Science Panel Recommendations to the International Council of Cruise Lines (ICCL)

Introduction

A volunteer, independent Science Panel convened by the Ocean Conservation and Tourism Alliance (OCTA) was asked to evaluate the management practices for cruise-ship wastewater discharges, and to recommend guidelines for good and improved practices to the International Council of Cruise Lines (ICCL). For the purposes of this exercise, wastewater is defined as graywater and blackwater; and good practices are defined as those that are effective, reliable, economically feasible, and minimize impacts on human health and the marine environment. Improved practices are those that further minimize the potential for impact on human health and the marine environment. Disposal of solids that are left over from the wastewater treatment process (sewage sludge) is also considered.

To identify and better understand the cruise industry's current waste management practices the Science Panel: i) gathered, reviewed and synthesized the currently available scientific data; ii) interviewed cruise line executives, environmental officers and other employees; and iii) met with representatives of organizations outside the cruise industry as well as from providers of advanced wastewater treatment systems. These efforts included a review of: i) where ICCL member cruise ships operate and areas of high traffic; ii) locations of wastewater discharges; iii) constituents, concentrations and volumes of discharges; iv) level, effectiveness, and type of treatment; v) potential effects these current practices might have on the marine environment, and vi) the volume of cruise ship wastewater discharges relative to that of other sources, such as other marine vessels, storm water runoff, and land-based wastewater discharges.

The panel recognizes that wastewater discharges from cruise ships occur within a context of these other sources, and supports the current efforts of the cruise industry to minimize their own impacts on the marine environment. The panel has taken a precautionary approach with regards to potential impacts on the marine environment from cruise wastewater discharges and based on available information, the following recommendations are meant as guidelines to further the efforts for good and improved wastewater discharge practices.

If you have any questions about the following recommendations, appendices, or maps, please contact David Krantz at Conservation International via phone, (202) 912-1578, or email, d.krantz@conservation.org.

Recommendations

1. All blackwater should be treated. Discharge of treated blackwater, whether from a Marine Sanitation Device (MSD) Type II or an Advanced Wastewater Purification System (AWPS), should be avoided in ports, close to bathing beaches or water bodies with restricted circulation, flushing or inflow. Blackwater treated by an MSD Type II system should be discharged at least 4 nm from the nearest 20- meter depth contour*, while traveling at a speed of no less than 6 knots. Recommended improved practice for ICCL members would be to discharge outside 12 nm from the 20-meter contour and beyond 4 nm of shellfish beds, coral reefs or other sensitive habitats (see recommendation #3 below). Blackwater treated by an AWPS and discharged in a warm water ecosystem should be discharged at least 1 nm from the 20-meter depth contour, shellfish beds, coral reefs and other sensitive habitats, while traveling at a speed of no less than 6 knots. For blackwater treated by an AWPS and discharged in a cold water ecosystem, it is recommended that cruise lines either discharge under the same conditions as recommended for AWPS releases in warm water (above), according to Alaska's discharge regulations, or in special cases (see item 1 of "*Rationale for Recommendations*" below), seek local scientific expertise to provide specific recommendations that are locally appropriate.

2. ICCL members should adopt as good practice a voluntary prohibition on the discharge of untreated graywater unless at least 4nm, preferably 12nm, from the nearest 20-meter depth contour or sensitive habitat, while traveling at a speed of no less than 6 knots. Improved practice would be to treat graywater through systems such as AWPS and discharge as described in recommendation #1.

3. ICCL is encouraged to commission a global mapping project to identify and integrate into navigational charts the sensitive marine areas where discharge should be avoided. These may include areas such as coral reefs, seamounts, and marine protected areas. Initially, the project should focus on the high traffic areas as identified by the GIS study referenced in the rationale section.

4. The panel recommends as improved practice offloading of sewage sludge to an approved land-based handling facility; such facilities should be defined by the cruise industry with the advice of appropriate experts. Recognizing that viable land-based options for offloading may not be available, good practice would be to discharge sewage sludge at a distance of at least 12 nm from the 20-meter contour and any sensitive habitats that may lie beyond the 20 m contour. Further research on the environmental advantages and disadvantages of sewage sludge incineration is recommended. Additional information would be required before the Science Panel could formulate specific recommendations regarding this practice.

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* 20 meters is about 65 feet, or slightly more than the 10 fathom contour commonly indicated on navigational charts.

5. If ballast tanks are used as holding tanks for gray or blackwater, then emptying the contents of these tanks should be done in accordance with recommendations 1 and 2 above.

6. ICCL members should adopt as good practice regular monitoring of all treatment systems to ensure that they are working as originally intended. In addition, random testing should be done by an independent third party. Improved practice would be development and adoption of standard sampling and analysis protocols.

7. ICCL members should adopt as good practice minimizing the use of chlorine and bromine disinfection. Improved practice would be to consider installing de-chlorination and de-bromination mechanisms as the final treatment step before discharge.

8. Good practice for ICCL members is to continue to install AWPS on ships. Improved practice would be to pursue advances in AWPS technology, or develop new technology altogether, that will improve treatment of black and graywater effluent as well as sludge. In particular, it is desirable to direct efforts towards the improved removal of nutrients, metals, constituents of emerging concern, the removal or inactivation of microbial pathogens, and to significantly reduce, or ideally remove, the amount of chlorine and/or bromine discharged into the marine environment.

9. The U.S. Environmental Protection Agency's Environmental Technology Verification (ETV) Program is suggested as a useful program to provide independent testing and demonstration of the effectiveness of emerging treatment systems. Information about this program is available at **http://www.epa.gov/etv.**

10. Good practice for ICCL members is to continue to improve source control, including the provision of biodegradable soaps and shampoos in cabins, the use of biodegradable detergents and cleaning agents. Improved practice would be for ICCL to improve passenger education about environmental stewardship by providing pre-boarding and onboard literature about waste management practices, especially discouraging disposal of unused pharmaceuticals or personal care products in the toilet.

11. Based on advancing technology and ongoing scientific studies, the OCTA Advisory Committee should revisit these recommendations annually.

Rationale for Recommendations

Recommendation 1

The cruise line industry is highly visible to the public, operates in marine environments across the world, and relies on the sea for its very existence. Aware of these facts, the industry has taken initiatives to introduce wastewater management strategies that protect human health and reduce environmental impacts on the marine ecosystem. With regard to the treatment of wastewater streams, the cruise industry has begun to install Advanced Wastewater Purification Systems (AWPS). These systems specifically treat blackwater, which is defined by ICCL as waste from toilets, urinals, medical sinks, and other similar facilities. Some systems also treat graywater; the water collected from the ship's galley, passenger and crew showers and the ship's laundry facilities (CRS, 2004).

Effective treatment of wastewater effluent prior to discharge, that minimizes the potential health and environmental concerns, consistent with those expressed in Annex IV of MARPOL, is considered good practice. Improved practices are those treatment processes that further minimize the potential impact on either human health or the marine environment.

Once wastewater streams are treated, the remaining effluent must be disposed of. Good disposal practices are therefore those that also minimize potential health and environmental impacts with improved discharge practices being those that further these goals.

Dilution and dispersion

An important factor to consider when assessing good and improved practices for wastewater discharge is the dilution and dispersion of effluent that occurs when done underway. The U.S. Environmental Protection Agency and other science panels have examined and modeled instantaneous and far-field dilution of ship discharges (CSWSAP, 2001; Colonell *et al*., 2000; Kin, 2000; Batelle, 2001a,b; EPA, 2002; ADEC, 2004). An Alaska Science Panel published a formula for calculating the immediate dilution of any discharge from beneath a large ship; this formula was later substantiated by direct measurements of dilution (Loehr *et al*. 2005). The formula for instantaneous dilution from a large cruise ship is:

$$\textit{Dilution factor} = 4 \times (\textit{ship width} \times \textit{ship draft} \times \textit{ship speed})/(\textit{volume discharge rate})$$

$$= 4x\,(\_\_\_\_\_ m \quad x\ \_\_\_\_\_ m \quad x\ \_\_\_\_\_ m\ sec^{-1})/(\_\_\_\_\_ m^{3} sec^{-1})$$

From the formula, a large ship traveling at 6 knots discharging 200 cubic meters per hour (considered to be the maximum rate of discharge from a large ship) results in the mixing of at least 1 part of wastewater to 50,000 parts of ambient ocean water. Based on direct measurements in the field by the EPA, dilution rates were found to be more typically 1:195,000 to 1:644,000. Far field dispersion processes could produce an additional dilution of 1:100. Detection of metals, organic compounds and toxicity in such a diluted discharge would be nearly impossible. This is not the case however, if discharge occurs from a stationary vessel. While near-field dilution is mainly controlled by ship size, speed, and the propulsion system, the far-field dispersion is a function of oceanographic processes, such current flow, tidal and wave action

Based on the available information and given these processes and the dilution levels that result, the impact on the open ocean environment of discharging treated wastewater while underway at 6 knots or greater appears to be minimized. Toxicity testing of dilute levels of treated blackwater indicates no short-term observable effect on the marine organisms examined (ADEC, 2002).

No discharge in shallow water, restricted water bodies or in port:

After examining the existing data on effluent from onboard AWPS in operation, the panel remains concerned about discharge in port, near bathing beaches or within water bodies with restricted circulation, inflow or flushing. At present we do not feel that there is adequate evidence that all AWPSs effectively and reliably remove (or inactivate) viruses, nutrients, or metals. These constituents pose potential risk in the marine environment. For instance, dissolved nitrogen in the form of ammonia (NH_3/NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-) and phosphorus present in wastewater are known to promote algae blooms in receiving waters (ADEC, 2002). Trace amounts of metals, such as copper, zinc and iron, found in wastewater can also influence phytoplankton growth and hence affect ecosystem functioning. In particular, in the tropics, numerous scientific studies indicate that elevated nutrient levels can have a variety of effects on marine ecosystems (see Appendix 1, Table 1). Effluent discharges made in cold-water environments like Alaska, or in freshwater environments with significant inflow or flushing like the Amazon River are of less concern. Recommendation #1 is meant to apply universally, but exceptions may be made in special cases like Alaska and the Amazon. These exceptions should be made based on the counsel of local scientific experts.

Regardless of whether wastewater is from land-based communities or from large cruise ships, wastewater would be expected to contain human viruses. The panel's concern with regards to viruses is that their small size (i.e. less than 0.2 µm) allows them to pass through filter membranes, that virus levels are only moderately reduced by conventional wastewater treatment processes requiring that the final effluent be disinfected, and once discharged into the environment some viruses are more resistant to inactivation than many bacterial pathogens. We recognize that many of the AWPSs utilize ultra-violet sterilization technology prior to discharge, however data regarding effectiveness of this treatment of cruise ship wastewater is limited. The panel is also aware of the ongoing study being conducted by Washington State regarding pathogens and shellfish and believes that the results of that study may help provide guidance to the cruise industry on good and improved practices for wastewater treatment. However, the final report from Washington State is not available at this time.

Effluent from AWPS is usually fresh water, and thus can be less dense than the surrounding surface ocean (taking into account temperature considerations). Without the intense mixing with seawater that occurs behind a moving vessel, the effluent can float and form a relatively thin, less than 1 meter, buoyant surface layer. These layers can drift, fairly intact, short distances in ports and lagoons, creating patches of relatively fresh water with high concentrations of compounds. These patches can certainly impact shallow benthic ecosystems, typical of many tropical ecosystems in the subtropics and tropics. Some of the AWPS systems appear to work better at removing constituents of concern than others, but there is generally a lack of data on the effectiveness of their operation. In addition, even when operating effectively, releases of large volumes of freshwater from AWPSs could have a detrimental impact on nearby sensitive habitats or organisms, especially in tropical marine environments or in areas with restricted circulation, low inflow or flushing. Thus, the panel recommends no continuous discharge in ports or lagoons, regardless of treatment systems. The 20 m criteria in recommendation #1 also ensures a safe depth of discharge and a safe distance from shallow reefs.

The 20 meter depth contour:

Loehr *et al*. (2005) report that the turbulent wake behind a cruise ship increases in area about a factor of 4 from the area formed by the draft times the beam of the ship. Turbulence from the stern of the ship propagates outward and to some extent downward in the water column. Given that the drafts of the larger ships are approximately 9 m, the mixing zone from these ships is confined to a doubling of the draft, or approximately 18 m (ten fathoms). Thus the intense mixing zone immediately behind the ship (as discussed above) is limited to a depth of about 20 meters.

Current regulations use distance-from-shore as an indicator of where discharges are permissible. The panel feels that this is inadequate, however, because shallow water may extend some distance from shore, such that a ship may be a legally permissible distance from shore, but still within several meters of sensitive habitat below. Many reefs shoal rapidly and do not rise above the surface water to form a "shoreline." For the purposes of good practices, the 20 m depth contour (near the 10 fathom depth contour already indicated on charts) should be considered the "shoreline", not the place where land emerges from the sea. Alaskan regulation recommends discharge underway at least 1 nm mile from the shoreline. The OCTA science panel, by considering the 20 m depth contour as the "shoreline," thus recommends AWPS discharges1 nm from this depth. In this way, many regions of the subtropical and tropical shelf areas are protected.

Four miles from the 20m-depth contour:

Four nautical miles was chosen based on existing practices as a safe distance and is supported by the results of a GIS analysis of existing discharge patterns (see Appendix 2). According to the data, the majority of existing cruise ship discharge locations currently lie at least 12 nm from shore, though depth is not presently considered.

Recommendation 2

While it is legal to discharge untreated graywater anywhere, given its typical composition the panel believes it should be treated prior to release to minimize the potential impact on human health and the marine environment. Tests for fecal coliform in graywater have shown concentrations as high as in blackwater and results published from whole effluent toxicity testing in Alaska indicated that the highest toxicities came from highly chlorinated graywater (Mearns *et al*., 2003).

Recommendation 3

The recommendations to limit discharges in shallow waters, near coral reefs or other sensitive habitats is the result of the panel's concern about the impact of chlorinated and brominated compounds, freshwater, nutrients, viruses, metals, and other chemical constituents not fully understood, such as pharmaceuticals. The recommendation to limit discharges around shellfish growing areas is because shellfish can concentrate pathogenic microorganisms and contaminants in the process of filtering large volumes of water each day. To ensure the protection of any sensitive marine areas that would not be covered by the proposed recommendations and to allow for future modifications of the recommendations as technology advances, a project is needed to map and integrate the location of no discharge zones into navigational charts.

