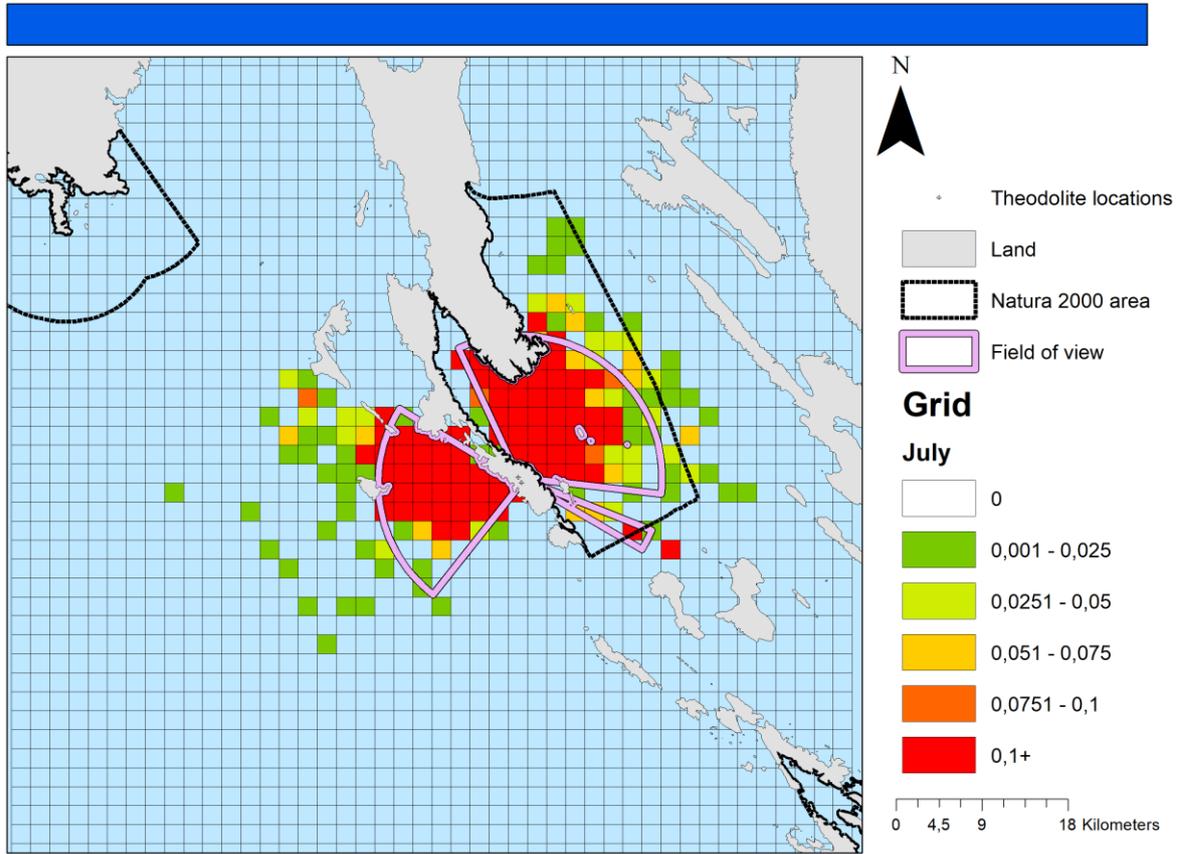


Figure 49. Relative density – July

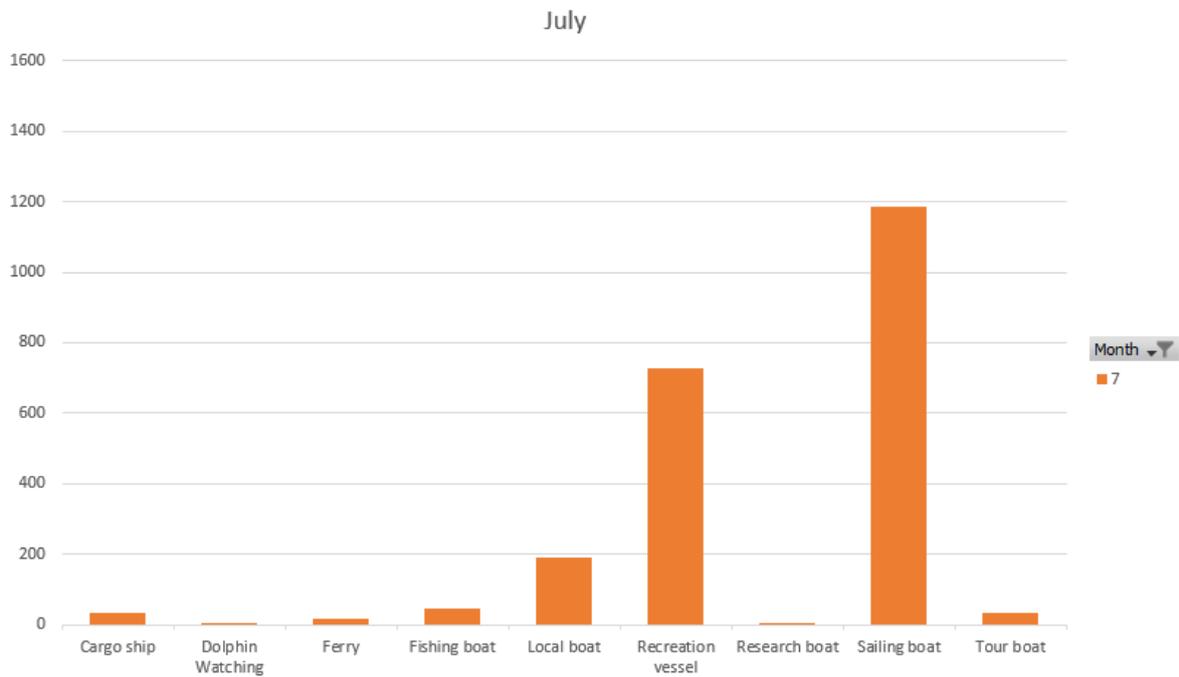


Figure 50. Number of vessels by categories - July

August

The next map shows the positions of all vessels during August 2020, from August 1st 2020 until August 31st 2020. Each category has a different colour which represents a different category.

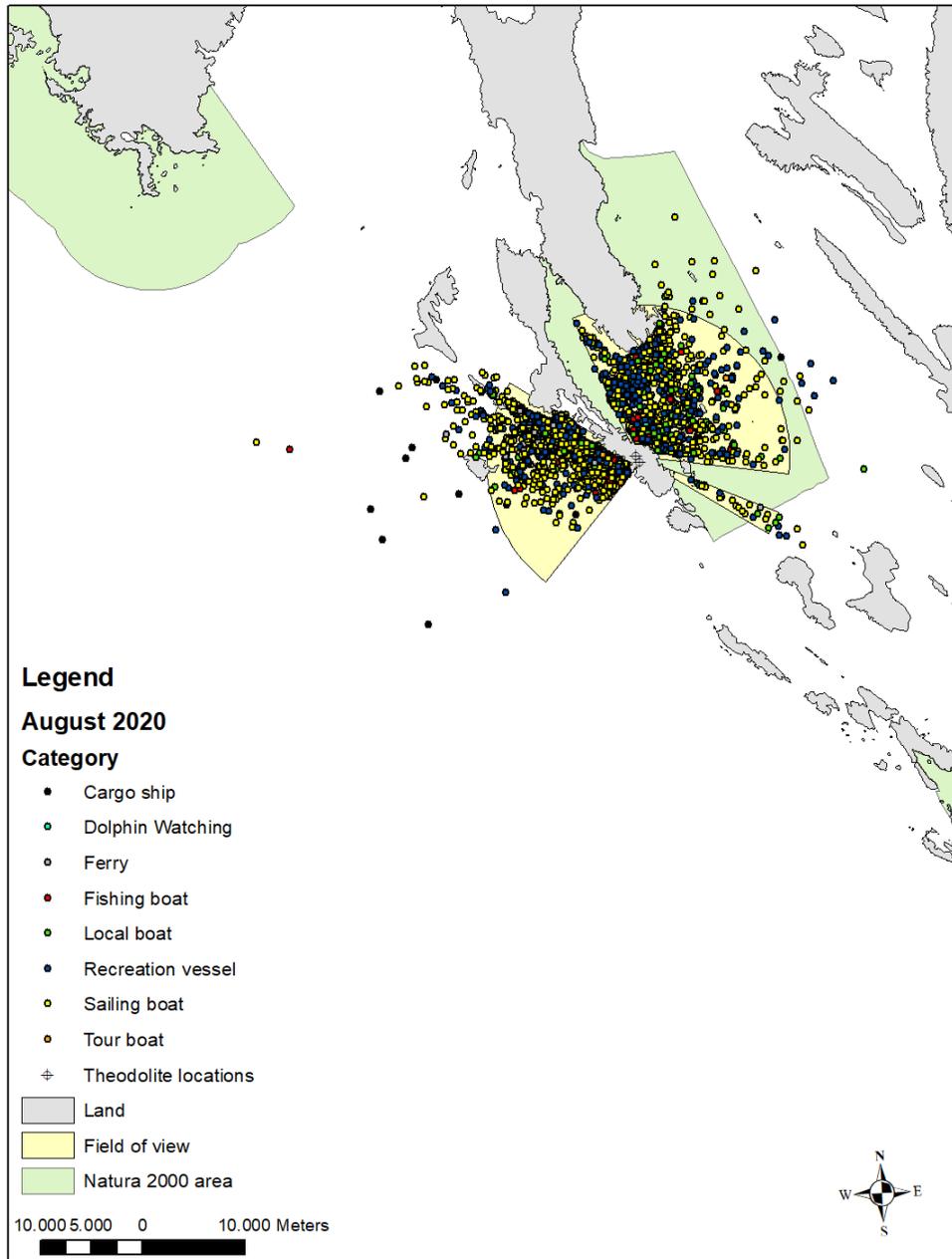


Figure 51. Locations of vessels - August

The next map shows the relative density of vessels during August 2020. Each grid cell was divided by a total number of sessions, from August 1st 2020 until August 31st 2020 (which were 68 sessions).