Recommendation 4

Sewage sludge is the concentrated remainder from wastewater treatment processes. Cruise ships that generate sewage sludge generally incinerate it, discharge it at sea, or offload it at port to a land-based facility. Given the constituents within sludge and the limited information regarding impacts on the marine environment, a precautionary approach is warranted, thus offloading to reliable land-based handlers (who ensure that the sludge is treated effectively prior to disposal) rather than discharging at sea is preferred. However, the Panel recognizes that the number of reliable handlers is extremely limited.

Although sewage sludge incineration raises some concerns about atmospheric deposition of contaminants, little is known about the practice's potential advantages or disadvantages. Until more information becomes available on the subject, the panel can neither encourage nor discourage the practice. Further study is recommended.

Recommendation 5

If graywater and/or blackwater are used as ballast or held in a ballast tank, their discharge should be done according to recommendations #1 and #2, and their respective rationales.

Recommendation 6

At the current time there are no requirements that effluents from Marine Sanitation Devices (MSDs) be sampled or tested after initial certification. Data from testing of MSDs in operation in Alaska demonstrated that many of the systems were not functioning as designed (ADEC, 2002). To maintain proper functioning and ensure effluents meet coliform standards, regular monitoring is required.

Alaska currently requires regular sampling and testing of AWPS effluent; this practice ensures that the systems are operating as intended. Routine testing of such systems on all ships, worldwide, will further ensure their proper functioning and minimize the environmental impact of discharges. Standardizing the testing protocols will improve the access to data, its usability, and comparability. The use of an independent third party for testing and protocol development would also ensure objectivity.

Recommendation 7

(Modified from: Chaidou *et al*., 1999; Jenner *et al*., 1997; Jolley, 1984; Sugam and Hlz, 1980; Wong, and Davidson, 1972)

Chlorine is a very reactive chemical used as a disinfectant in many water treatment systems. While chlorine itself poses a threat to marine organisms and the environment, it also combines quickly and randomly with organic matter producing a class of chemicals called halogenated organic compounds such as dihalomethane and trihalomethane (THMs). The higher the organic content of the treated water the higher the potential for 'accidental' by-product formation. In freshwater, chloroform is the major THM. In seawater, bromoform predominates because of the presence of bromide in seawater. When other chemicals are present in the source water, different halogenated compounds can be formed. For example, the presence of ammonium ion yields bromoamines and chloramines and phenols result in the formation of halogenated phenolic compounds. Research has shown that these halogens are toxic to aquatic life and carcinogenic in humans. Due to increasing environmental and health concerns about THMs in general and a lack in understanding of the metabolic pathways of chlorine in the marine ecosystem, we recommend minimizing the use of chlorine as a disinfectant on cruise ships thereby limiting the release of chlorine and its by-products into the marine environment.

Recommendation 8

Please see Recommendation 1 above in this *Rationale and Recommendations* section regarding nutrients and viruses. There is growing concern over the impact of pharmaceuticals and other emerging constituents on the marine environment (see Appendix 1, Table 2), thus improved treatment systems should consider their removal, reduction or inactivation. The Science Panel encourages research into development of treatment technology that may not necessarily be based on either MSD Type II or AWPS systems, but that provides improved removal of nutrients, metals, microbial pathogens, constituents of emerging concern and significantly reduces, or ideally removes, the amount of chlorine and/or bromine discharged into the marine environment.

Recommendation 9

The Environmental Technology Verification Program is an existing program that tests emerging technologies. It provides independent, rigorous scientific assessment of the effectiveness and reliability of new technologies. ICCL members would benefit from having the manufacturers of AWPS participate in the ETV program; this could help avoid the potential purchase and installation of ineffective or unreliable treatment systems.

Recommendation 10

ICCL members have control over the products they use on their ships and therefore what enters the wastewater streams. Progress has been made on reducing the use of products that contain compounds that could cause harm in the marine environment. By continuing to search out new and less harmful products, the quality of effluent will be improved. Educating passengers about the products they bring onboard, their use, and how they are disposed of will further improve the quality of the effluent being discharged.

Recommendation 11

Technology for the treatment of wastewater on cruise ships has advanced significantly over the past several years. It is expected that further developments will occur in the years to come and improve the efficacy of treatment. Associated with this and from ongoing scientific studies there will be a wealth of new data available which is relevant to the management of cruise ship wastewater. Therefore the recommendations of the OCTA Science Panel may need to be modified based on new information as it becomes available.

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Appendix 1

Table 1: Effects of elevated nutrient levels on tropical ecosystems

Effect	Reference
Decrease in:	
Water quality	Weiss and Goddard, 1977; Hallock and Schlager, 1986;
Dissolved oxygen	Heatwole, 1987, Lapointe and Clark, 1992; Laws *et al*., 1994
Coral cover	Smith et al., 1981; Tomascik and Sander, 1987
Calcification rate	Kinsey and Davis, 1979
Coral recruitment	Smith et al., 1981; Hunte and Wittenberg, 1992; Tomascik, 1991
Larval production	Tomascik and Sander, 1987
Coral diversity	Pastorak and Bilyard, 1985; Tomascik and Sander, 1987
Coral growth	Tomascik and Sander, 1985
Seagrass productivity	Cambridge and McComb, 1984; Silberstein et al., 1986
Seagrass coverage	Cambridge and McComb, 1984
Recovery time/potential	Loya, 1976
Increase in:	
Seagrass epiphytes	Cambridge and McComb, 1984; Borum, 1985; Silberstein et al., 1986
Seagrass mortality	Silberstein et al., 1986
Grazer abundance	Walker and Ormond, 1982
Benthic filter	Weiss and Goddard, 1977; Birkeland, 1977; Smith et al., 1981
Benthic algal cover	Maragos et al., 1985; Lapointe and O'Connell, 1989
Phytoplankton blooms	Paerl, 1988
Phytoplankton biomass	Banner, 1974; Smith et al., 1981; Laws and Redajle, 1982
Reef erosion	Hallock and Schlager, 1986
Primary productivity	Kinsey and Davis, 1979; Smith et al., 1981; Laws and Redajle, 1982
Coral mortality rate	Walker and Ormond, 1982, Wittenberg and Hunte, 1992
Susceptibility to disease	Rublee et al., 1980
Viral/bacterial concentration	Heatwole, 1987; Paul et al., 1993, 1995

Increase in: (con't)	
Sedimentation	Walker and Ormond, 1982
Surface nutrient concentration	Smith et al., 1981; Tomascik and Sander, 1985
Groundwater nutrient concentration	Capone and Bautista, 1985; Lapointe et al., 1990; Valiela et al., 1990
Change in:	
Species composition	Birkeland, 1977; Marszalek, 1987; Littler et al., 1992
Mode/onset of reproduction	Tomascik and Sander, 1987

Source: Water Quality Conservation in Protected Areas, 2001

Table 2: Emerging Constituents

Steroids	Nonprescription drugs
Insect repellant	Detergents
Disinfectants	Plasticizers
Fire Retardants	Antibiotics
Insecticides	PAHs
Reproductive hormones	Prescription drugs
Antioxidants	Fragrances
Solvents	

Appendix 2

Temporal and Geographic Distribution of Global Cruise Line Discharge

A report by Conservation International's Center for Applied Biodiversity Science

In order to estimate general patterns of cruise line discharge in time and space, the OCTA Science Panel requested data on discharges directly from ICCL vessels. Non-member vessels were also invited to submit information. The panel first examined sample logs of discharges of a subset of vessels in order to learn the types of data that are routinely recorded and how the data are organized. A temporary website interface was then designed to capture relevant data that are common to all vessels. These data generally correspond to reporting requirements established by the industry and by monitoring or enforcement agencies.

Level of Response

The website was open for reception of data from 10/06/2004 to 10/29/2004, and 112 ICCL member vessels (over 85% of the global fleet) responded by directly entering data from their individual vessel logs. In addition, 11 non-member vessels submitted data, resulting in a total response from 123 ships, or 93% of the world's cruise line vessels that were operating during the time periods covered by the data call. In view of the very high level of response, the data are deemed to be representative of global discharge patterns by the cruise line industry.

Organization of Data Call

The preliminary examination of vessel logs showed that the basic unit of information is a "discharge event" beginning when pumps are activated at sea and having a variable duration from less than one day to periods of several days. Each vessel records such events separately for any of five types of waste: food waste, gray water, black water, mixed gray/black water, and wastewater sludge. Vessels were therefore asked to list and characterize multiple discharge events over variable time periods corresponding to the actual duration of the event.

Each discharge event was further characterized by the following information:

- Geographic coordinates of the two points where the event began and ended
- Times and dates where the event began and ended
- Type of treatment applied to discharged material (grinding, AWPS, MSD II, none)
- Whether discharge was chlorinated
- Volume of discharge (m^3)
- Average speed of ship over the course of the discharge event
- Name and company of ship
- Ship's gross tonnage
- Ship's passenger and crew capacity

In order to detect possible seasonal variation in discharge patterns, vessels were asked to provide data for the set of discharge events for any voyage that occurred on or nearest to each of four dates at different times of year (17 August 2003, 7 December 2003, 08 February 2004, and 23 May 2004).

Methods

The start and stop point for each discharge event was recorded in the database. For purposes of modeling, the discharge tracks were recorded as linear features. It was assumed that each ship traveled in a straight line following the shortest path distance on the globe during its time of discharge. For each pair of recorded start and stop points, a line feature was created in a Gnomonic projection to produce an arc along the corresponding great-circle for each point pair. These lines were then unprojected into decimal degrees for subsequent analysis.

To help eliminate data entry errors, modeled line segments that intersected any part of a land feature were eliminated from subsequent analyses. The coastline used for determining land features was NIMA's VMAP0, a GIS dataset of base-data features at 1:1,000,000 scale.

To analyze geographic patterns in the distribution of waste, summary statistics were calculated using a 0.5 degree grid cell system. This returned the total count of lines per 0.5 x 0.5 degree cell for various subsets of the data. ESRI's ArcView 3.3 GIS software package was used for all of the GIS processing.

In order to provide a comparative context in which to evaluate the significance of cruise line discharge at sea, the total annual volume of cruise line effluent was estimated and compared to land-based sources for which similar data could be obtained. For each vessel, the average daily volume of each effluent type was taken from data covering all seasons. The total daily volume of each effluent type was multiplied by 365 days. The reporting vessels account for 85% of the global fleet, and an estimated global total was obtained by extrapolation.

Of the 9635 discharge events reported, 1534 were suspected to involve data entry errors and were not included in this analysis, which is based upon the 8101 remaining discharge events (84% of the total received).

Geographic Distribution of Cruise Line Traffic

The line of shortest distance between the endpoints of each discharge event was used as a proxy for the actual cruise track, and these lines were combined to reveal over-all and temporal patterns of cruise line traffic on a global scale. Data combined for the full year (Fig. 1) show that the greatest concentration of traffic is in the Caribbean Basin and its approaches, followed in descending order by the Mediterranean Sea, Alaskan/Canadian coast, and Baltic Sea.

In addition to having the greatest traffic over-all, the Caribbean Basin is notable in having the lowest level of seasonal variation in traffic (Figs 2-5). Traffic in the Baltic and near the Alaskan/Canadian coast is highly seasonal, with concentrations of traffic shown in the May and August windows. The Mediterranean carries moderate traffic at all times, but concentrations occur in the May and August windows. A minor concentration of traffic occurs in the southwestern Pacific in the February window.

Geographic Distribution of Discharge

The general global regions of the ocean receiving cruise line discharge are indicated by the patterns of traffic in Figs. 1-5. However, it is possible to delineate smaller areas that are most likely to receive the highest levels of discharge by assuming that peak discharge occurs at the beginning of the discharge event when waste that has been stored while in port and near the coast is released. In view of this storage effect, it is estimated that waste is discharged at a maximum rate (determined by pumping capacity and estimated at approximately 50 cubic meters per hour) at the beginning of the event. These high-discharge points are most likely to occur about 12 nm from the coast, which is a limit set voluntarily by some ICCL member lines, and which exceeds the ICCL standard of 4 nm, and the International Maritime Organization's requirement of 3 nm. We used these discharge event start points to delineate the areas where greatest discharge is most likely to occur.

At the global scale, highest discharge is concentrated in the Caribbean region (Figs. 6-10), especially in the December and February windows (Figs. 8, 9). During the May and August windows, the distribution of high-discharge points shifts from an over-all Caribbean pattern to one concentrated in the northern Caribbean region and the Antilles. In the Mediterranean, high-discharge areas are concentrated along the European coast with peaks in the May and December windows. Moderate concentrations occur in spring and summer along the Alaskan/Canadian coasts and the coasts of the Baltic and North Seas.

At the global scale, it was detected that there are several 30-minute cells where the high-discharge start points are concentrated. The general distribution of such high-discharge cells is shown on an annual basis in Fig. 6, and high-discharge cells for each season are shown in Figs 7-10. These areas of concentrated discharge likely reflect unintended coincidence in the locations where vessels departing the most heavily used ports initiate discharge events. This is particularly likely in places where the approaches to ports are restricted by geography or where vessels are following nearly the same short-distance tracks between ports that are close together.

In order to resolve areas of high discharge at finer scale, the high-discharge start points for each track were plotted regionally. Over-all patterns for the Wider Caribbean are shown in Fig. 11. The greatest concentration of discharge in the region occurs off Ft. Lauderdale, Miami, and Nassau (for detail of inset, see Fig. 12), followed by the Virgin

Islands and an area northeast of Puerto Rico (Fig. 13) as well as areas near Cozumel, Mexico (Fig. 14). Detail maps show the start point and the vector to the end point; marine protected areas, the 100-m contour, and coral reefs are shown for context.

General patterns of high discharge off the Alaskan and Canadian coasts are shown in Fig. 15. Two areas of particularly high discharge occur in Canadian waters north of Vancouver Island (Fig. 16), but high-discharge points are generally well dispersed in Alaskan waters. General patterns around the coasts of Europe are shown in Fig. 17, with regionally significant high-discharge zones occurring south of Finland (Fig. 18) and just off the French and Italian Riviera (Fig. 19).

These concentrations of high-discharge segments could likely be diffused by coordination among vessels aimed at spreading out the start points of discharge events when they occur within a short time of each other. For example, a voluntary standard could be set such that vessels departing port within a few hours of each other should communicate to assure that they initiate their respective discharge events at a minimal distance to be specified. Generally, adequate spacing of discharge events could be achieved by slightly delaying the second discharge event (e.g., at a speed of twenty knots, a delay of fifteen minutes would result in separation by 5 nm).

Distribution of Chlorinated Discharge

In a subset of discharge events, effluent is chlorinated prior to discharge, but information on the volume of chlorine is not available. Geographic patterns in the discharge of chlorinated effluent were estimated using the number of high-discharge points per cell for those segments receiving chlorine. The cells receiving the largest amount of chlorinated discharge occur in the northern and eastern Caribbean and the northern Mediterranean (Fig. 20).

Relative Discharge of Cruise Line Vessels and Land-Based Sources

The estimated annual volume of discharge for the global cruise line industry is approximately 33,368,081 m^3, including all levels of treatment. The relative impact of this discharge can be put in context by comparing it to the volume of wastewater dumped into coastal waters by cities near the areas traversed by cruise line vessels. On the Canadian Pacific coast, the City of Victoria, British Columbia, discharges 37,800,000 m^3 of wastewater into the ocean annually, exceeding the discharge of the global cruise line fleet, and 90% of the city's volume is raw sewage (Sierra Legal Defence, 2004). On the east coast of Canada, the cities of St. John's, Newfoundland, and St. John, New Brunswick, discharge a combined total of 39,800,000 m^3 of raw sewage into coastal waters each year (op. cit., 2004). In the Caribbean, just three cities (Kingston, Havana and Cartegena) dump a total of 72,270,000 m^3 of untreated and under-treated waste water per year (Caribbean Environmental Program, UNEP, 1996; UNDP/UNEP, 1999), a volume that is more than double the total annual discharge of the global cruise line industry.

Literature Cited

Caribbean Environmental Program, UNEP, 1996. Planning and Management for Heavily Contaminated Bays and Coastal Areas in the Wider Caribbean. Washington, DC: Global Environmental Facility.

Sierra Legal Defence, 2004. The National Sewage Report Card, Grading the Sewage Treatment of 22 Canadian Cities. Sierra Legal Defence Rep. 3:1-67.

UNDP/UNEP, 1999. Demonstrations of Innovative Approaches to the Rehabilitation of Heavily Contaminated Bays in the Wider Caribbean. Washington, DC: Global Environmental Facility.

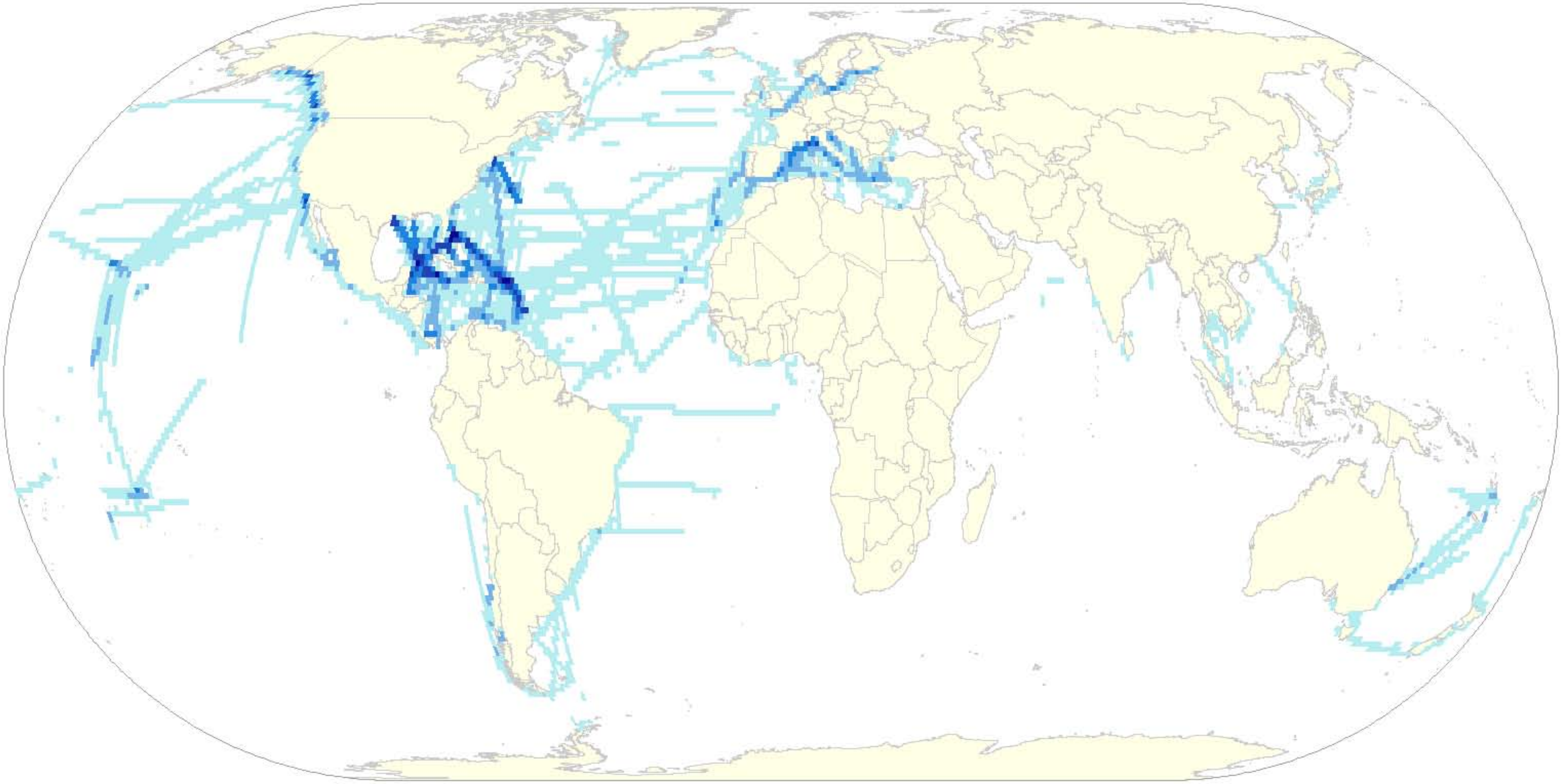

Figure 1: Density of Discharge Tracks

Reported cruise tracks for all reported dates

2000 1000 0 2000 4000 6000
kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Discharge Tracks per one degree cell

- 1 - 10
- 11 - 35
- 36 - 70
- 71 - 150
- 151-238

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cartography: Erica Ashkenazi
July 2005

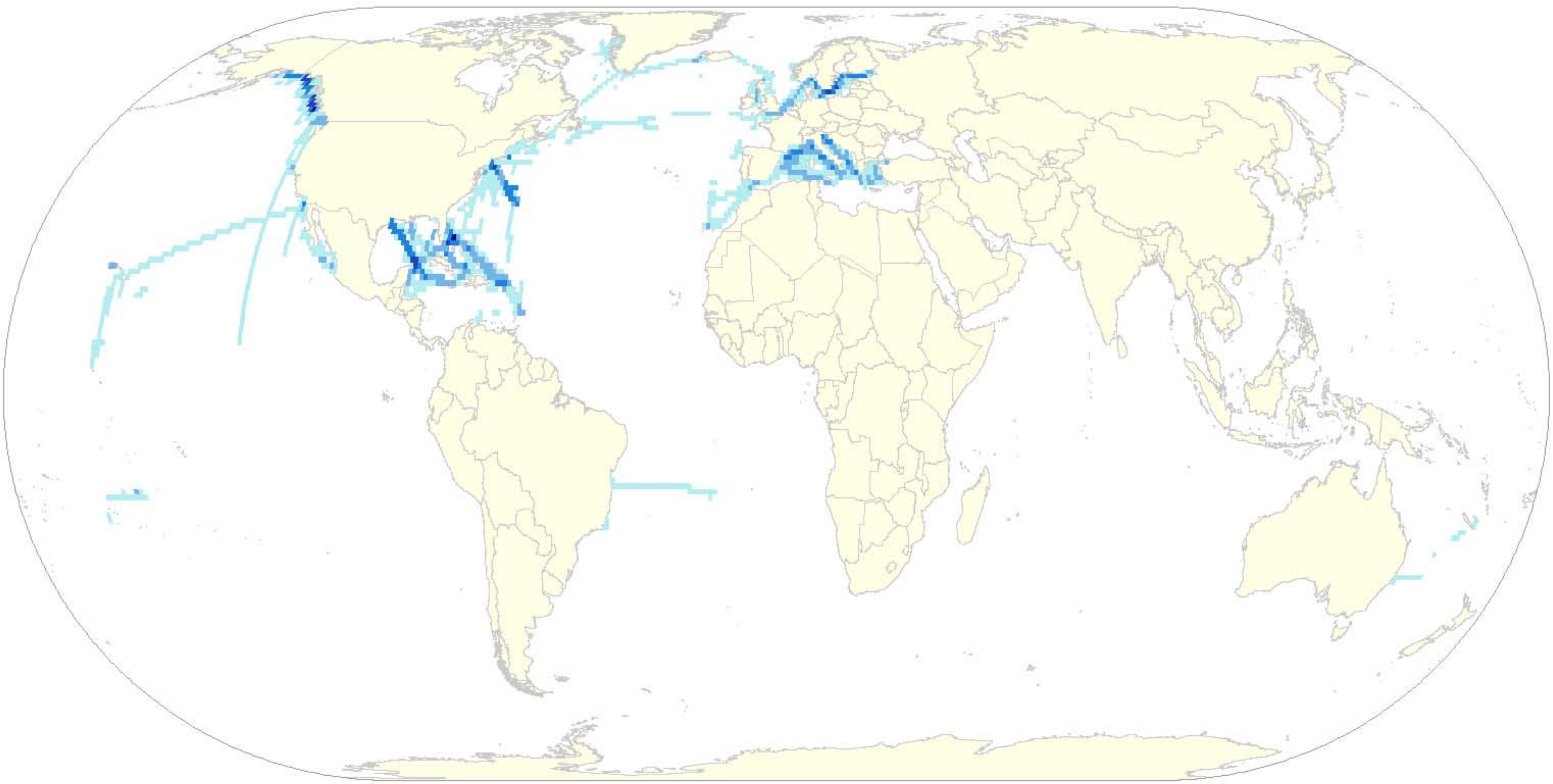

Figure 2: Density of Discharge Tracks

Reported cruise tracks for August 17, 2003 target date

2000 1000 0 2000 4000 6000

kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of DischargeTracks per one degree cell

- 1 - 5
- 6 - 15
- 16 - 30
- 31 - 50
- 51-200

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cartography: Erica Ashkenazi
July 2005

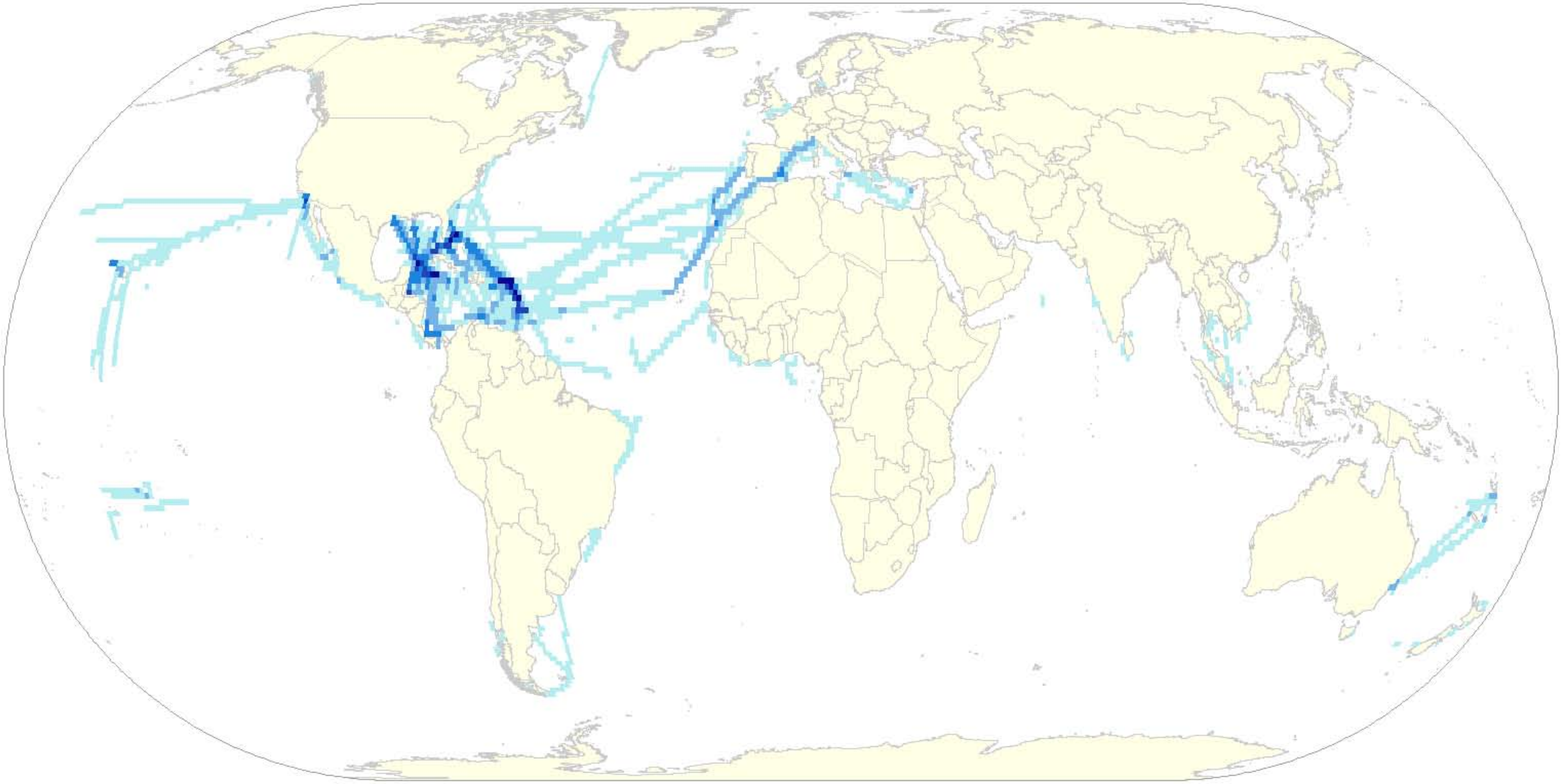

Figure 3: Density of Discharge Tracks

Reported cruise tracks for December 7, 2003 target date

2000 1000 0 2000 4000 6000

kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Discharge Tracks per one degree cell