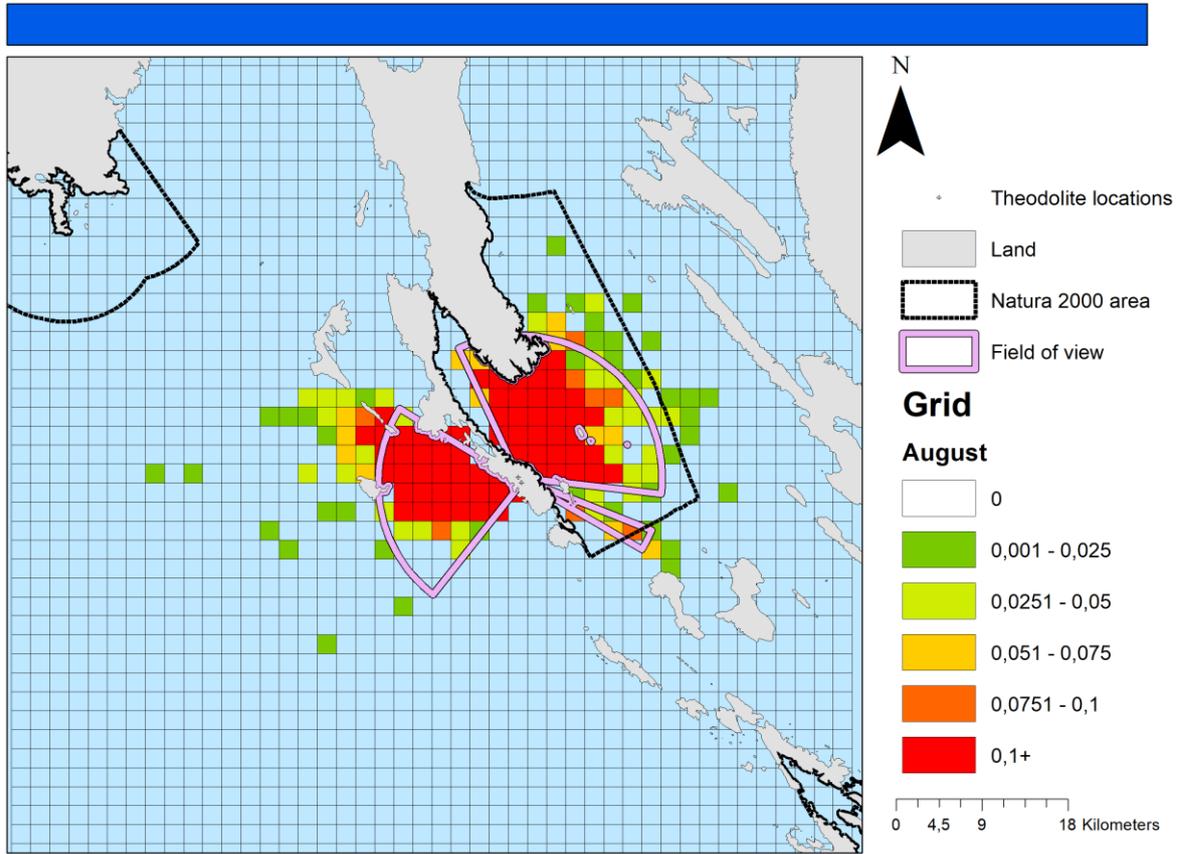


Figure 52. Relative density – August

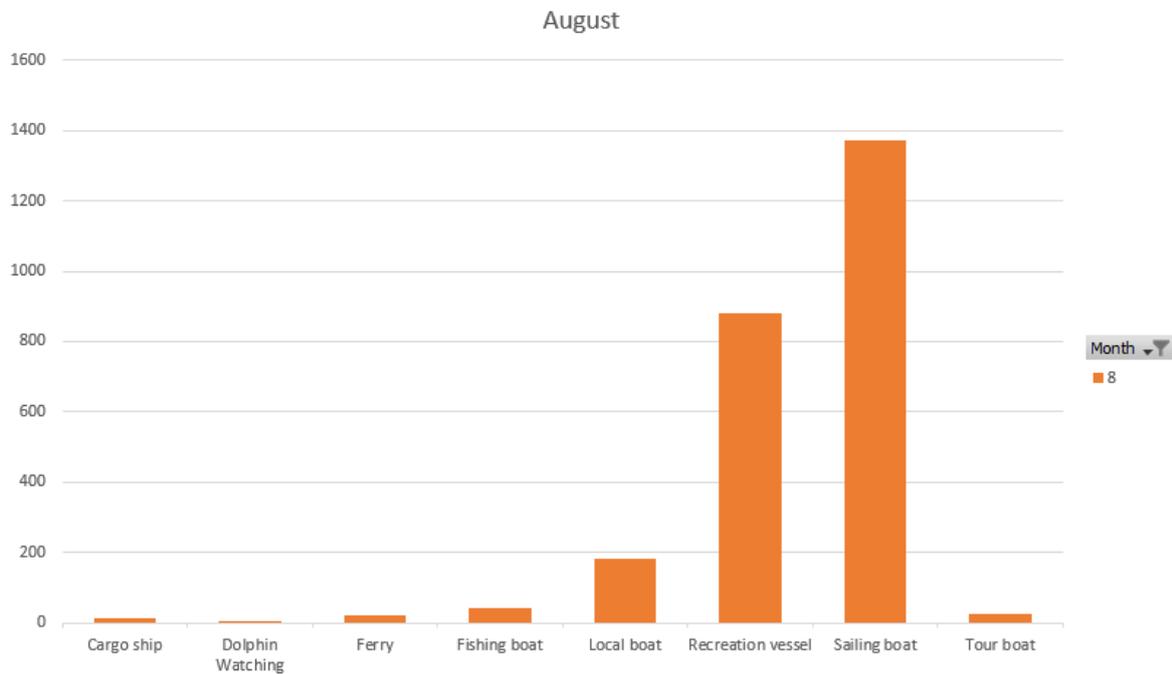


Figure 53. Number of vessels by categories - August

September

The next map shows the positions of all vessels during September 2020, from September 1st 2020 until September 30th 2020. Each category has a different colour which represents a different category.

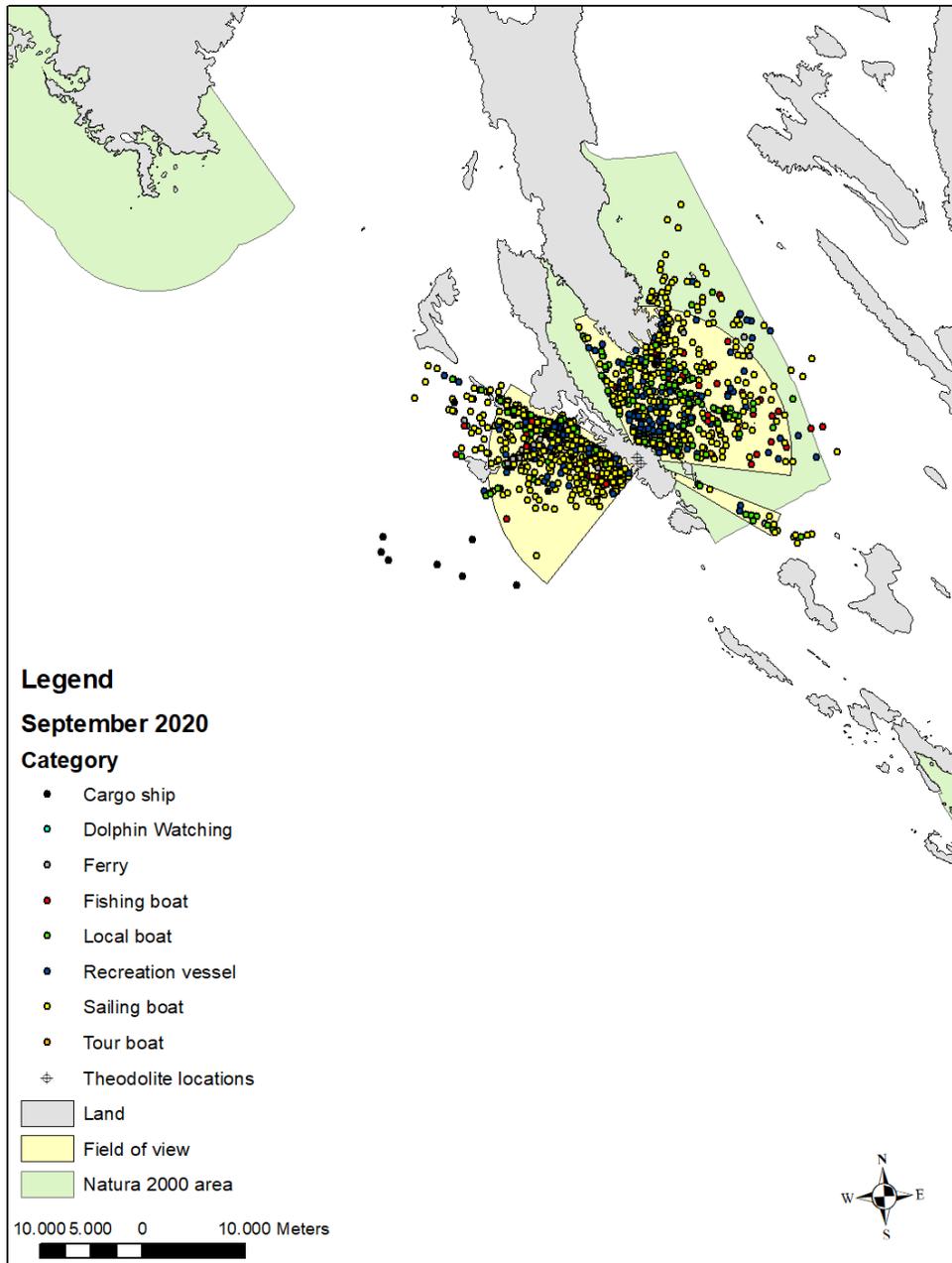


Figure 54. Locations of vessels - September

The next map shows the relative density of vessels during September 2020. Each grid cell was divided by a total number of sessions, from September 1st 2020 until September 30th 2020 (which were 62 sessions).