1 - 5
6 - 15
16 - 30
31 - 50
51-200

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

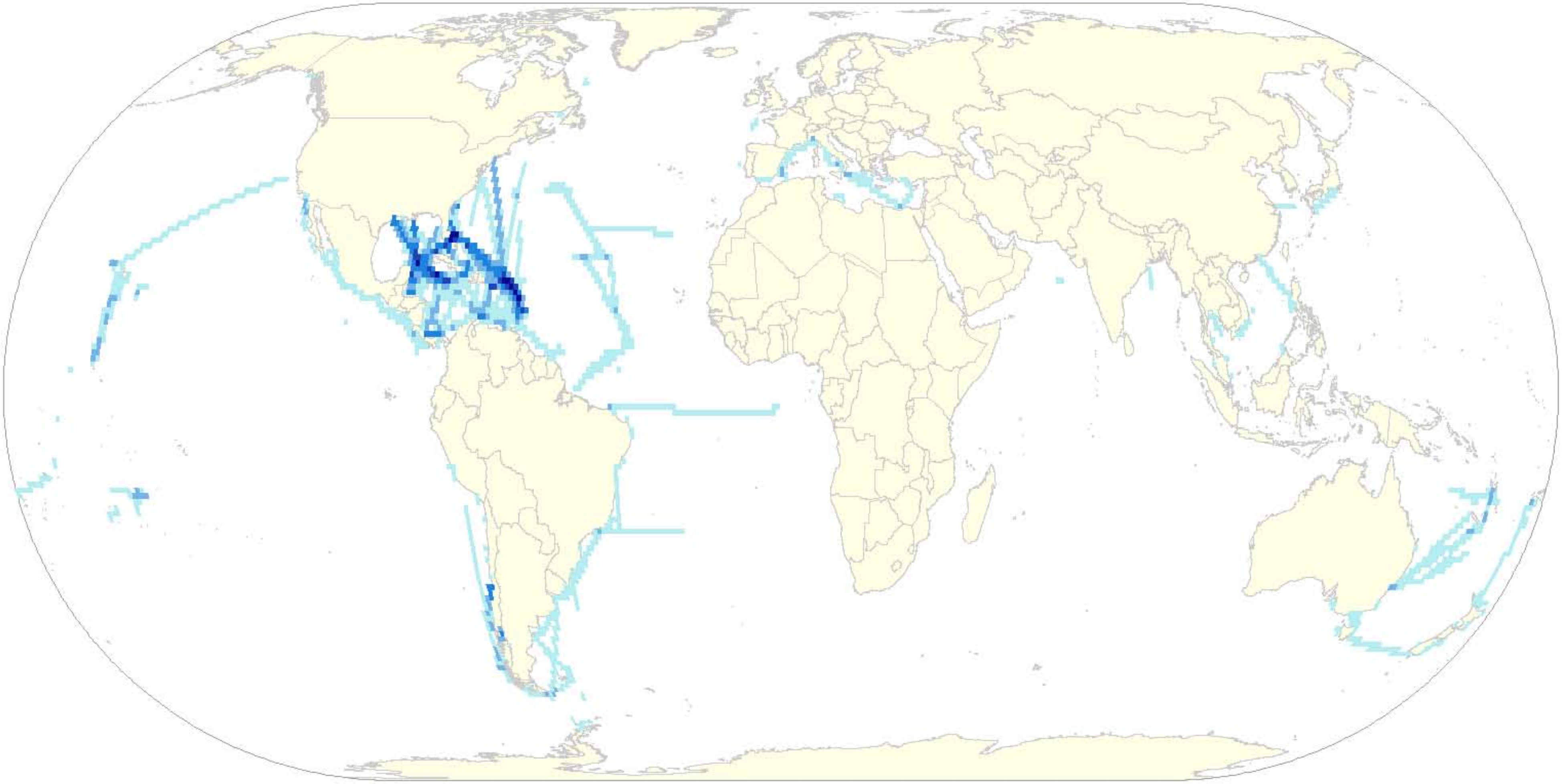

Figure 4: Density of Discharge Tracks

Reported cruise tracks for February 8, 2004 target date

2000 1000 0 2000 4000 6000

kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Discharge Tracks per one degree cell

- 1 - 5
- 6 - 15
- 16 - 30
- 31 - 50
- 51-200

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

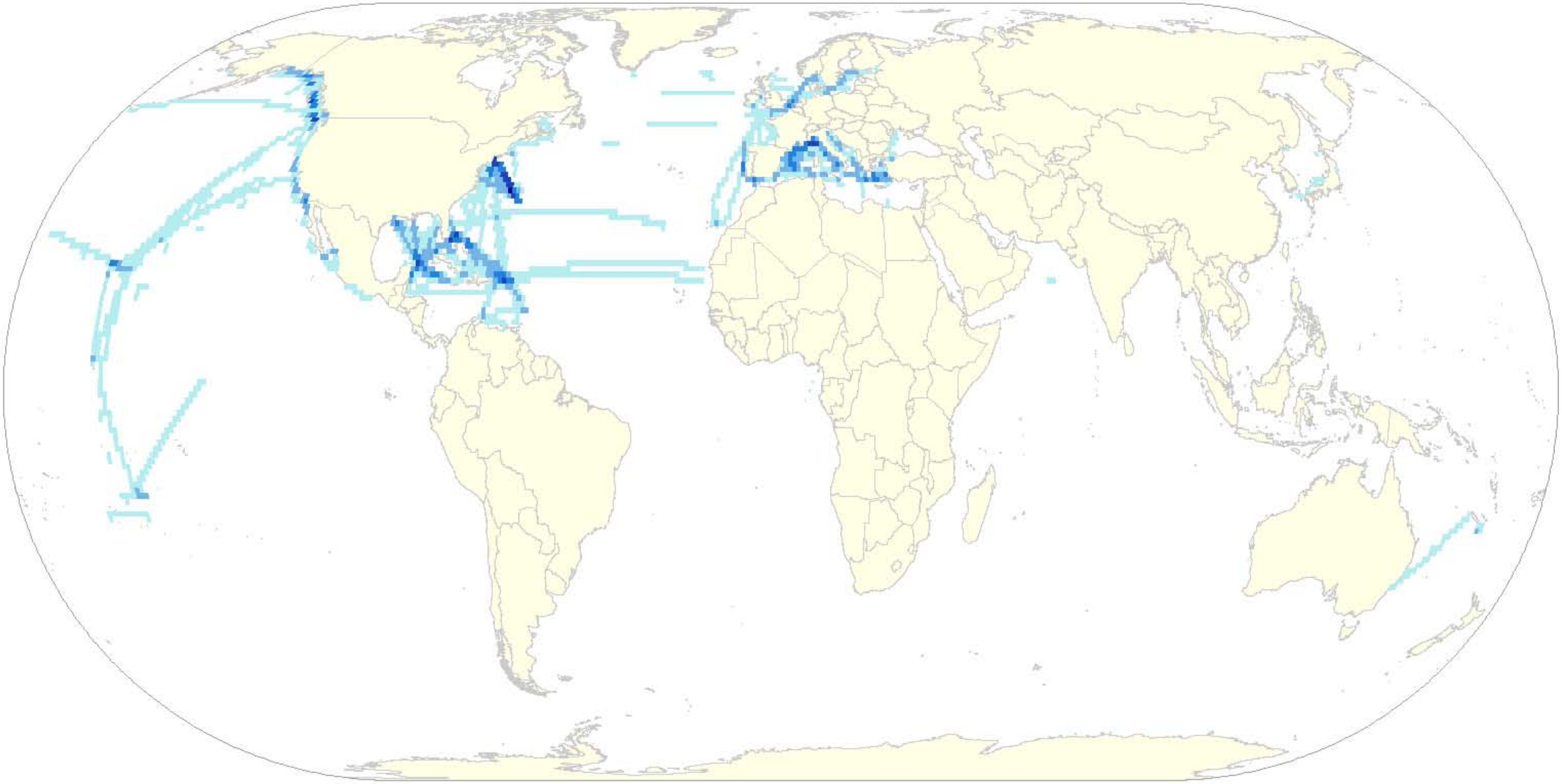

Figure 5: Density of Discharge Tracks

Reported cruise tracks for May 23, 2004 target date

2000 1000 0 2000 4000 6000

kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Discharge Tracks per one degree cell

- 1 - 5
- 6 - 15
- 16 - 30
- 31 - 50
- 51-200

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

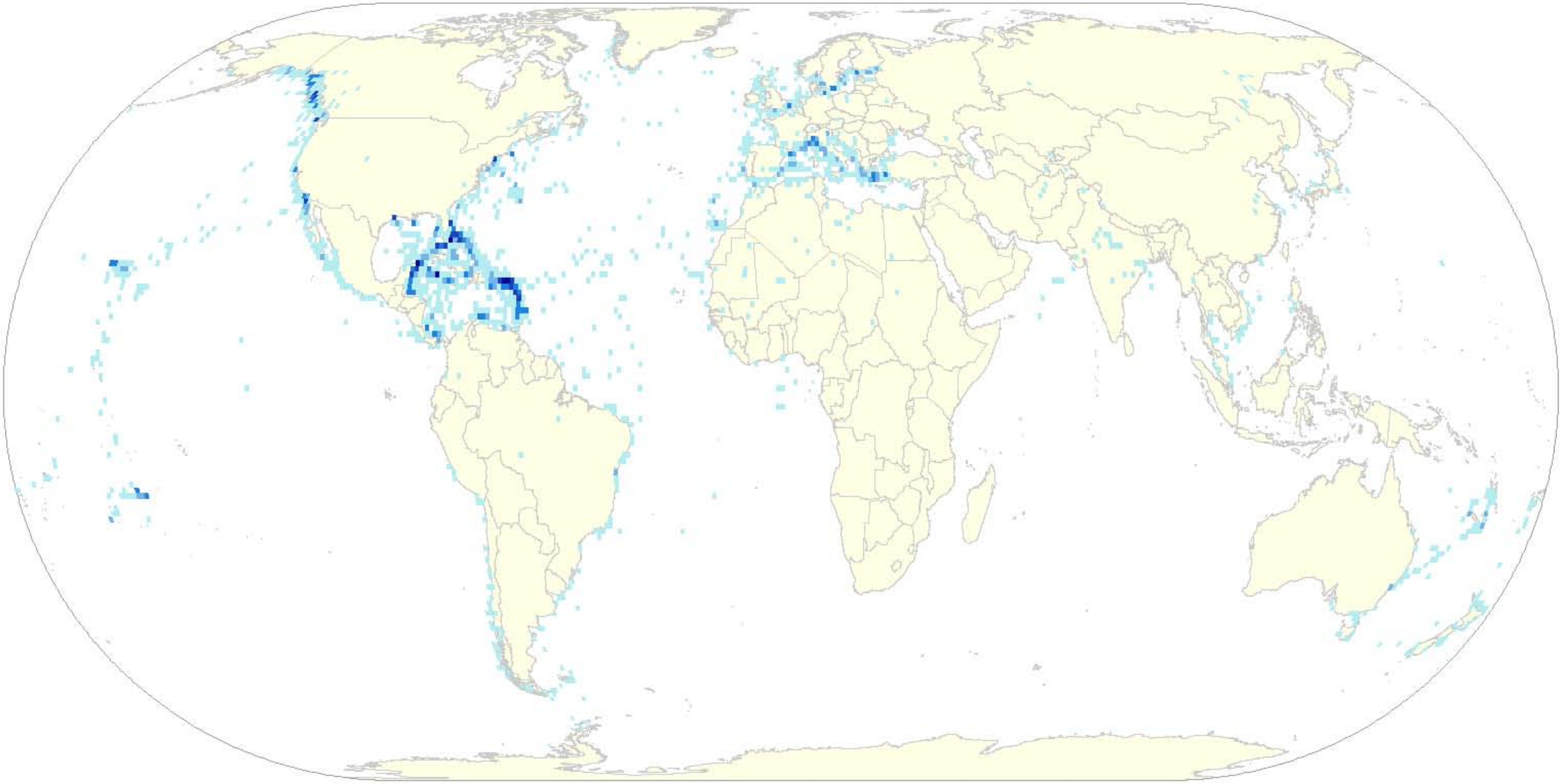

Figure 6: Density of Discharge Start Points

Reported cruise start points for all reported dates

2000 1000 0 2000 4000 6000

kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Discharge Start Points per one degree cell

- 1 - 10
- 11 - 20
- 21 - 50
- 51 - 100
- 100-167

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

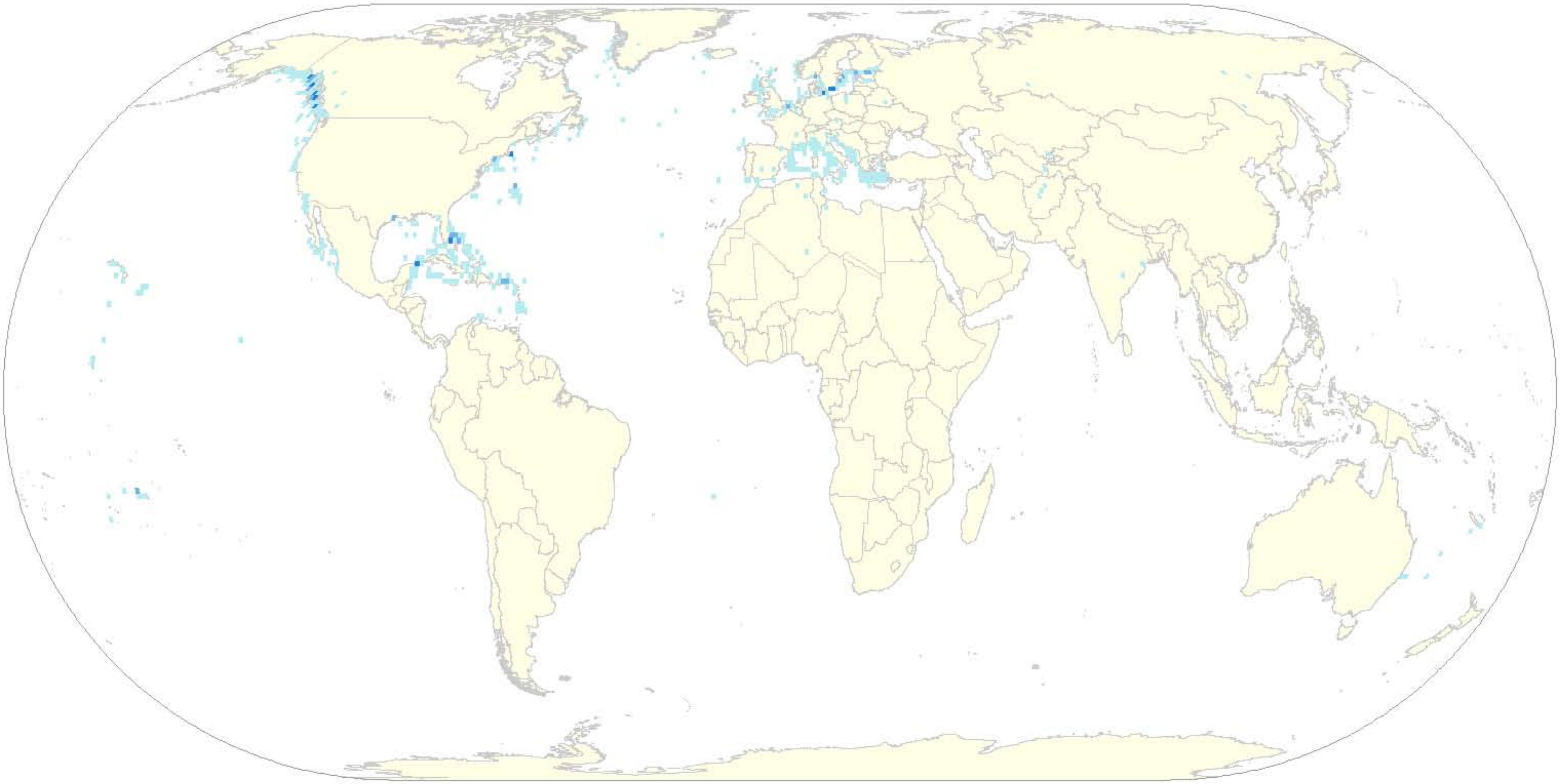

Figure 7: Density of Discharge Start Points

Reported cruise start points for August 17, 2003 target date

2000 1000 0 2000 4000 6000

kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Discharge Start Points per one degree cell

- 1 - 10
- 11 - 20
- 21 - 40
- 41 - 60
- 61 - 167

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

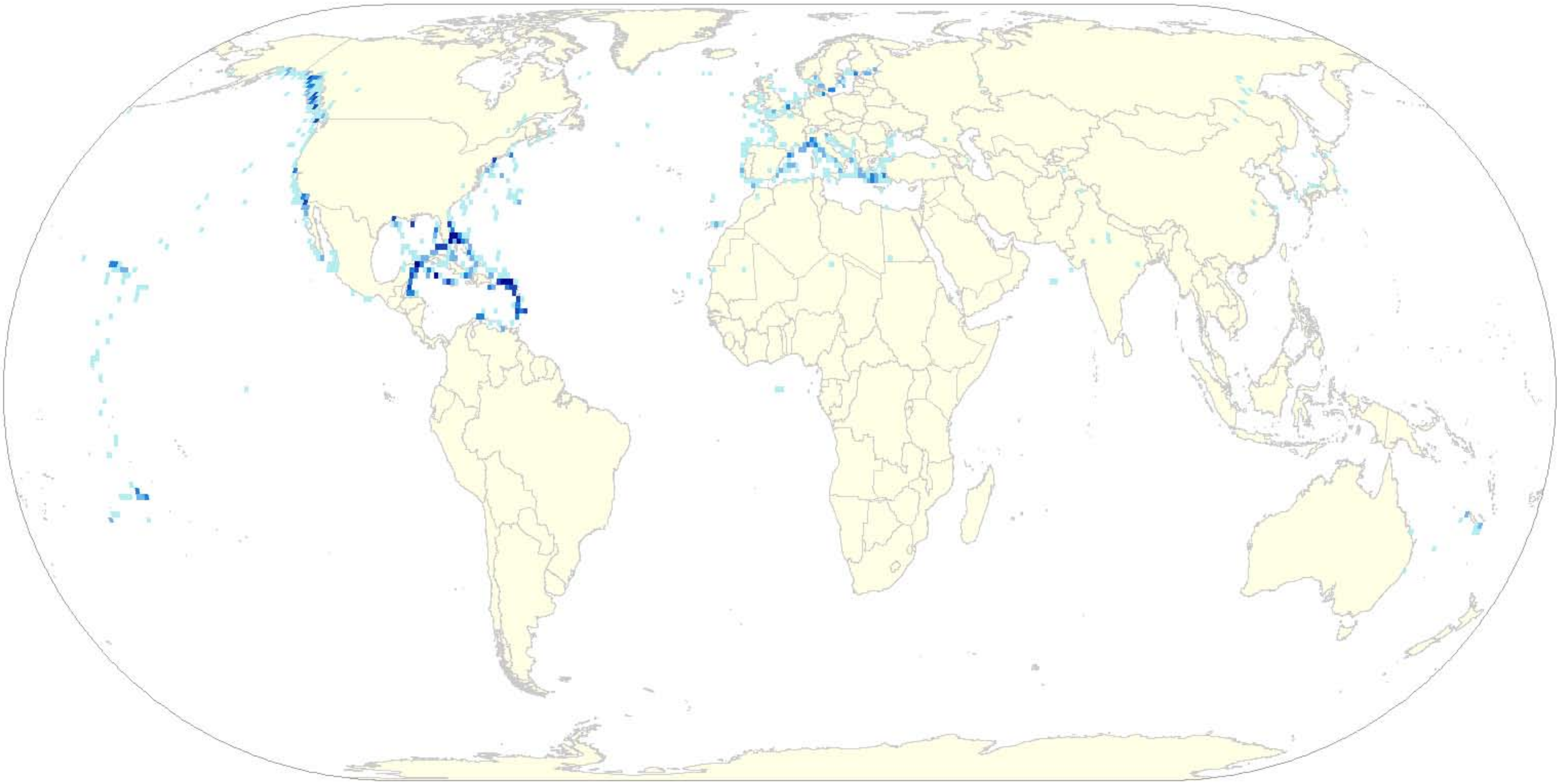

Figure 8 : Density of Discharge Start Points

Reported cruise start points for December 7, 2003 target date

2000 1000 0 2000 4000 6000

kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Discharge Start Points per one degree cell

- 1 - 10
- 11 - 20
- 21 - 40
- 41 - 60
- 61 - 167

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

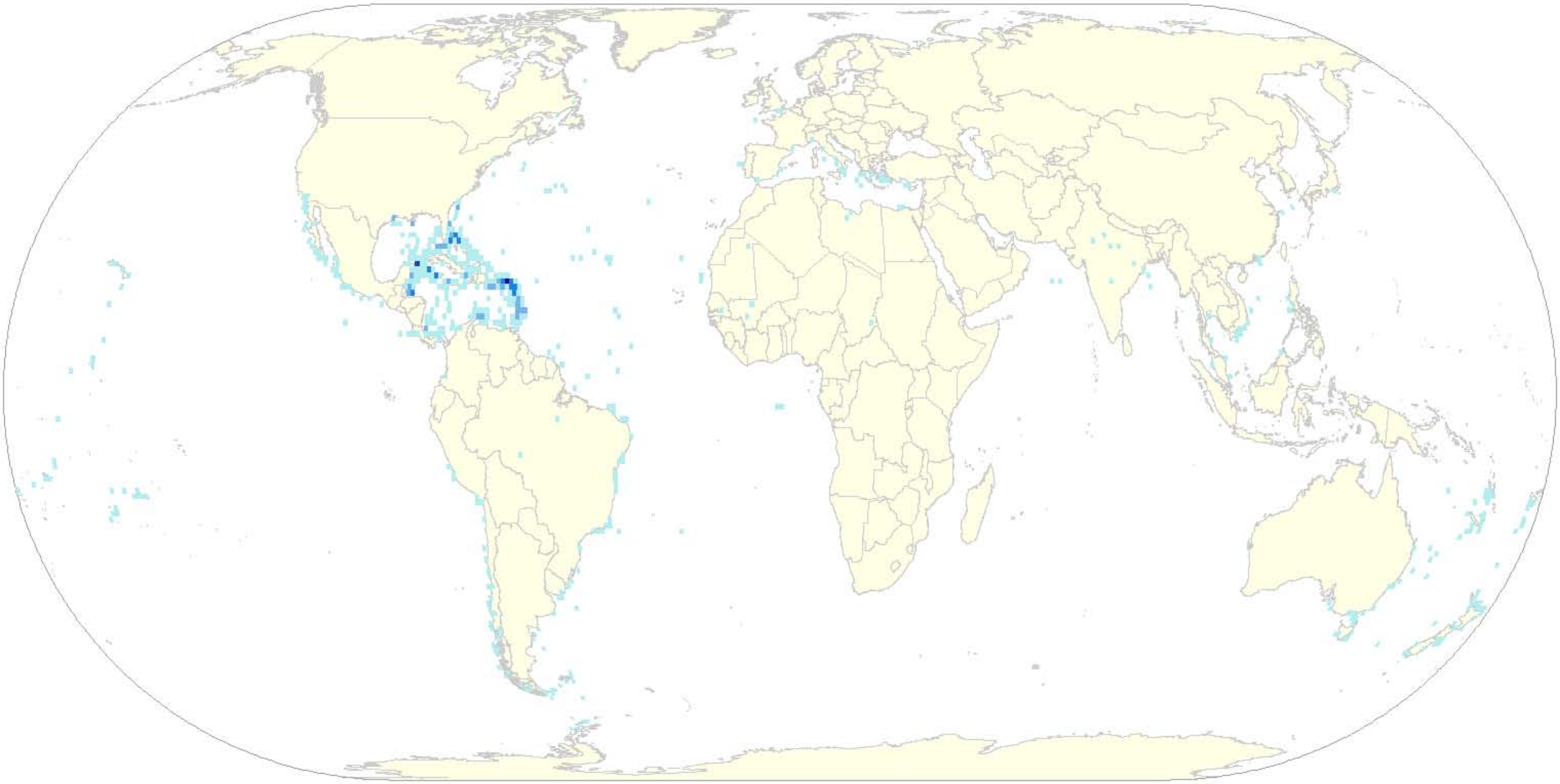

Figure 9: Density of Discharge Start Points

Reported cruise start points for February 3, 2004 target date

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Discharge Start Points per one degree cell

- 1 - 10
- 11 - 20
- 21 - 40
- 41 - 60
- 61-167

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

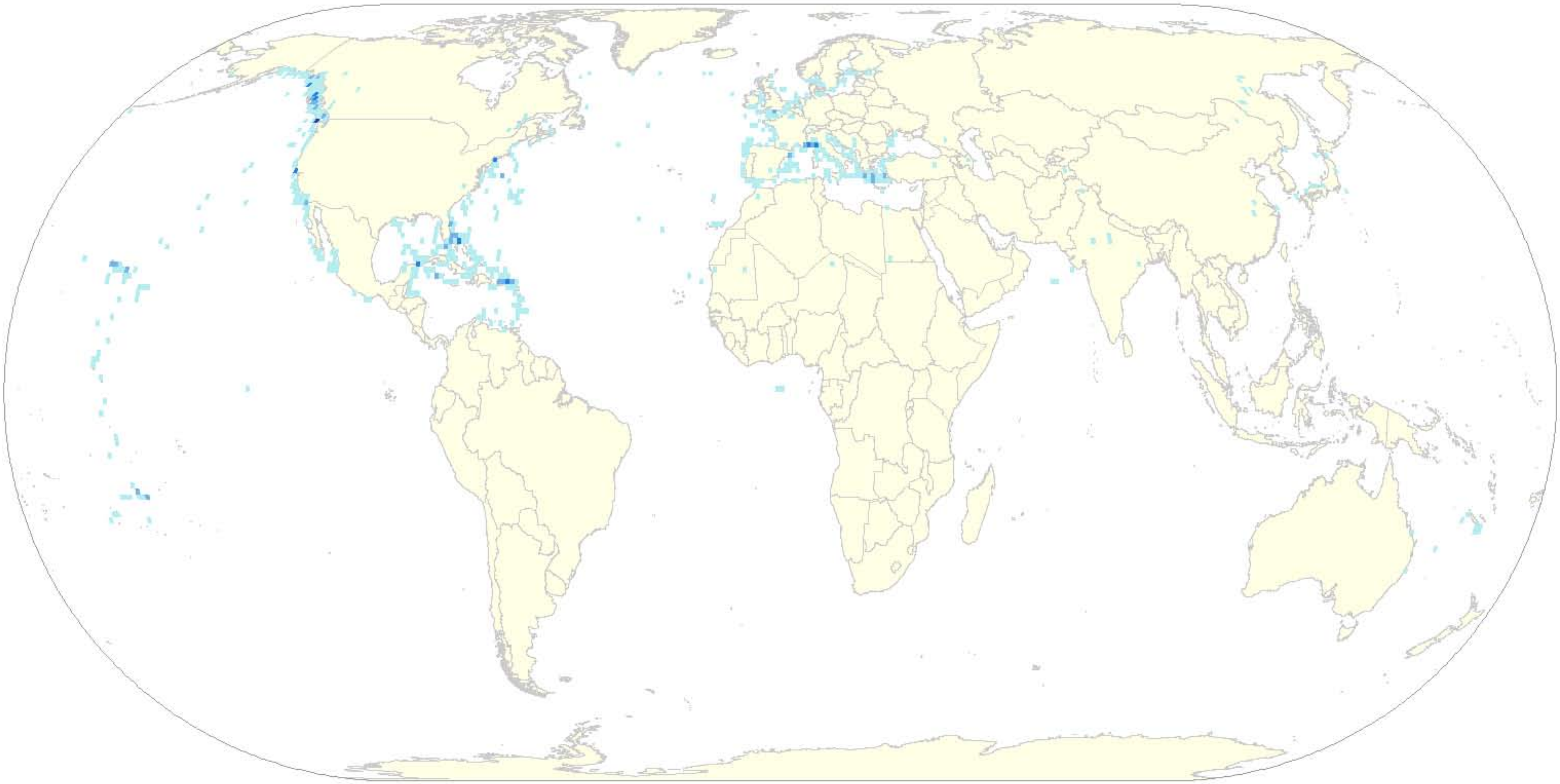

Figure 10: Density of Discharge Start Points

Reported cruise start points for May 23, 2004 target date

2000 1000 0 2000 4000 6000

kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Discharge Start Points per one degree cell