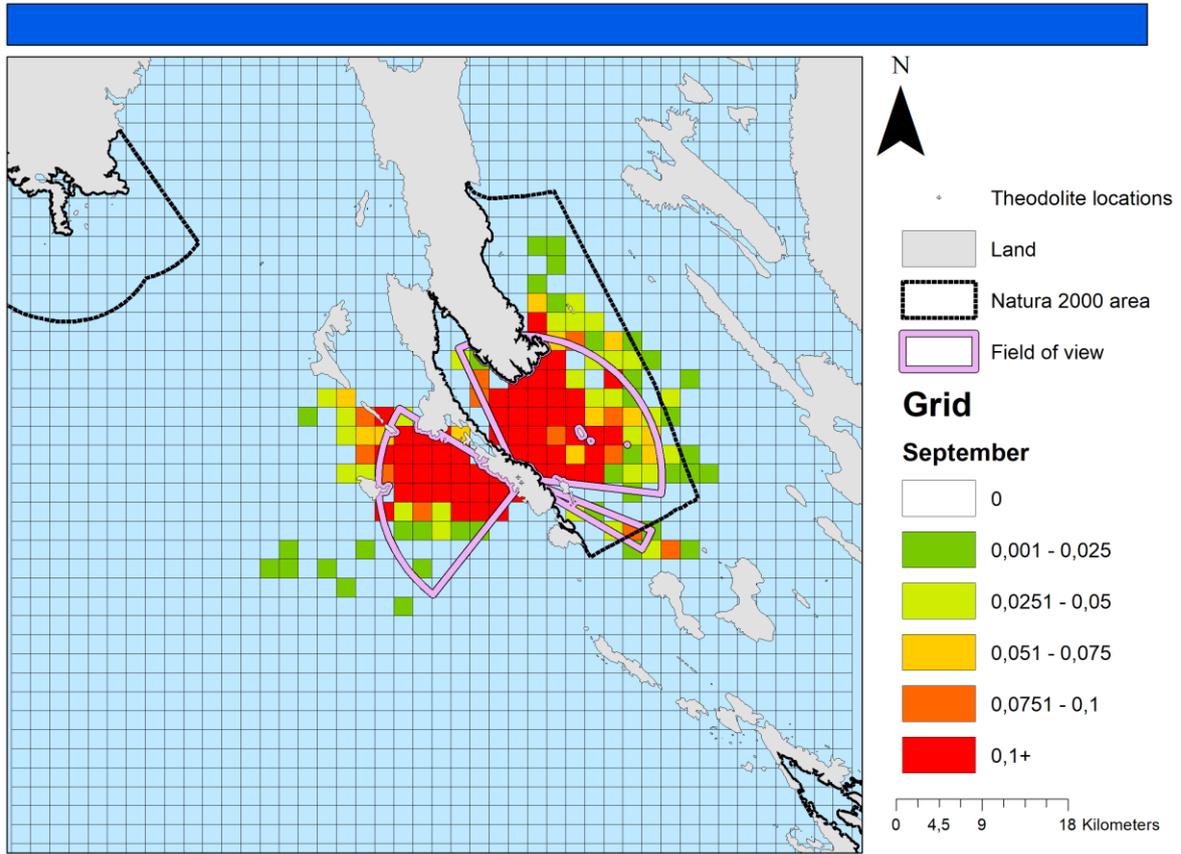


Figure 55. Relative density – September

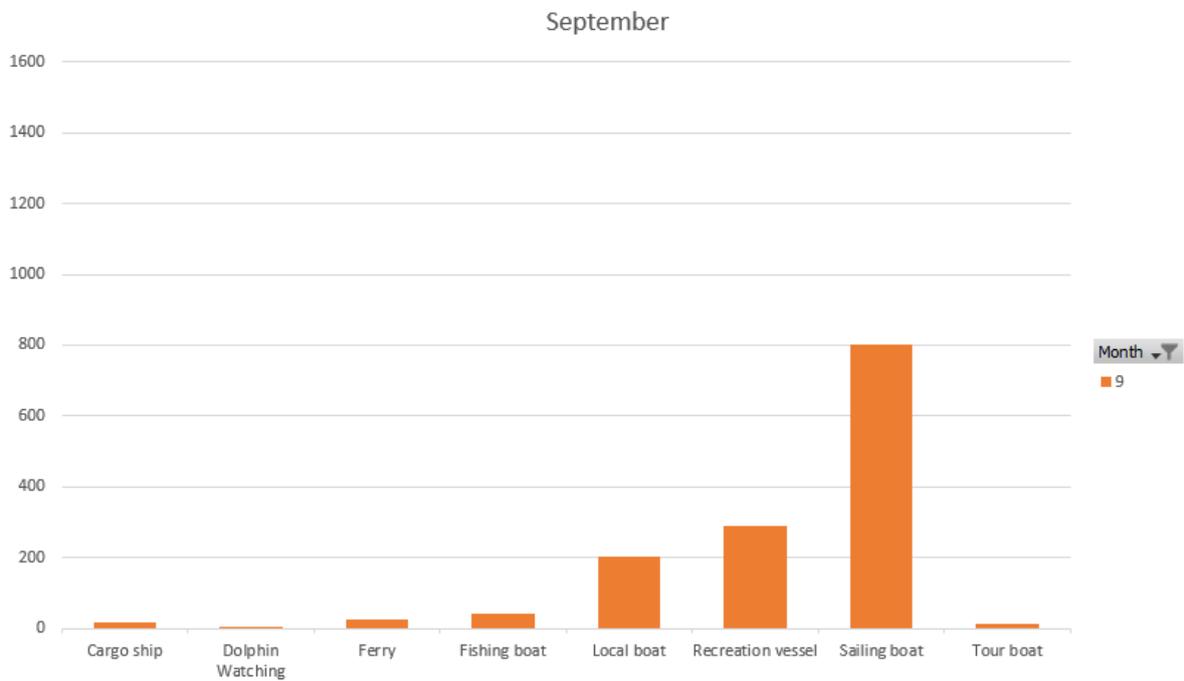


Figure 56. Number of vessels by categories - September

October

The next map shows the positions of all vessels during October 2020, from October 1st 2020 until October 31st 2020. Each category has a different colour which represents a different category.

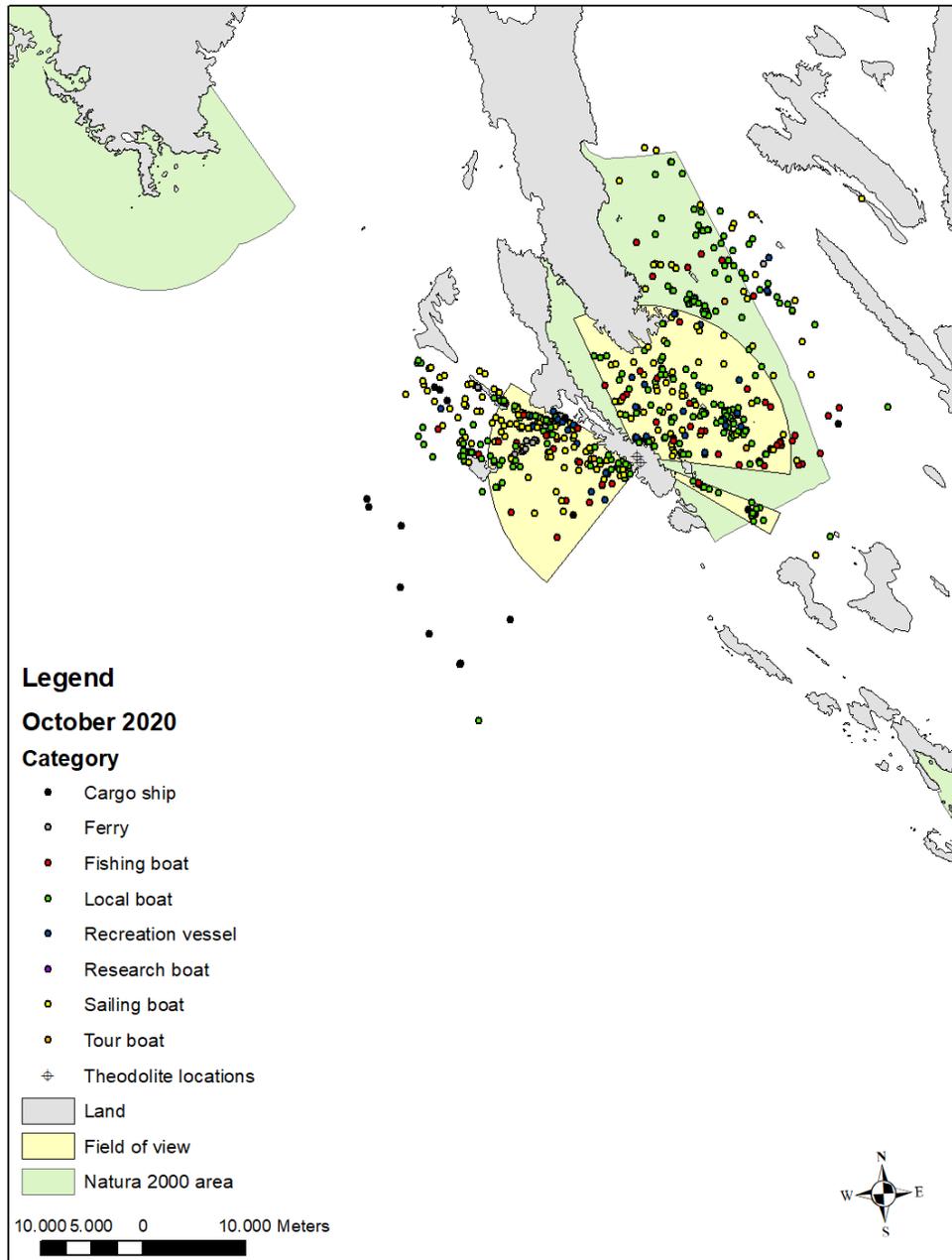


Figure 57. Locations of vessels - October

The next map shows the relative density of vessels during October 2020. Each grid cell was divided by a total number of sessions, from October 1st 2020 until October 31st 2020 (which were 35 sessions).