- 1 - 10
- 11 - 20
- 21 - 40
- 41 - 60
- 61 - 167

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cartography: Erica Ashkenazi
July 2005

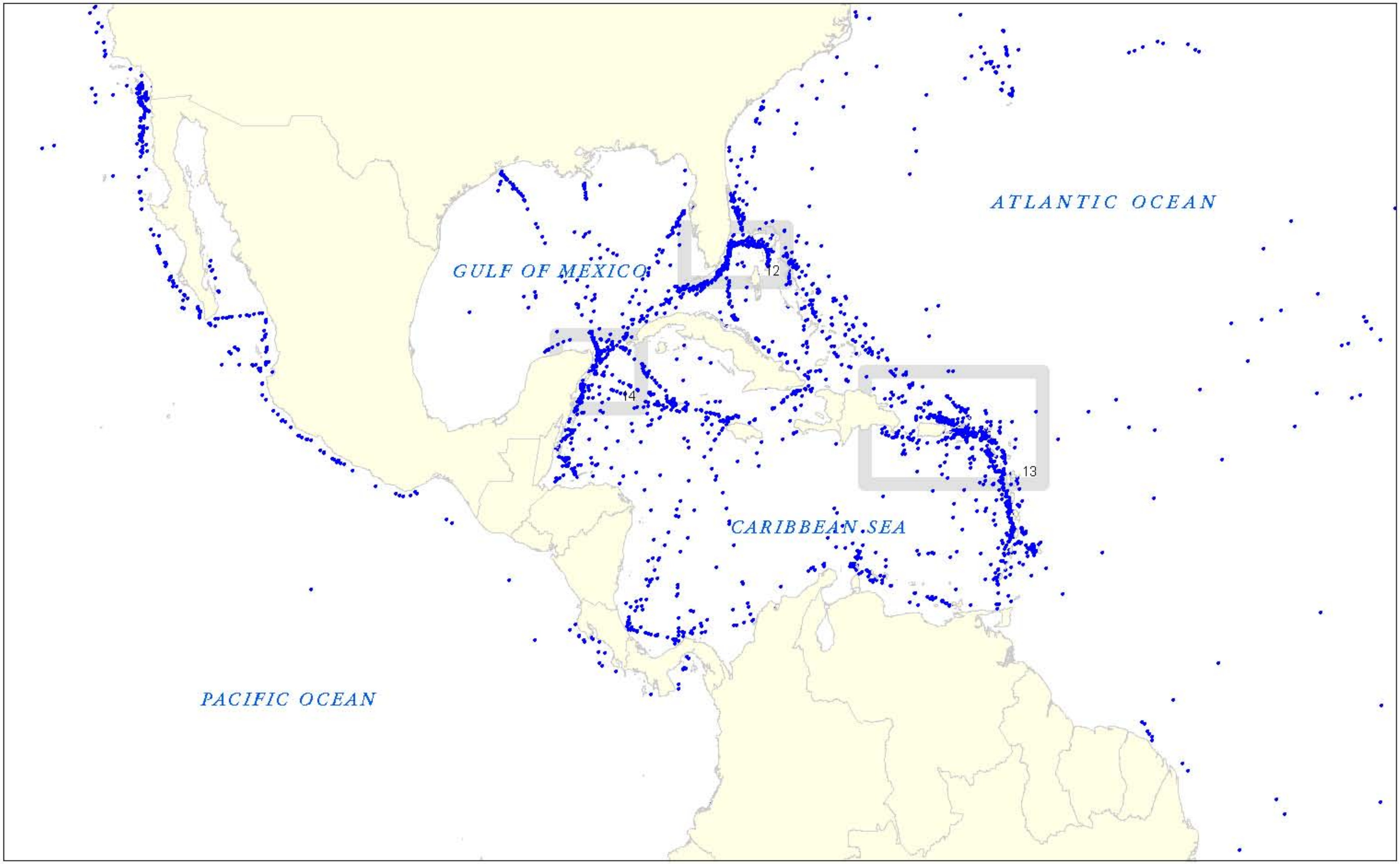

Figure 11: Discharge Start Points

Caribbean

300 0 300 600 900
kilometers

Scale: 1:28,750,000
Projection: Eckert IV

Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Discharge Start Points
Land
Extent of detail figure
14 Detail figure number

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cartography: Erica Ashkenazi
July 2005

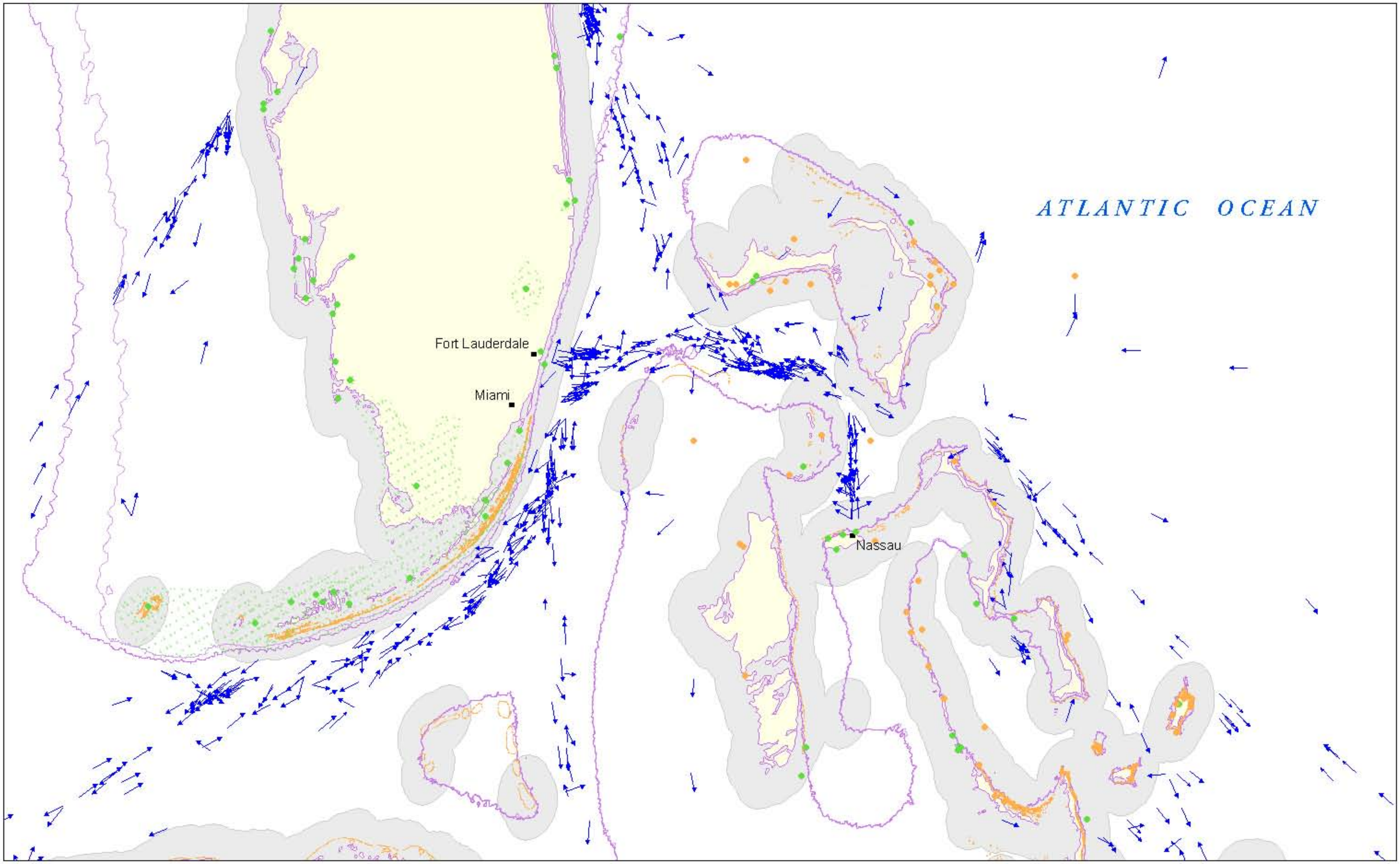

Figure 12: Discharge Start Points with Vector

Southern Florida

50 25 0 50 100 150
kilometers

Scale: 1:3,935,000
Projection: Eckert IV

Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises
reefbase.org
World Resources Institute, Reefs at Risk in the Caribbean, 2004
World Database of Protected Areas (WDPA) 2005

Cities
Discharge Start Points with Vector
Land
Marine Protected Area Polygons
Marine Protected Area Points
12 Nautical Miles from Coast
Coral Reefs
Bathymetric Contours (m)
60
100

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

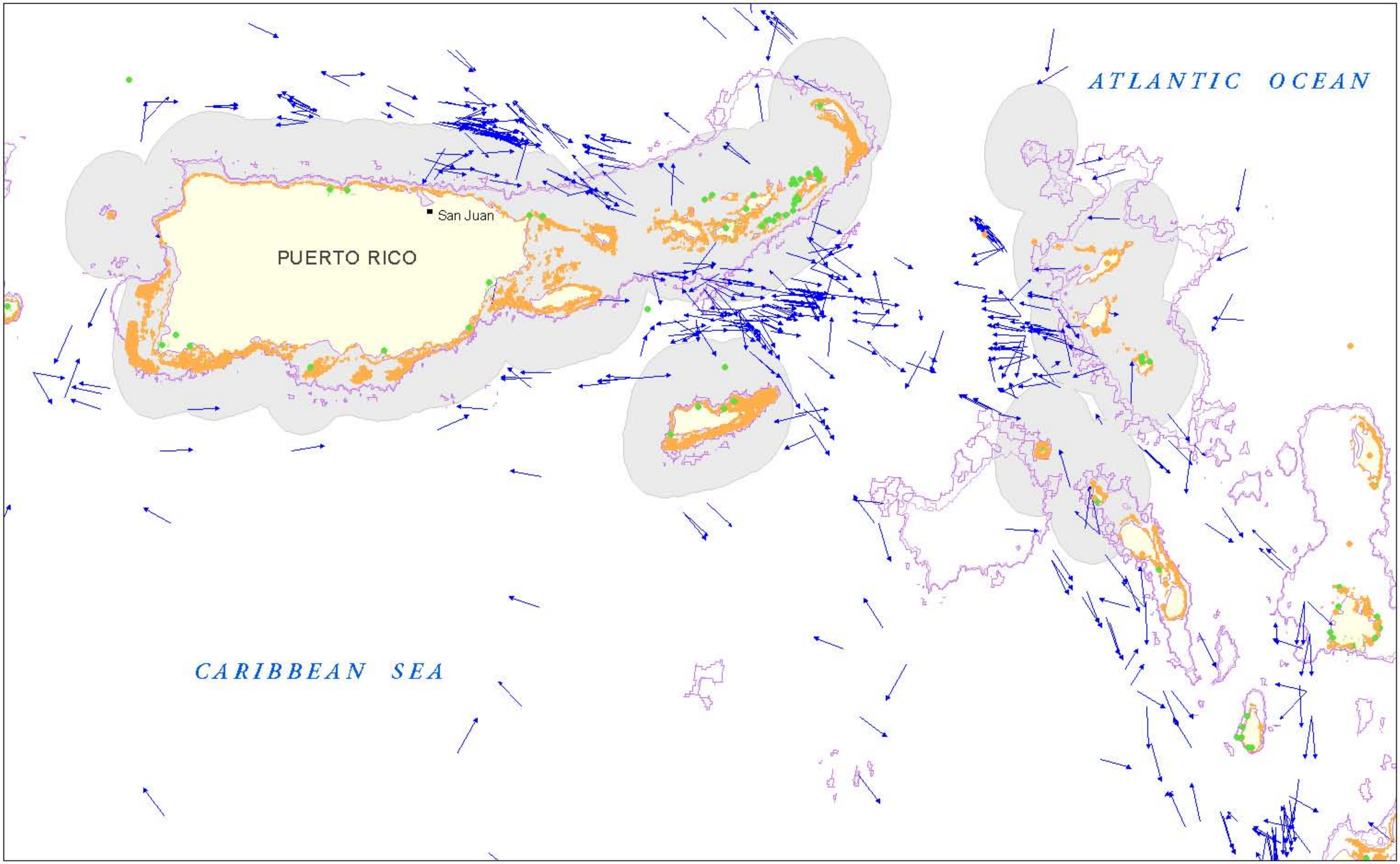

Figure 13: Discharge Start Points with Vector

Puerto Rico and vicinity

30 15 0 30 60 90
kilometers

Scale: 1:2,220,000
Projection: Eckert IV

Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises
reefbase.org
World Resources Institute, Reefs at Risk in the Caribbean, 2004
World Database of Protected Areas (WDPA) 2005

Cities
Discharge Start Points with Vector
Land
Marine Protected Area Polygons
Marine Protected Area Points
12 Nautical Miles from Coast
Coral Reef
Bathymetric Contours (m)
60
100