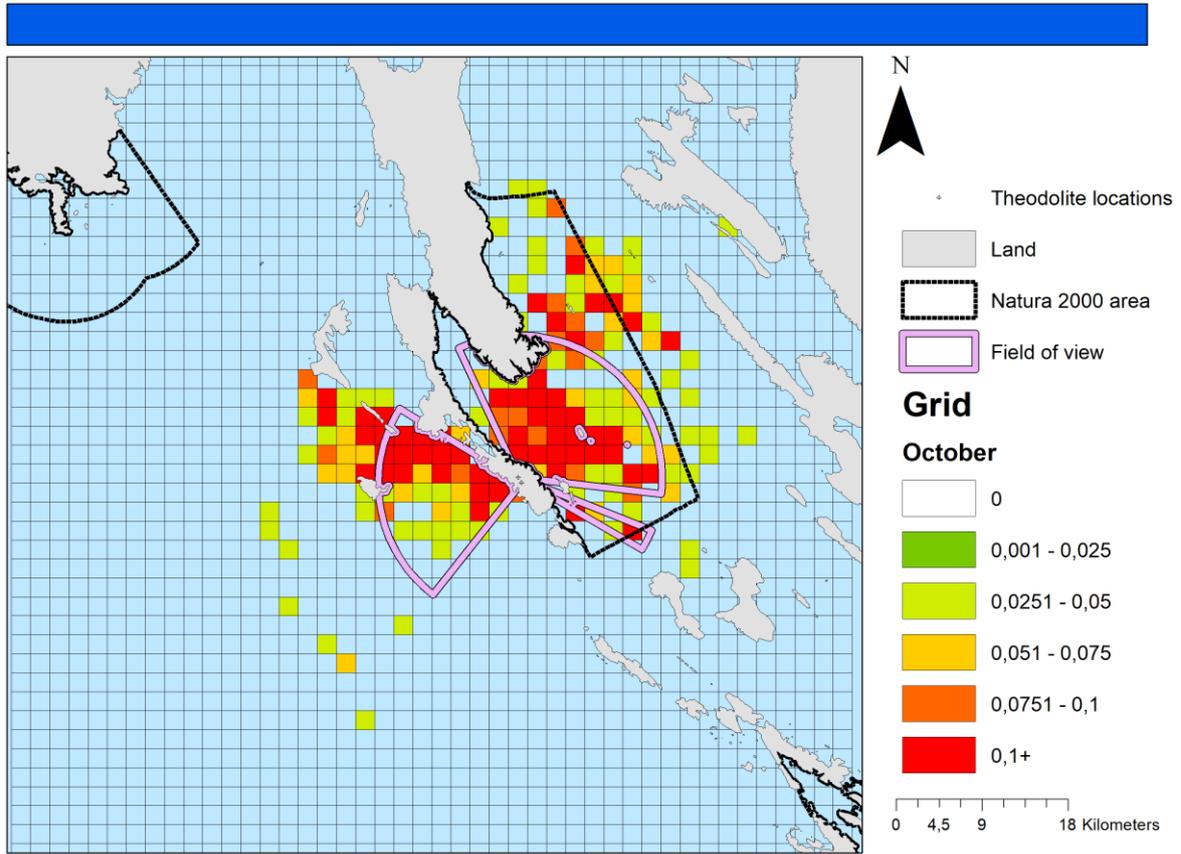


Figure 58. Relative density – October

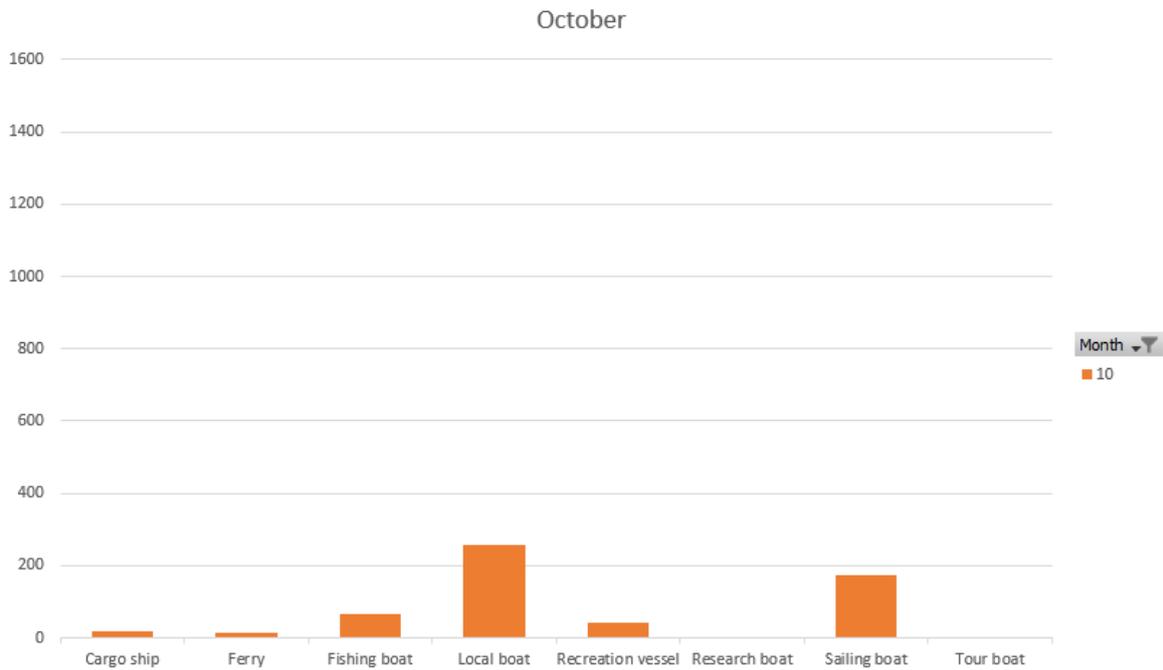


Figure 59. Number of vessels by categories - October

November

The next map shows the positions of all vessels during November 2020, from November 1st 2020 until November 28th 2020. Each category has a different colour which represents a different category.

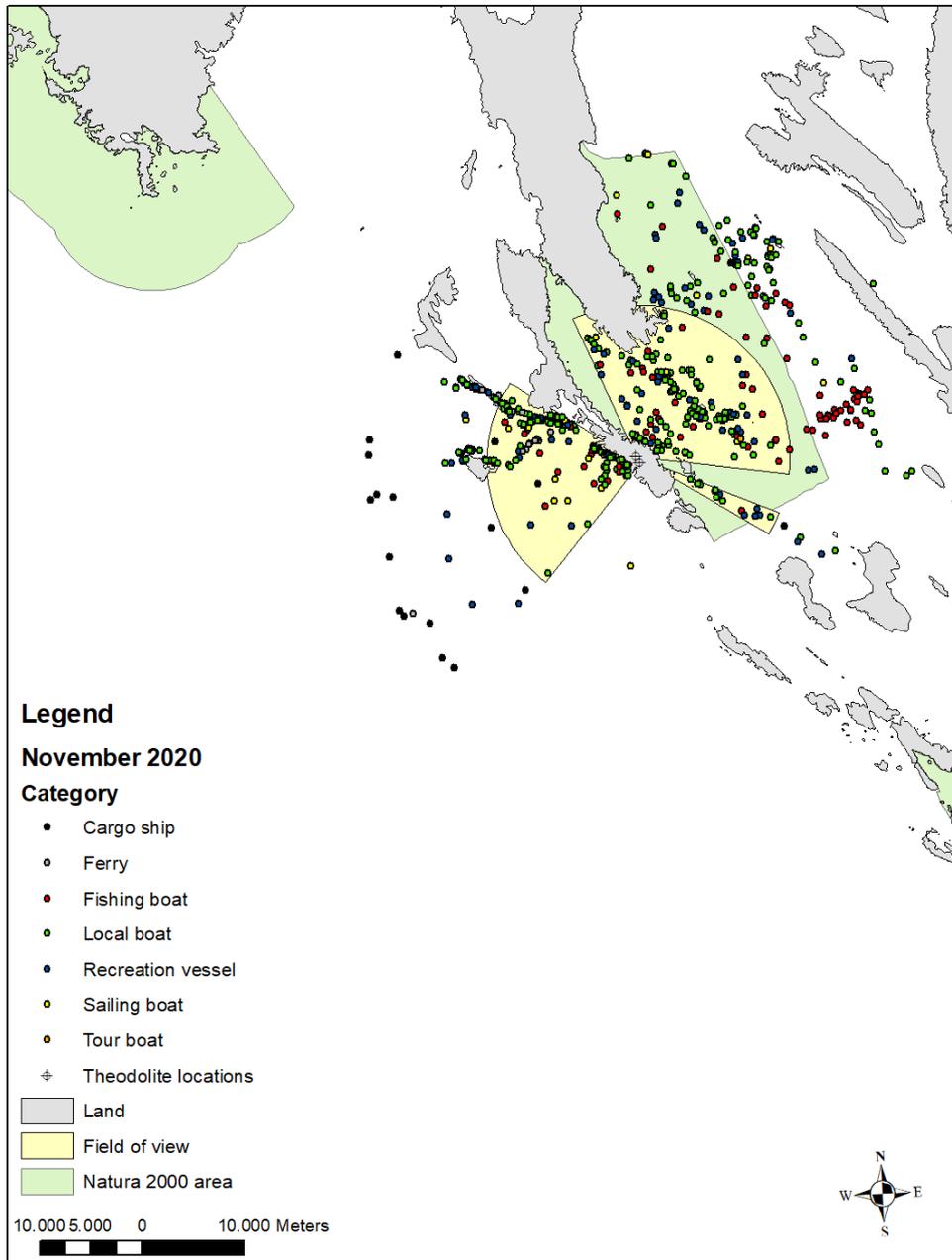


Figure 60. Locations of vessels - November

The next map shows the relative density of vessels during November 2020. Each grid cell was divided by a total number of sessions, from November 1st 2020 until November 28th 2020 (which were 39 sessions).

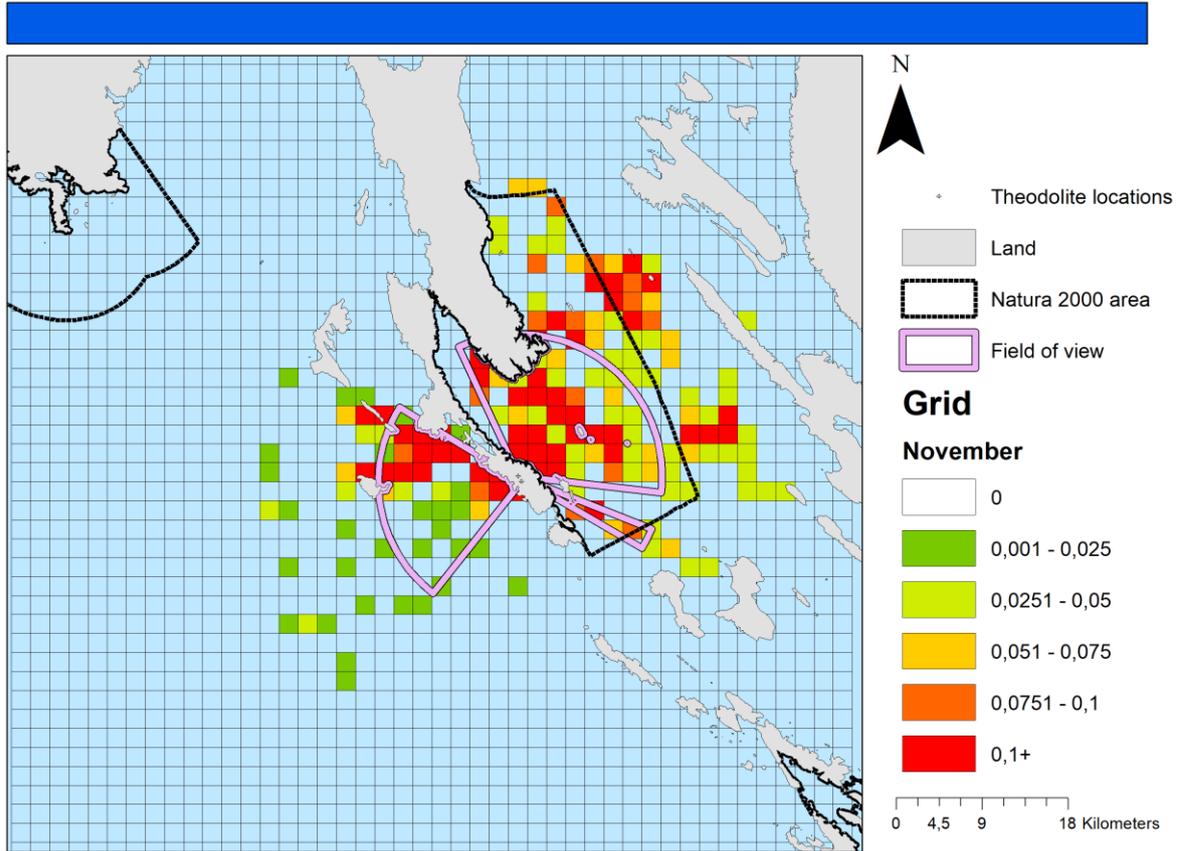


Figure 61. Relative density – November

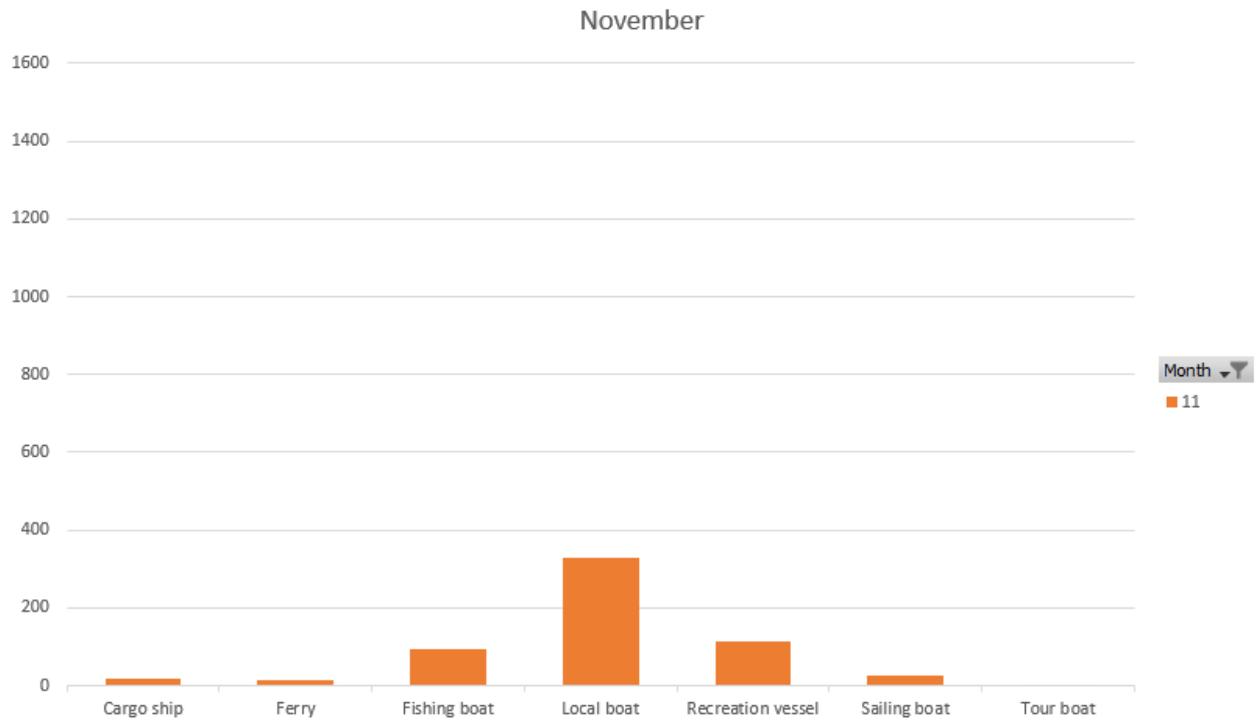


Figure 62. Number of vessels by categories - November

December

The next map shows the positions of all vessels during December 2020, from December 1st 2020 until December 20th 2020. Each category has a different colour which represents a different category.

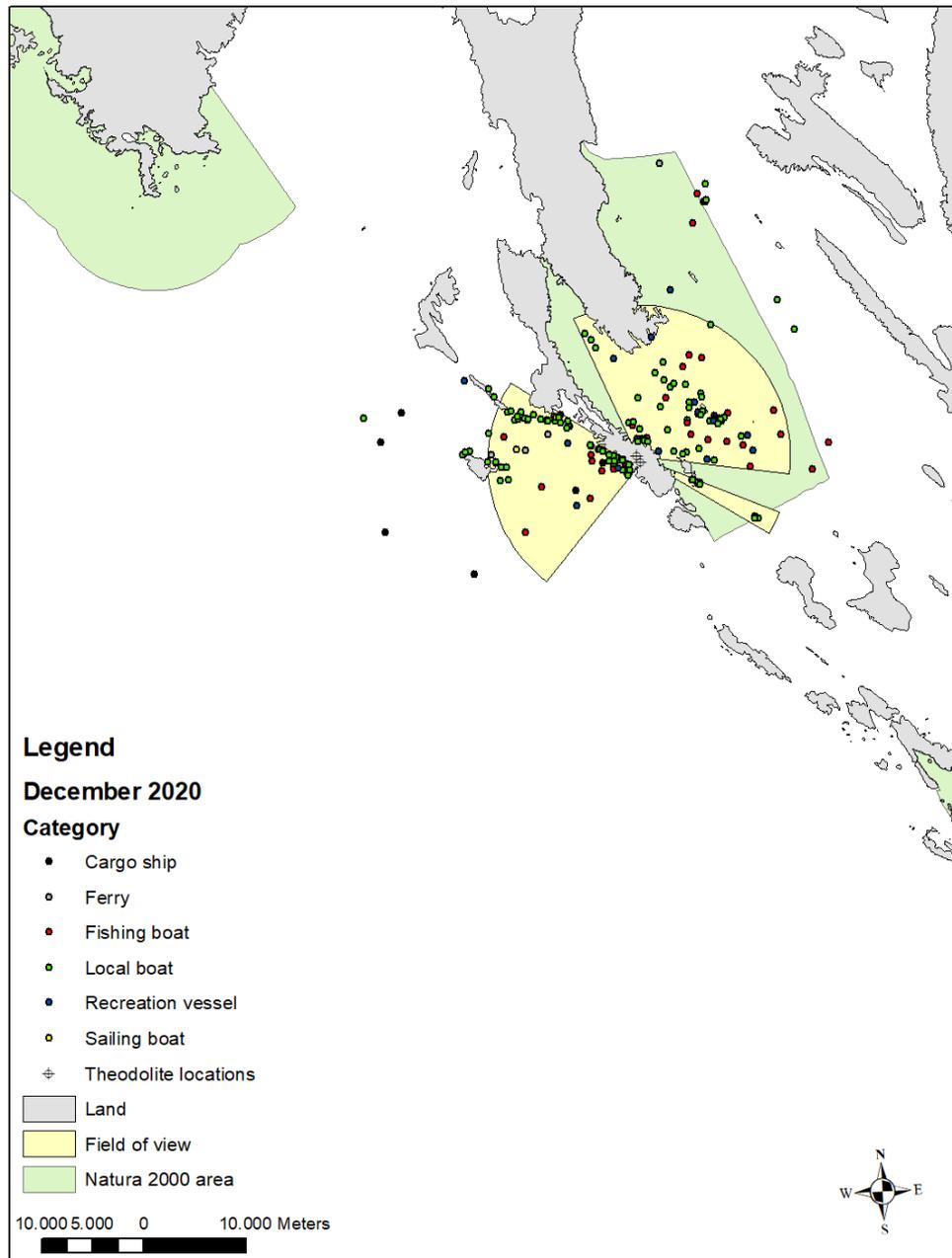


Figure 63. Locations of vessels - December

The next map shows the relative density of vessels during December 2020. Each grid cell was divided by a total number of sessions, from December 1st 2020 until December 20th 2020 (which were 19 sessions).