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

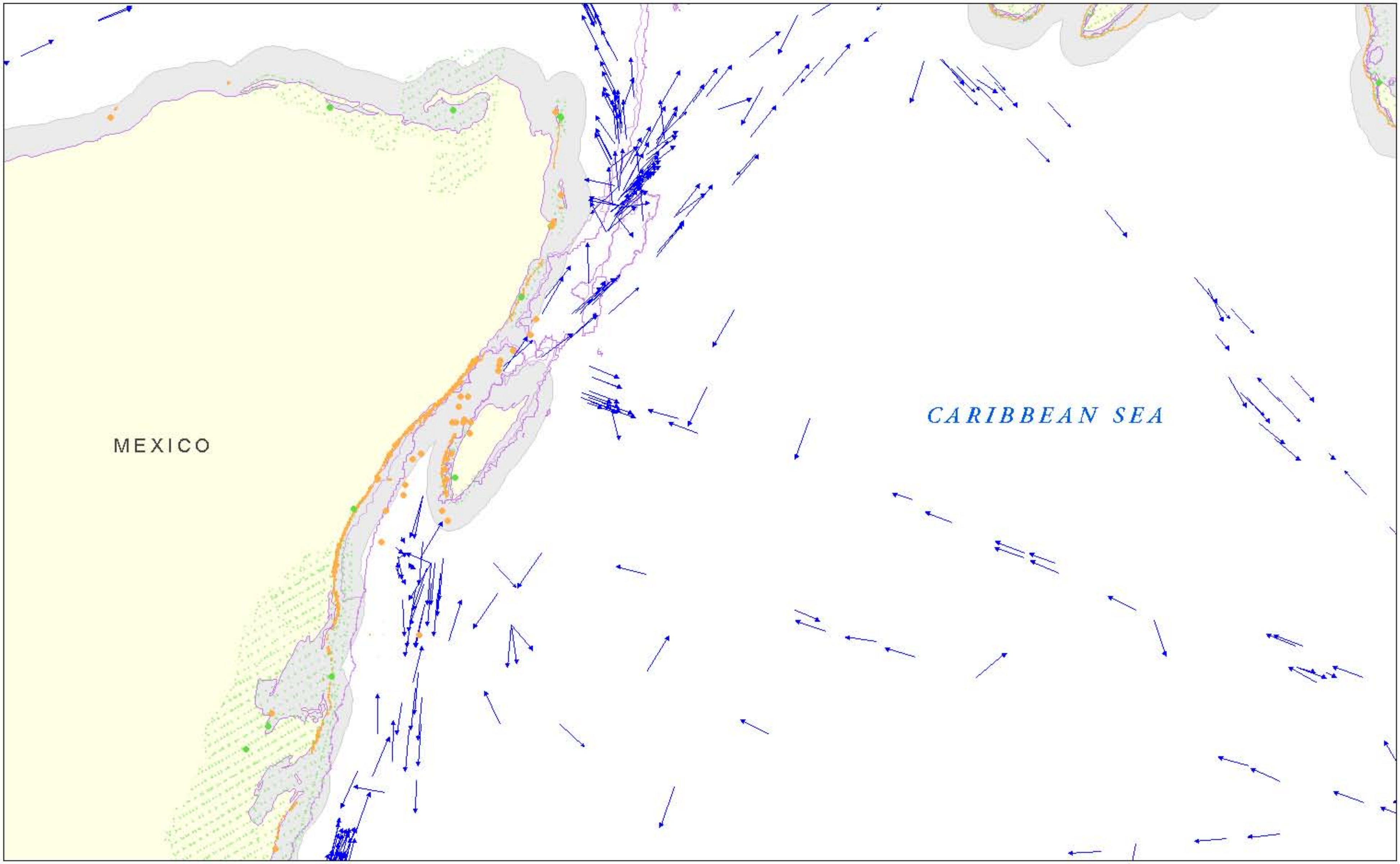

Figure 14: Discharge Start Points with Vector

Cozumel

30 15 0 30 60 90
kilometers

Scale: 1:2,215,000
Projection: Eckert IV

Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises
reefbase.org
World Resources Institute, Reefs at Risk in the Caribbean, 2004
World Database of Protected Areas (WDPA) 2005

Discharge Start Points with Vector
Land
Marine Protected Area Polygons
Marine Protected Area Points
12 Nautical Miles from Coast Line
Coral Reefs
Bathymetric Contours (m)
60
100

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

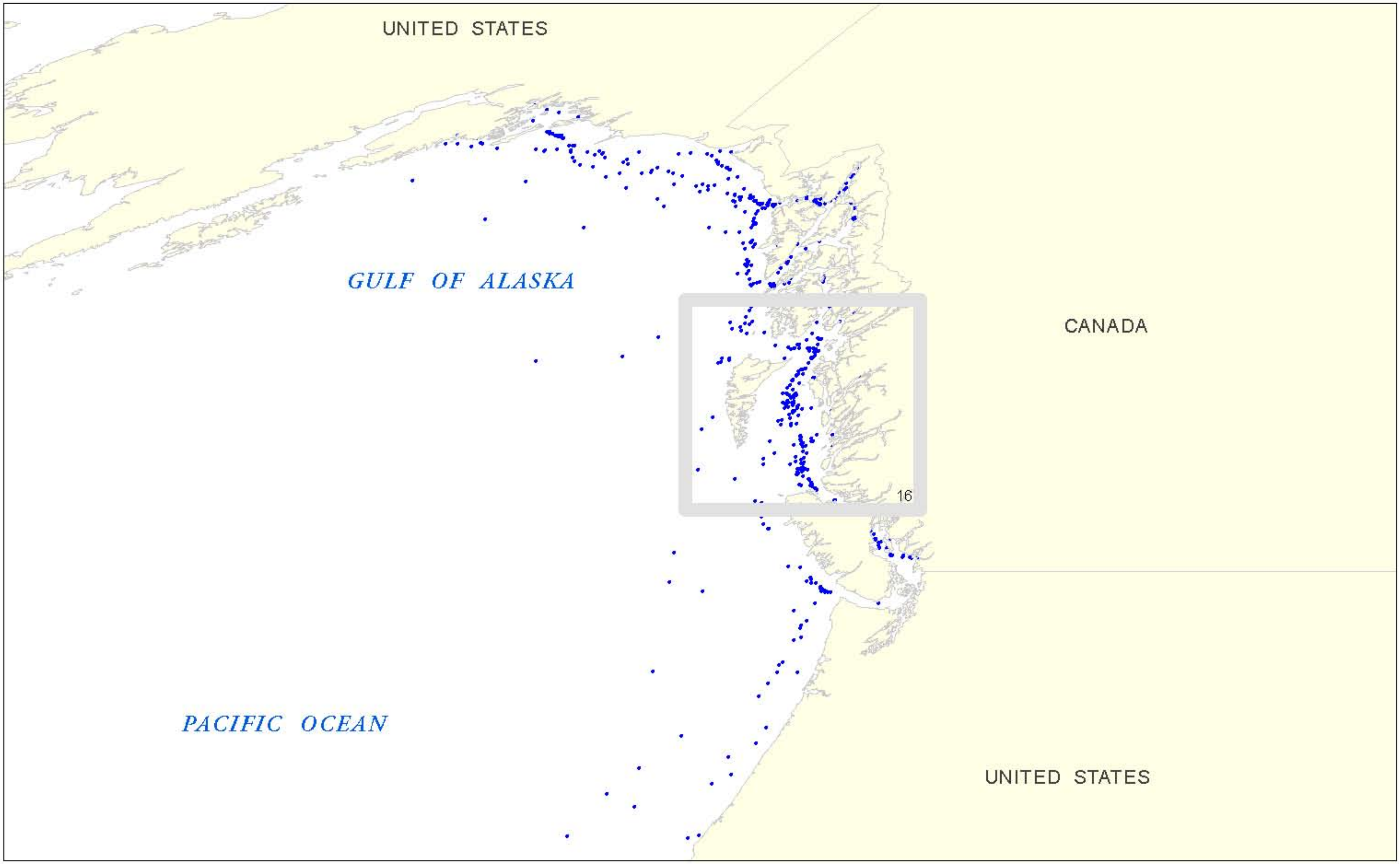

Figure 15: Discharge Start Points

Alaska and western Canada

150 75 0 150 300 450
kilometers

Scale: 1:12,800,000
Projection: Eckert IV

Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Discharge Start Points
Land
Extent of detail figure
16 Detail figure number

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

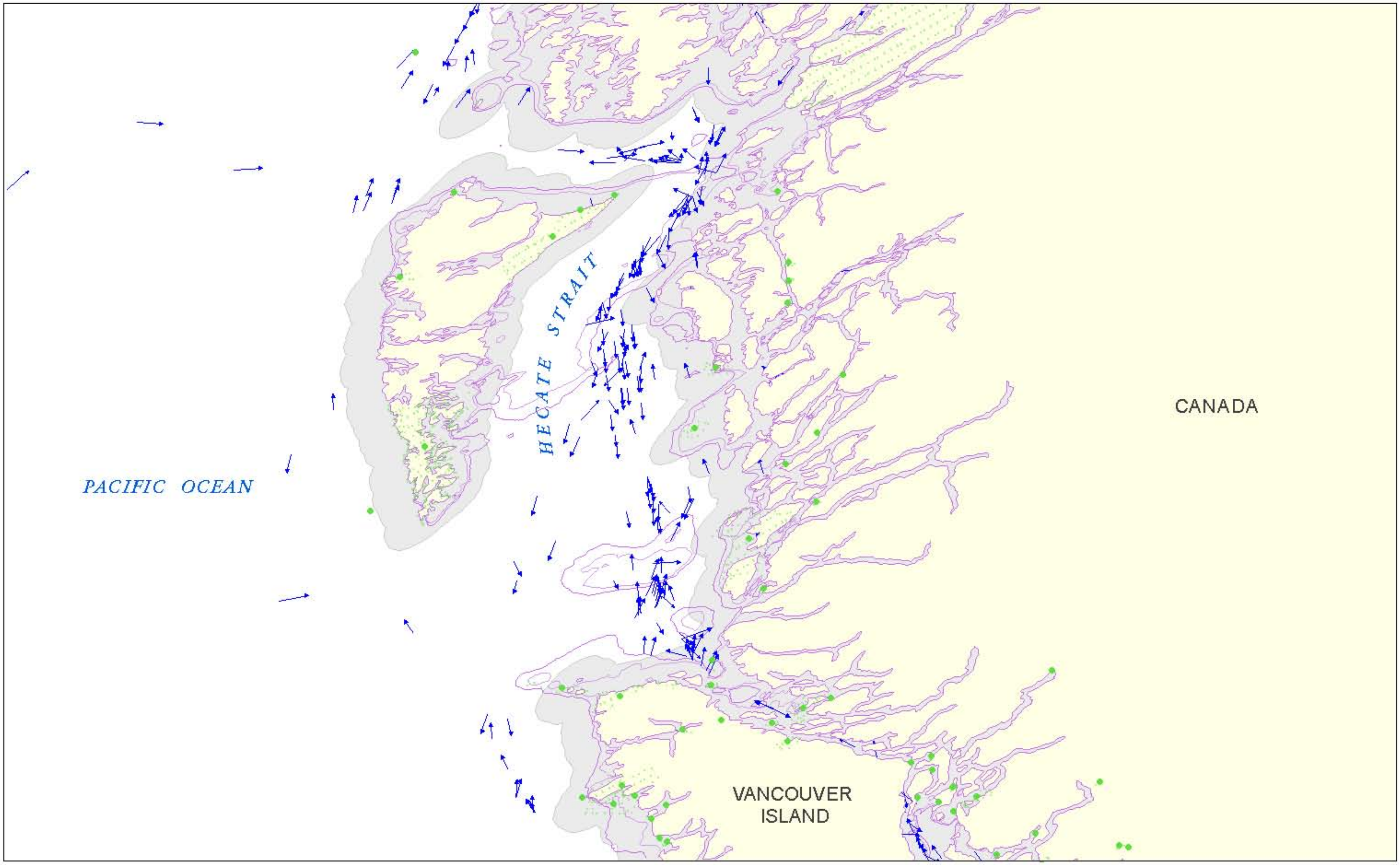

Figure 16: Discharge Start Points with Vector

Vancouver Island and northern vicinity

50 25 0 50 100 150
kilometers

Scale: 1:3,550,000
Projection: Eckert IV

Data:
AIDA Cruises
Digital Chart of the World
ETOPO2 Global 2 Minute Gridded Elevations (NOAA/NESDIS/NGDC)
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Discharge Start Points with Vector
Land
Marine Protected Area Polygons
Marine Protected Area Points
12 Nautical Miles from Coast
Bathymetric Contours (m)
60
100

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

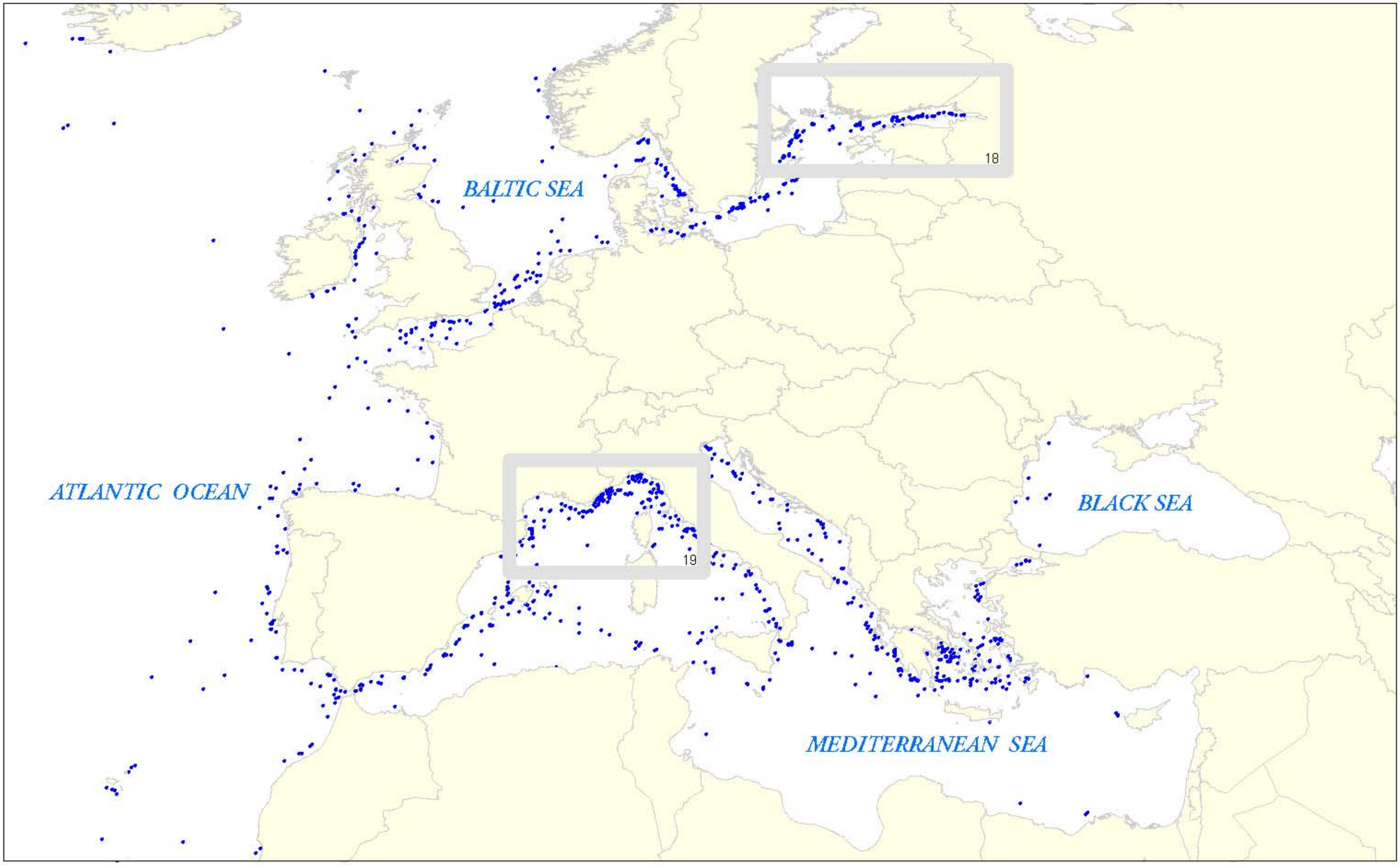

Figure 17: Discharge Start Points

Europe

300 150 0 300 600 900
kilometers

Scale: 1:23,000,000
Projection: Eckert IV

Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Discharge Start Points
Land
Extent of detail figure
18
Detail figure number

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

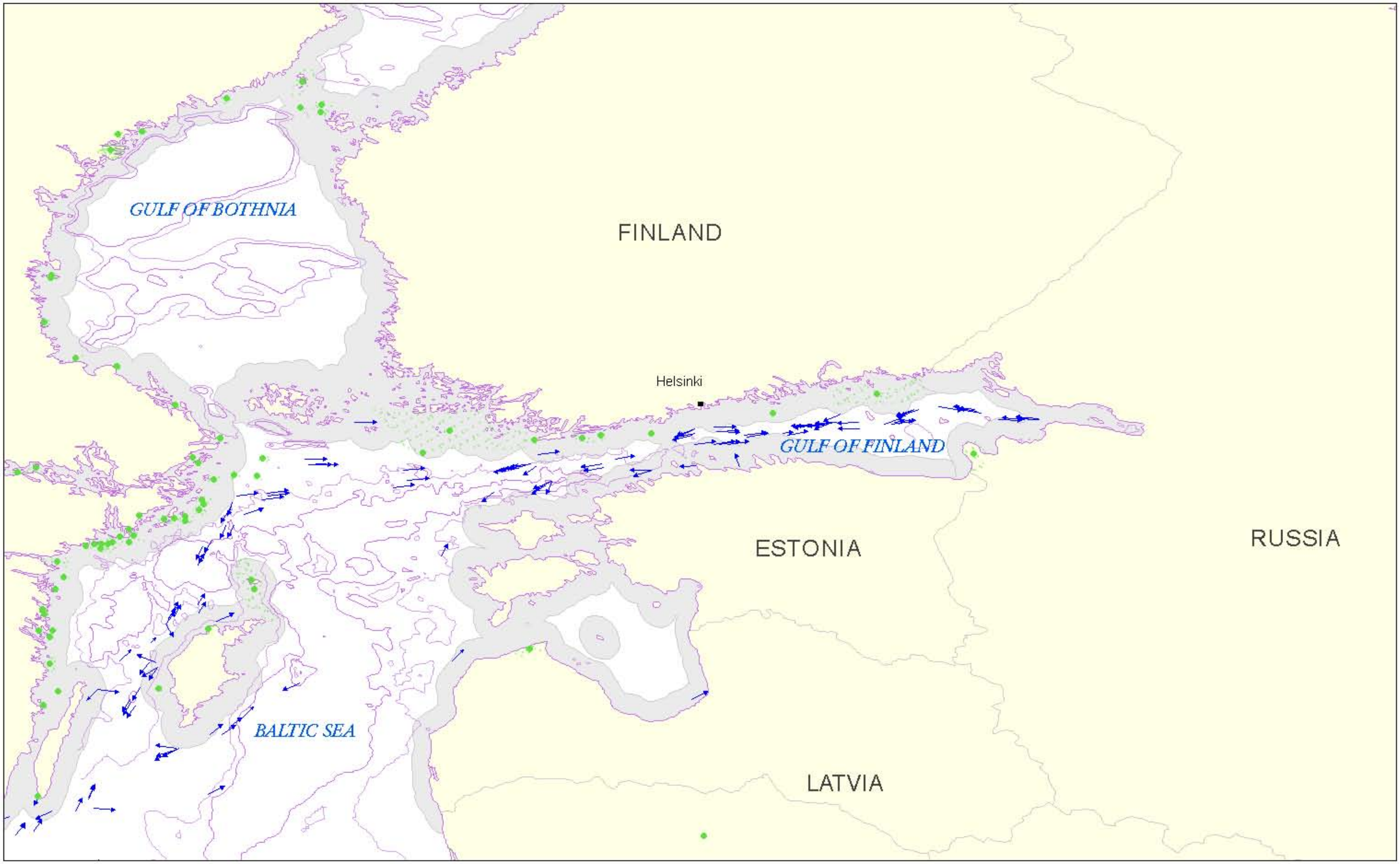

Figure 18: Discharge Start Points with Vector

Northern Europe

50 25 0 50 100 150
kilometers

Scale: 1:3,830,000
Projection: Eckert IV

Data:
AIDA Cruises
Digital Chart of the World
ETOPO2 Global 2 Minute Gridded Elevations (NOAA/NESDIS/ NGDC)
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

City
Discharge Start Points with Vector
Land
Marine Protected Area Polygons
Marine Protected Area Points
12 Nautical Miles from Coast
Bathymetric Contours (m)
60
100

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

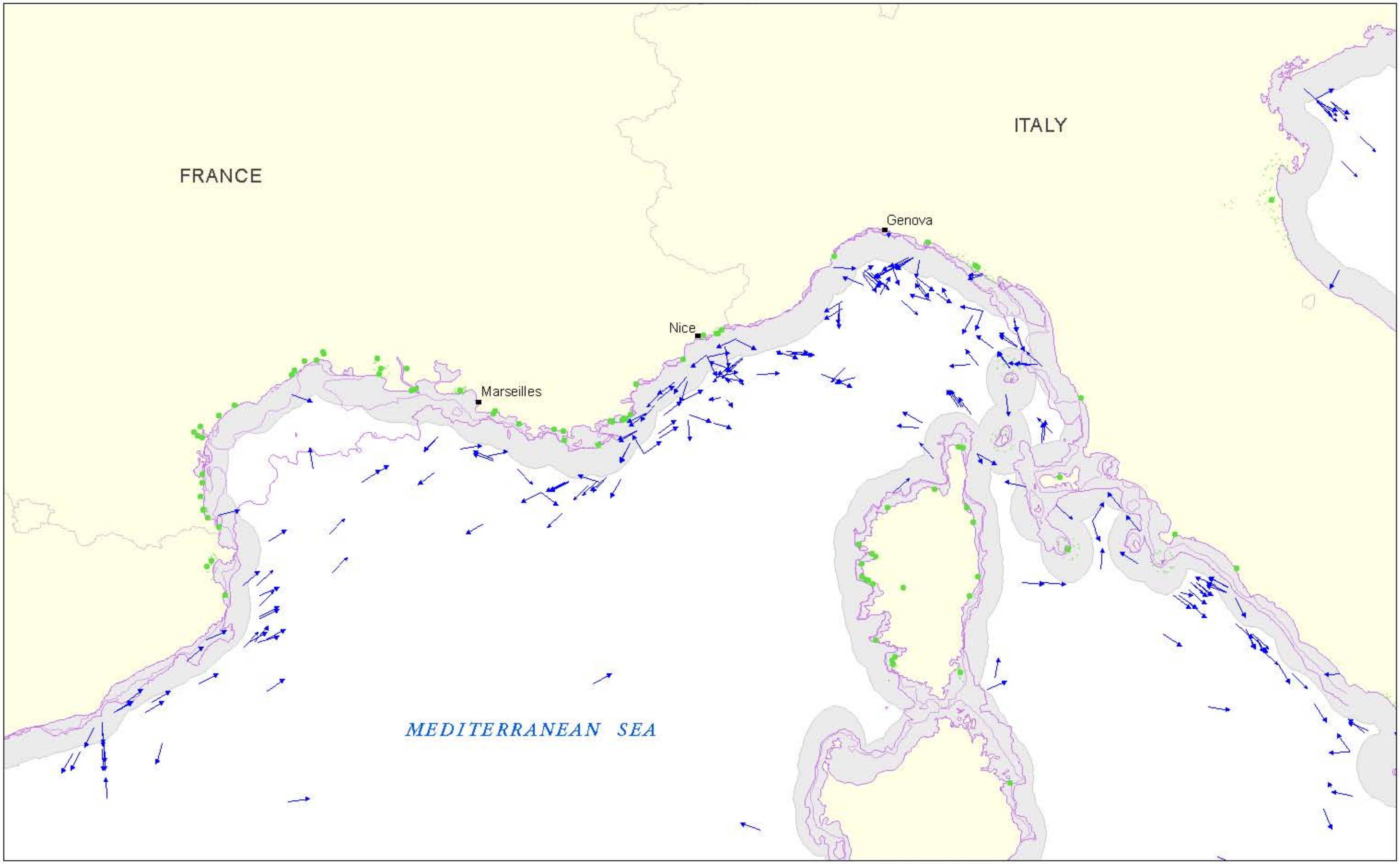

Figure 19: Discharge Start Points with Vector

French and Italian Rivieras

50 25 0 50 100 150
kilometers

Scale: 1:3,800,000
Projection: Eckert IV

Data:
AIDA Cruises
Digital Chart of the World
ETOPO2 Global 2 Minute Gridded Elevations (NOAA/NESDIS/ NGDC)
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Cities
Discharge Start Points with Vector
Land
Marine Protected Area Polygons
Marine Protected Area Points
12 Nautical Miles from Coast
Bathymetric Contours (m)
60
100

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005

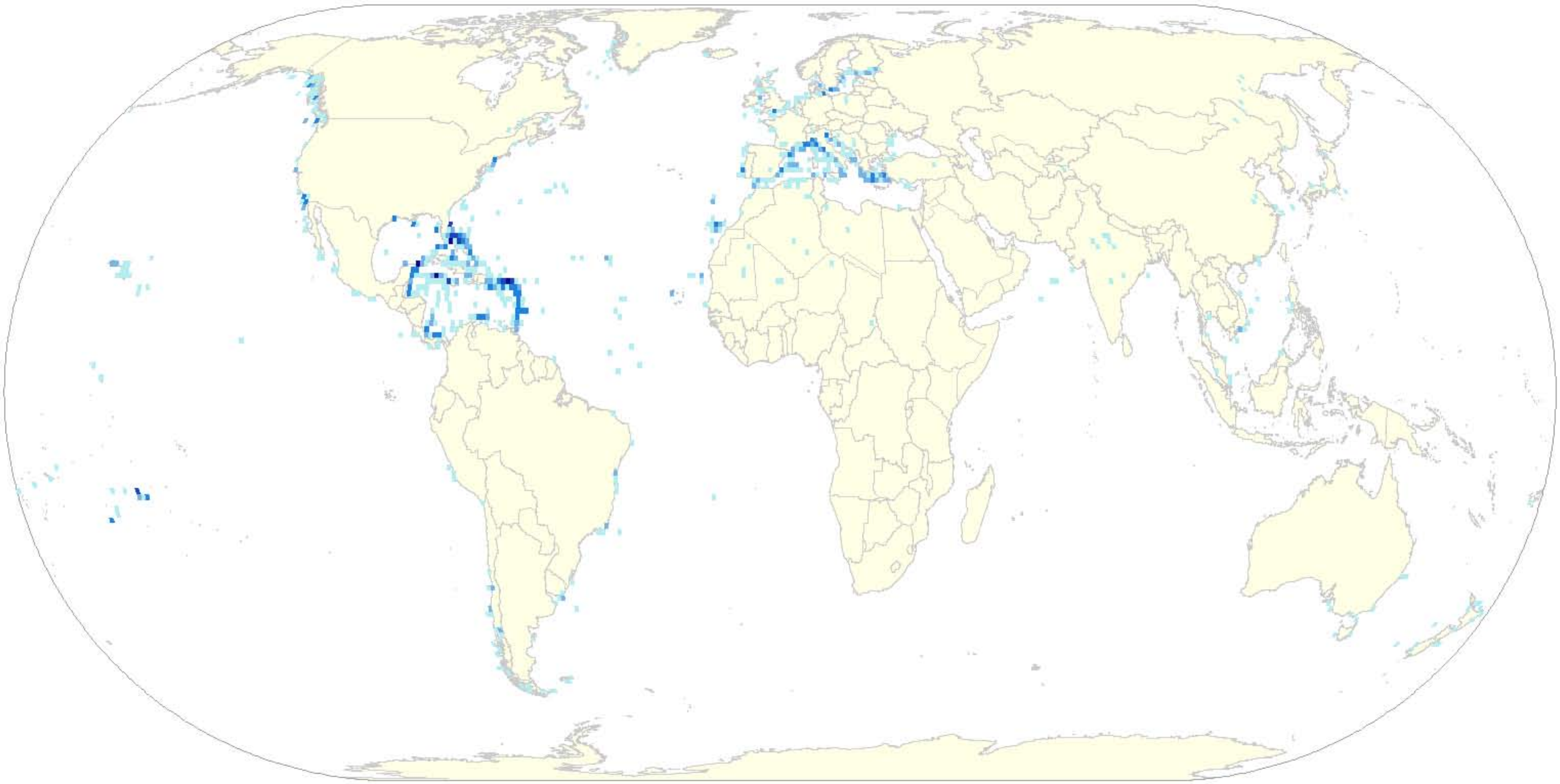

Figure 20: Density of Chlorinated Discharge Start Points

Reported cruise start points for all reported dates

2,000 1,000 0 2,000 4,000
kilometers

Scale: 1:132,000,000
Projection: Eckert IV
Data:
AIDA Cruises
Digital Chart of the World
International Council of Cruise Lines (Carnival Cruise Lines, Celebrity Cruises, Costa Cruise Lines N.V., Crystal Cruises, Cunard Line, Disney Cruise Line, Holland America Line, NCL America, Norwegian Cruise Line, Orient Lines, Princess Cruises, Radisson Seven Seas Cruises, Royal Caribbean International, Seabourn Cruise Line, Silversea Cruises, and Windstar Cruises)
P&O Cruises

Number of Chlorinated Discharge Start Points per one degree cell

- 1 - 4
- 5 - 10
- 11 - 25
- 26 - 40
- 41 - 68

This map was produced by the Conservation Mapping Program Center For Applied Biodiversity Science at Conservation International.

cartography: Erica Ashkenazi
July 2005