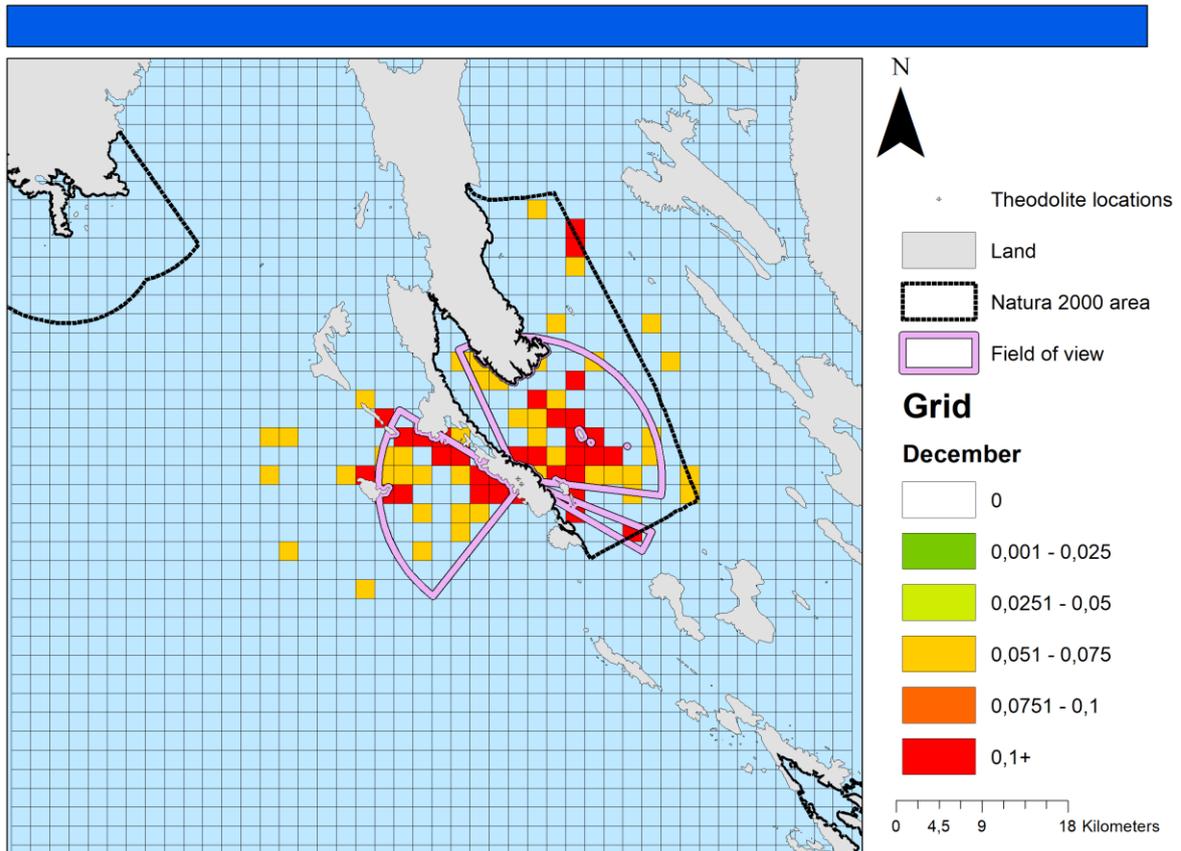


Figure 64. Relative density – December

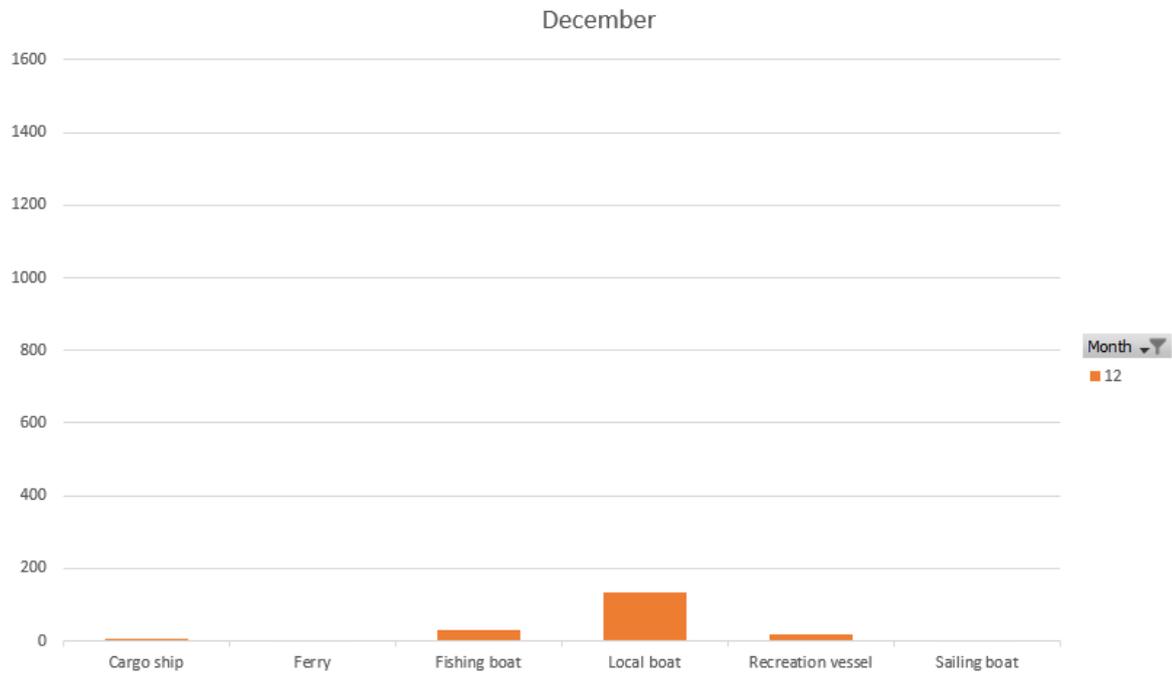


Figure 65. Number of vessels by categories - December

January

The next map shows the positions of all vessels during January 2021, from January 4th 2021 until January 28th 2021. Each category has a different colour which represents a different category.

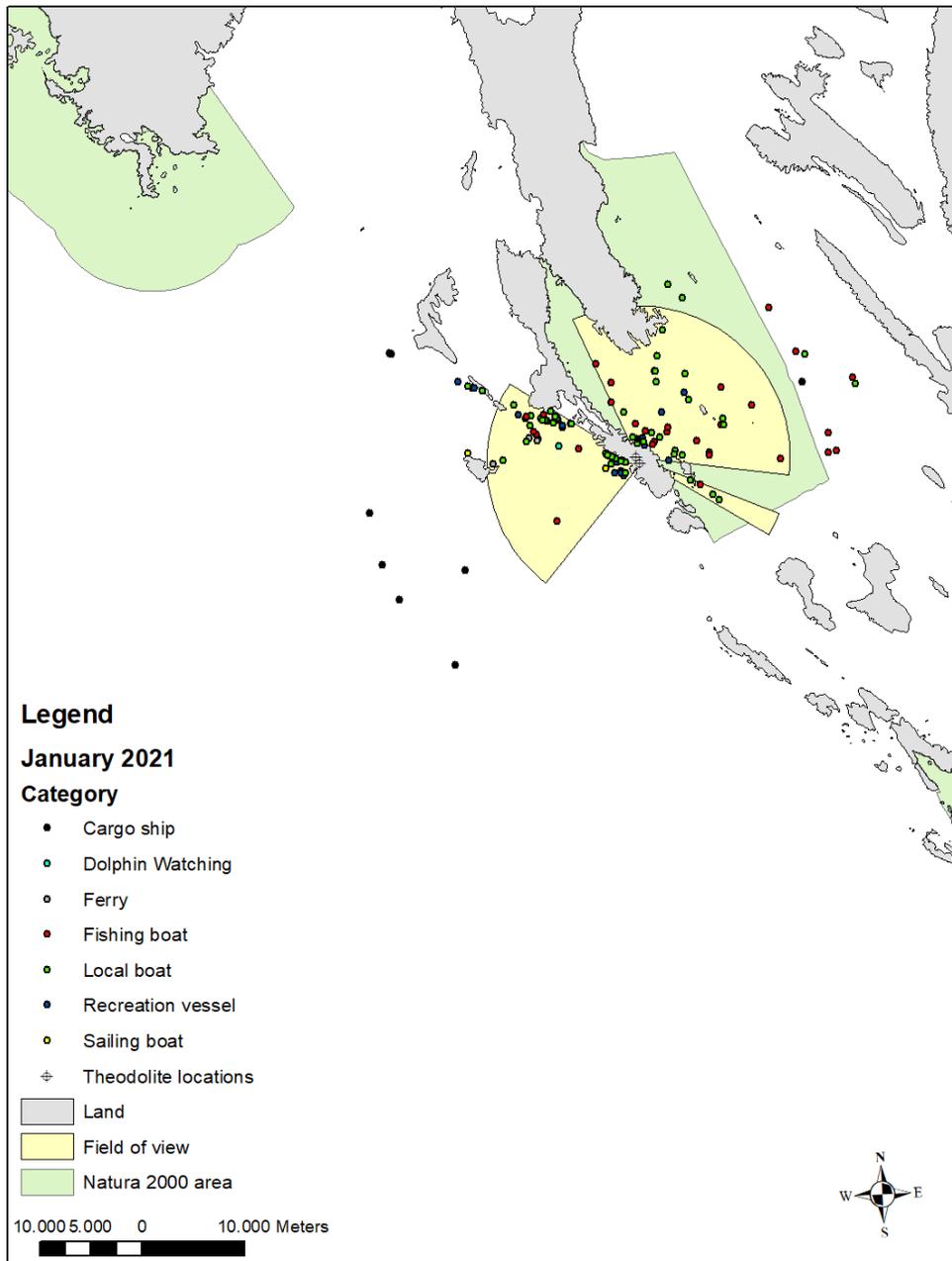


Figure 66. Locations of vessels - January

The next map shows the relative density of vessels during January 2021. Each grid cell was divided by a total number of sessions, from January 4th 2021 until January 28th 2021 (which were 19 sessions).

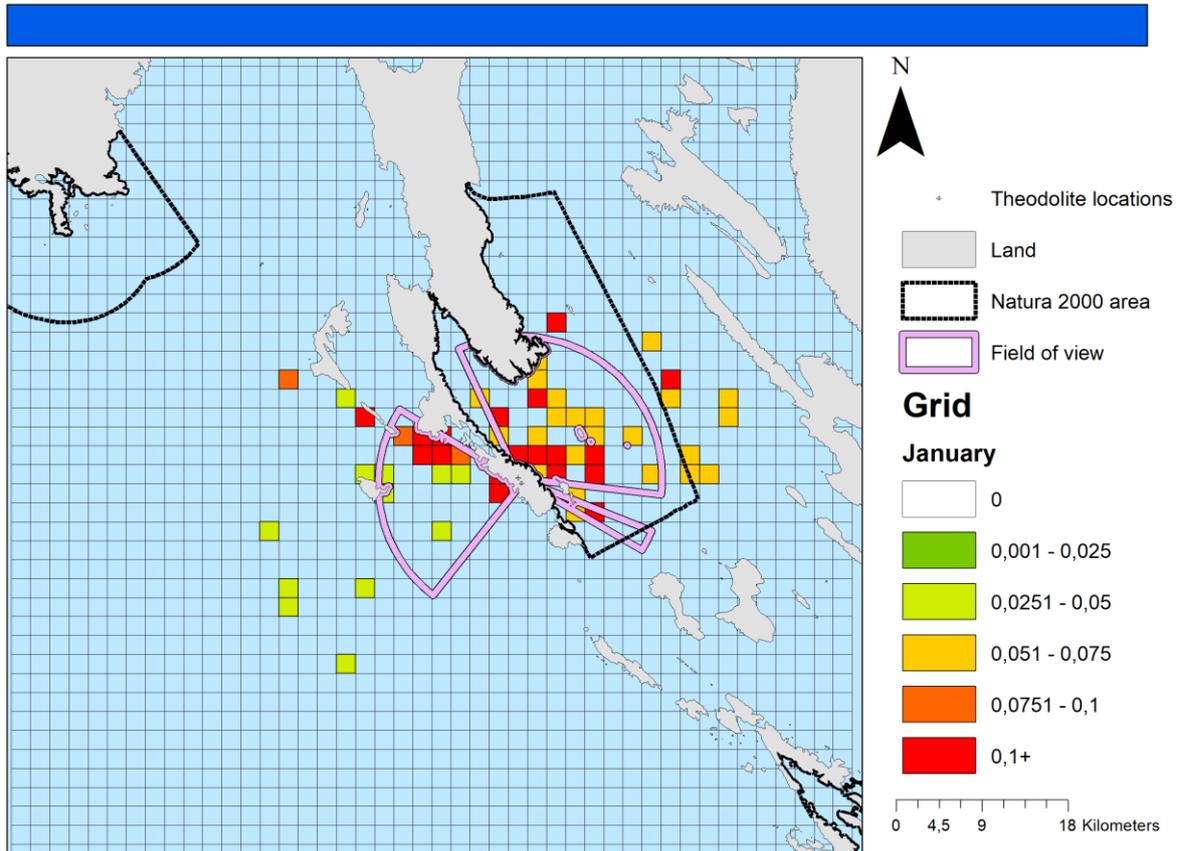


Figure 67. Relative density – January

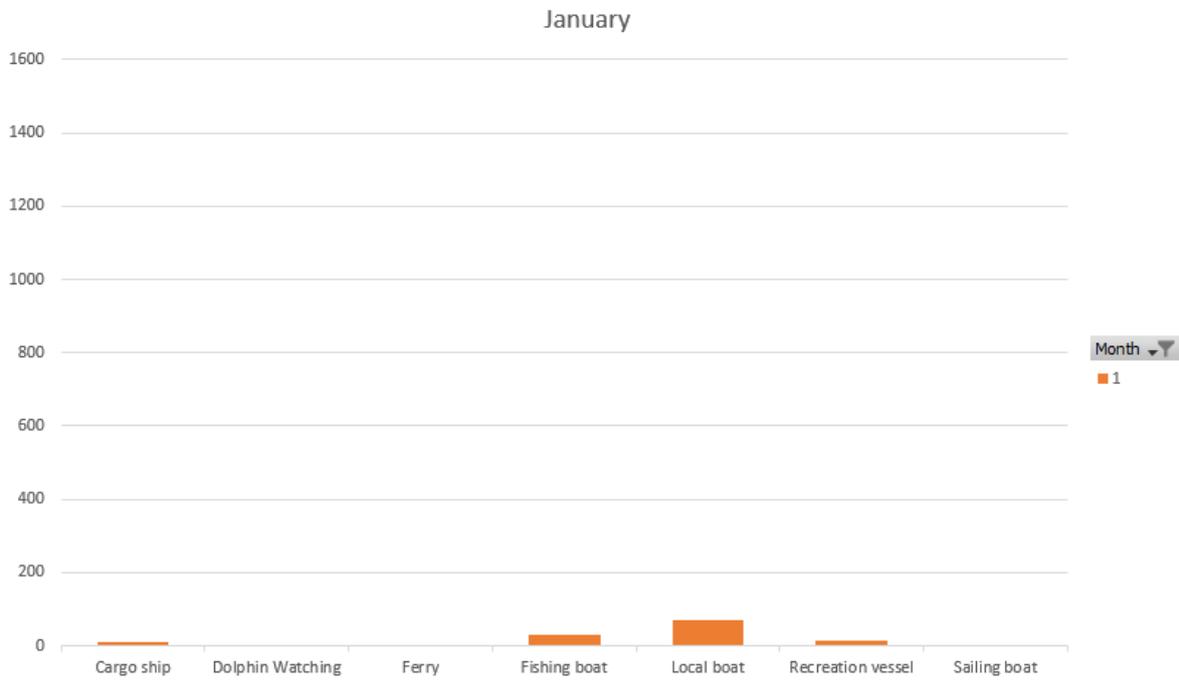


Figure 68. Number of vessels by categories - January

February

The next map shows the positions of all vessels during February 2021, from February 1st 2021 until February 28th 2021. Each category has a different colour which represents a different category.

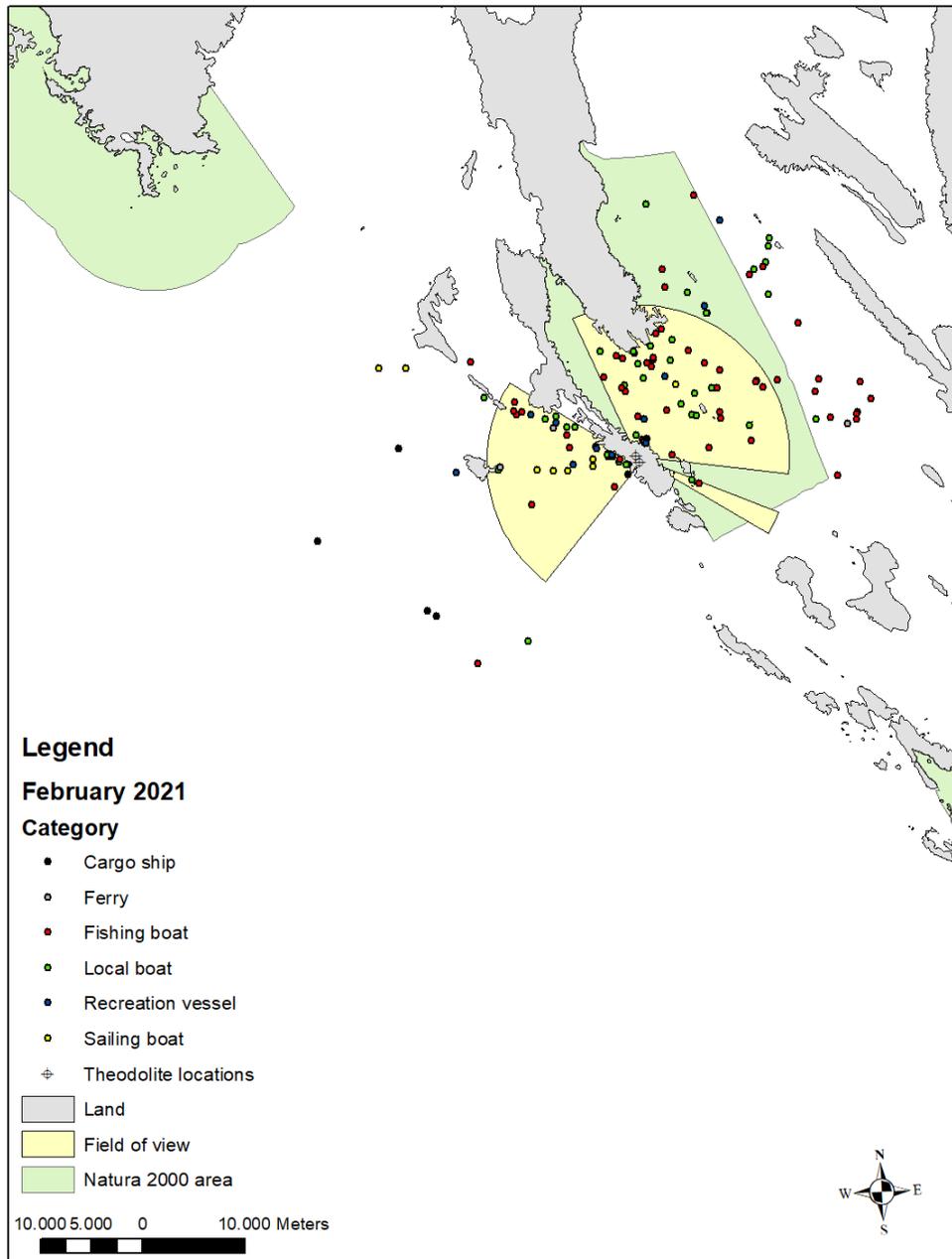


Figure 69. Locations of vessels - February

The next map shows the relative density of vessels during February 2021. Each grid cell was divided by a total number of sessions, from February 1st 2021 until February 28th 2021 (which were 30 sessions).

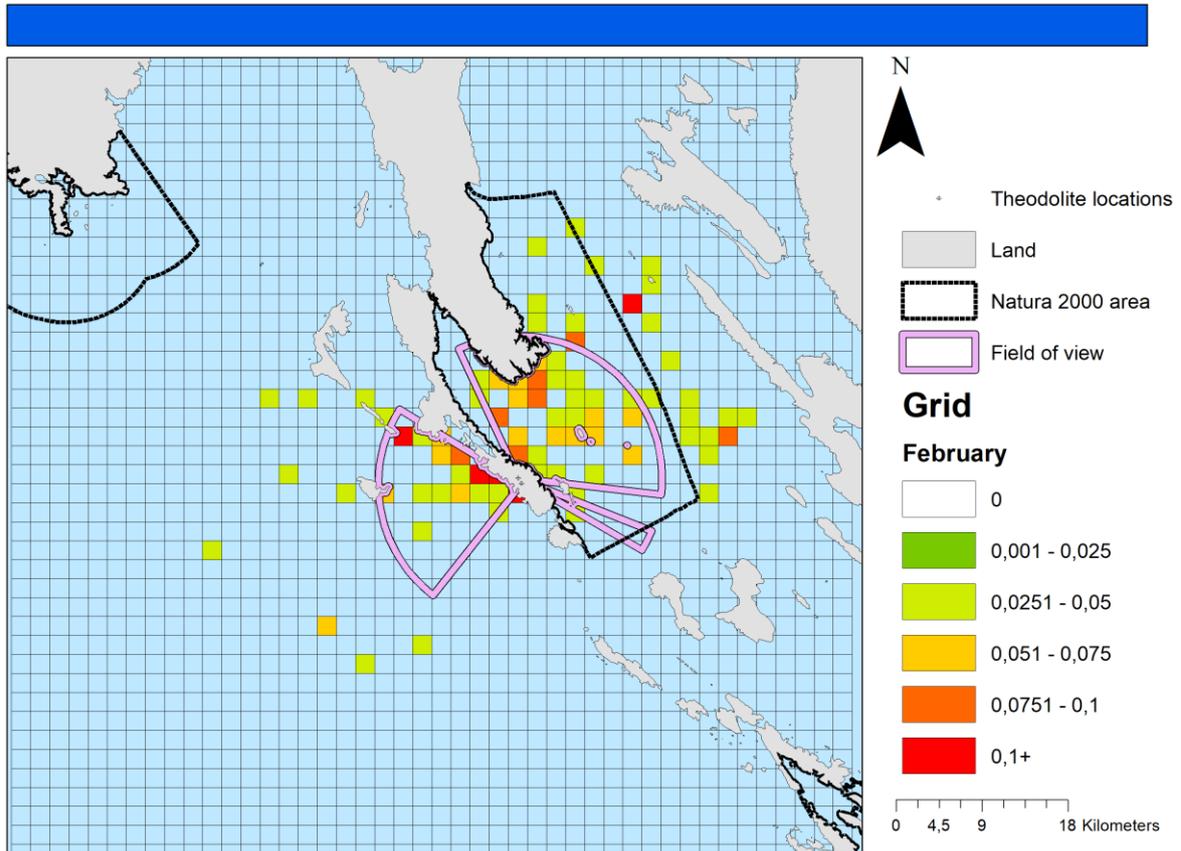


Figure 70. Relative density – February

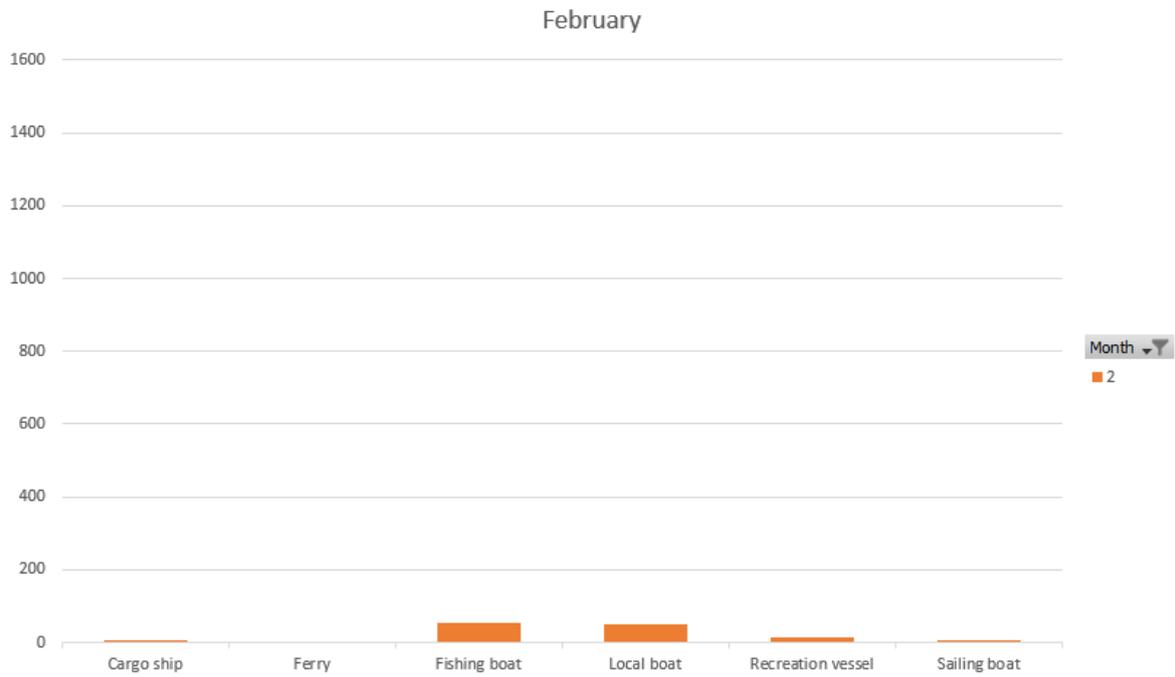


Figure 71. Number of vessels by categories - February

March

The next map shows the positions of all vessels during March 2021, from March 1st 2021 until March 31st 2021. Each category has a different colour which represents a different category.

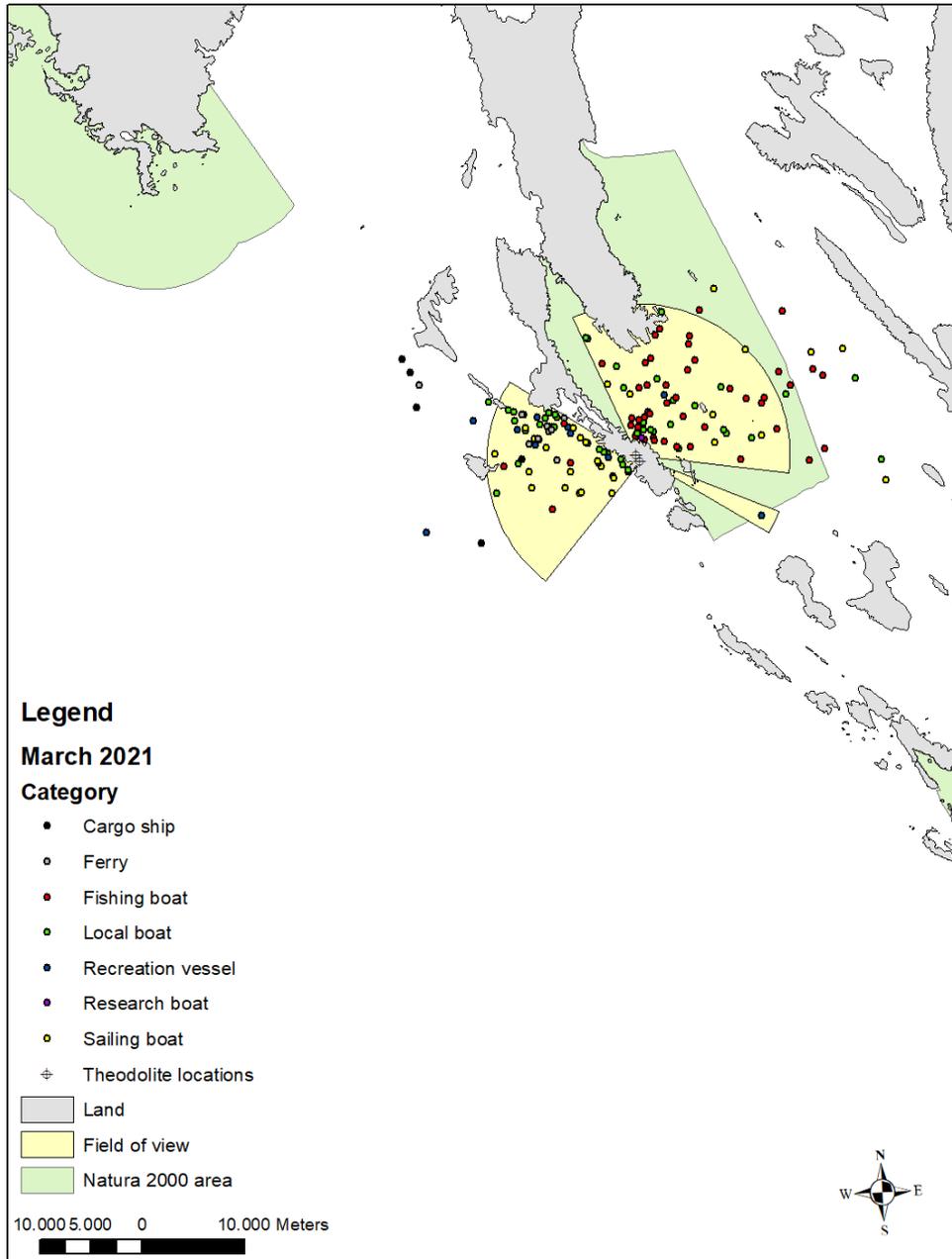


Figure 72. Locations of vessels - March

The next map shows the relative density of vessels during March 2021. Each grid cell was divided by a total number of sessions during that interval of time (which were 41 sessions).

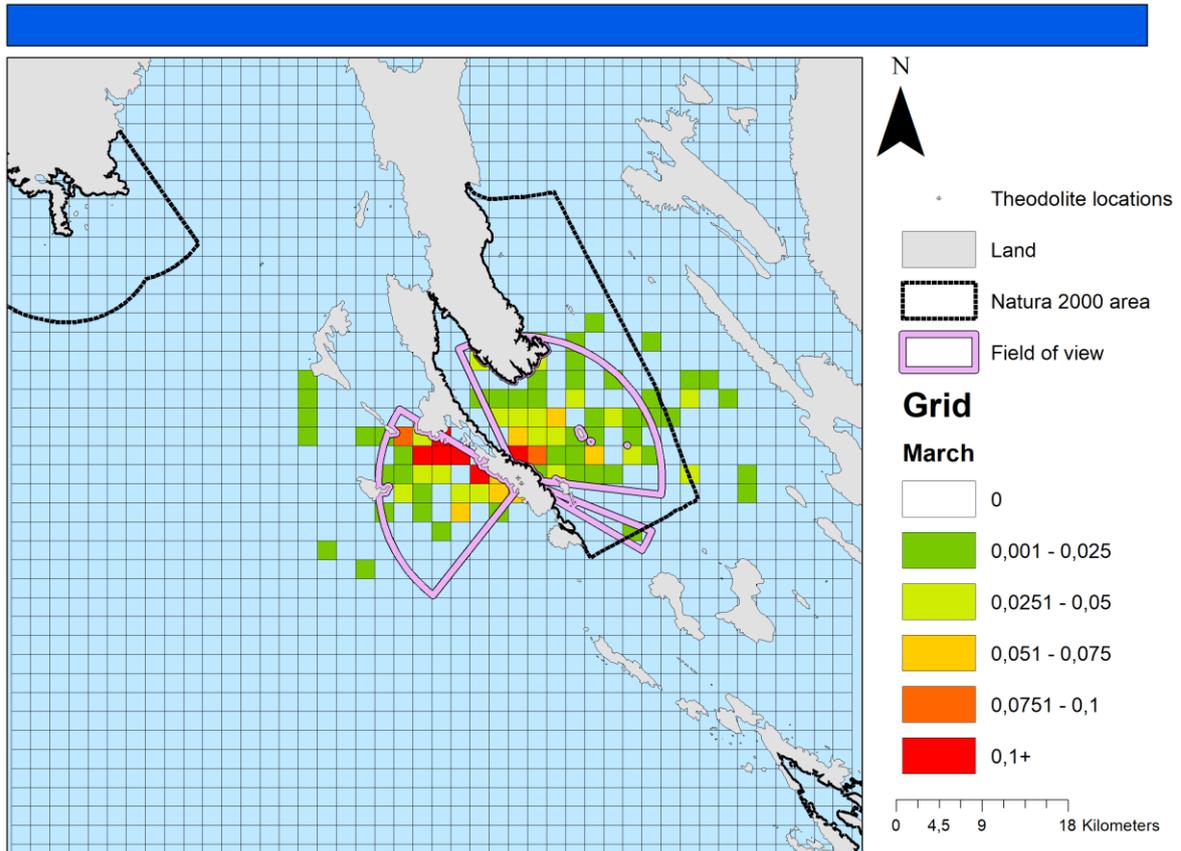


Figure 73. Relative density – March

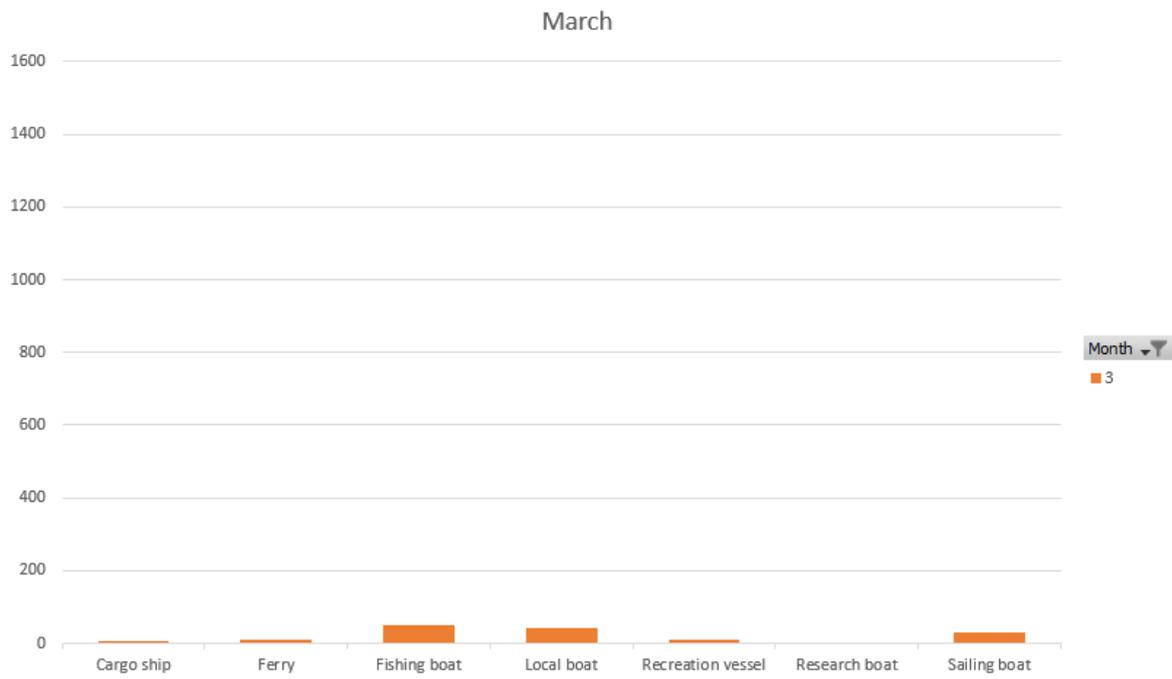


Figure 74. Number of vessels by categories - March

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