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Spatial and Temporal Patterns in Marine Resource Use within Raja Ampat Region from Aerial Surveys 2006

Report compiled by:
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in collaboration with
Conservation International and WWF Indonesia

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Cover Photo: Fishing boats and coastal development in Raja Ampat ©TNC Indonesia Marine Program

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Executive Summary

The Raja Ampat archipelago is located off the northwestern tip of Indonesia's West Papua Province in the 'heart' of the Coral Triangle and encompasses four million hectares of small islands, coral reefs and open waters. This region is home to the world's most diverse coral reefs and populations of endangered sea turtles and marine mammals including dugongs.

In 2006, the Government of Raja Ampat established six new MPAs bringing the total number of MPAs to 7 and encompassing close to 1 million hectares.

The population of Raja Ampat Regency in 2006 was 32,055 but is rapidly expanding. Most people rely on natural resources as a source of food and income. Understanding existing patterns of resource use, distribution of key habitats and species is critical to inform management decisions and spatial planning for natural resource management and MPA planning. Aerial surveys are a well established and useful method to collect data across large spatial scales and have been used to collect information on the distribution and abundance of marine mammals and other large marine biota.

In January and September 2006, aerial surveys were done in Raja Ampat using a small fixed wing aircraft. Each survey lasted for 30 hours over 5 days and covered approximately 4,000 km. Observers noted and described all vessels and their activities, recorded fixed gear or structures and any biota such as turtles or marine mammals. GPS locations and photos were recorded for all observations. Data were mapped and analyzed graphically to determine differences in resource use or distribution of biota among areas within Raja Ampat and among MPAs.

The majority (>75%) of vessels seen were small fishing boats – canoes with small or no engines. This demonstrates a high level of use of coastal marine resources by local communities for artisinal fisheries. Although small vessels are more numerous,other studies in the region have shown that up to 80% of fisheries catch is taken by a few outsiders using larger vessels.

Fixed gears in Raja Ampat are predominantly used for fishing and are unregulated. However a significant amount of fish are likely to be caught by these structures or using these structures as support for fishing activities in remote areas (Bailey et al. 2008). Understanding the number, location and type of fixed gears is important in understanding the true amount of fishing effort in Raja Ampat and can be used as a basis for any future licencing or quota system to regulate these fishing gears.

Manta rays, whales and dolphins was significantly more abundant in January with more than twice the number of individuals seen compared to September. Most biota sightings were between Sorong and Salawati Island, in Dampier Strait and around Kofiau Island. The MPA network currently does not encompass many of the important areas for these species.

This study has shown that aerial surveys are a highly useful method to survey resource use and large marine fauna in remote and extensive areas. There is great potential to combine aerial surveys with vessel activities to assist in enforcement patrols and alert authorities to illegal activities. It is also an excellent method to assess the number, type and distribution of unregulated structures such as fishing traps and shelters.

1 INTRODUCTION

The Raja Ampat archipelago is located off the northwestern tip of Indonesia's West Papua Province in the 'heart' of the Coral Triangle. This region encompasses around 4 million hectares of land and sea including the four large islands of Waigeo, Batanta, Salawati, and Misool and hundreds of smaller islands. Many of the islands are covered by intact forests protected within National Parks. The reefs around these islands support the world's highest biodiversity of corals and fish. Scientific surveys have recorded at least 553 species of scleractinian corals (Veron et al. 2009) and at least 1,320 reef fish species, the highest count in the world for an area of that size (Allen and Erdmann 2009). Cetaceans and large marine biota are also an important part of the Raja Ampat ecosystem with a total of 16 species of cetaceans recorded including sperm whales, 'Pacific' blue whales, Indo-Pacific humpbacked dolphins. Dugongs are also frequently sighted. Several marine mammal species that are known or suspected to occur in this region are IUCN listed as vulnerable or endangered species. The Raja Ampat archipelago is part of the Bird's Head seascape, which also contains Cendrawasih Bay, the largest marine national park in Indonesia, and Jamursba Medi, housing some of the most important sea turtle nesting beaches in the world.

The capital of Raja Ampat Regency, Waisai is located on the southern coast of this island of Waigeo. The population of Raja Ampat Regency in 2006 was 32,055 distributed throughout the capital and 88 villages (Firman and Azhar 2006). The population is rapidly expanding with the Regency Government actively pursuing a transmigration program which will see thousands of people from Java moving to Raja Ampat.

Local communities and the regional economy rely heavily on natural resources – both terrestrial and marine - for industries such as fishing, mining, forestry, oil and gas, aquaculture and tourism. However, some activities associated with these industries or coastal development associated with increasing populations threatens the biodiversity and health of marine and terrestrial communities in Raja Ampat. The future prosperity of this region will depend on policies and management which support sustainable industries for the benefit of local communities and protect the outstanding biodiversity of this region.

In 2006, the Government of Raja Ampat established six new MPAs in the region encompassing close to 1 million hectares: Kofiau, South East Misool, Selat Dampier, Teluk Mayalibit, Ayau, and Wayag Sayang. Together with the existing MPA of West Waigeo, this brought the total number of MPAs in Raja Ampat to seven. This declaration and subsequent extensions of Selat Dampier and Teluk Myalibit in 2009, indicates that the Regency recognizes and values the importance of marine conservation as an investment in developing the sustainable fisheries and marine-based tourism sectors. The Nature Conservancy and Conservation International are currently working closely with the Raja Ampat government to support management of the MPA network. This includes support for the development and implementation of MPA zoning and management plans and fisheries policies and spatial planning at both Provincial and Regency levels. Through these processes an ecosystem based management approach to the management of marine resources in Raja Ampat and throughout the Bird's Head Seascape is encouraged.

Understanding existing patterns of resource use, distribution of key habitats and species is critical to inform management decisions and spatial planning. Aerial surveys are a well established and useful method to collect data across large spatial scales and have been used to collect information on the distribution and abundance of marine mammals and other large marine biota e.g. turtles. These surveys provide a 'snapshot' of the area and if repeated over time can be used to determine seasonal/annual trends. These data can be particularly powerful in determining the success of management plans/policies by determining the degree of compliance with MPA boundaries, fishery and other regulations across a large geographic area.

The objective of this study was to determine the spatial and temporal patterns in the distribution and type of marine resource users and large marine biota in Raja Ampat Regency.

2 METHODOLOGY

2.1 AERIAL SURVEYS

In 2006, two aerial surveys were done in Raja Ampat following the TNC Aerial Survey Protocol (Mous 2005) using a small fixed wing aircraft, a Pilatus PC-6 ('Pilatus Porter'). The first survey was done between 9-13 January 2006, and the second between 8-22 September 2006. Each survey (flight) lasted for 30 hours over 5 days and covered approximately 4,000 km along the targeted flight path **(**

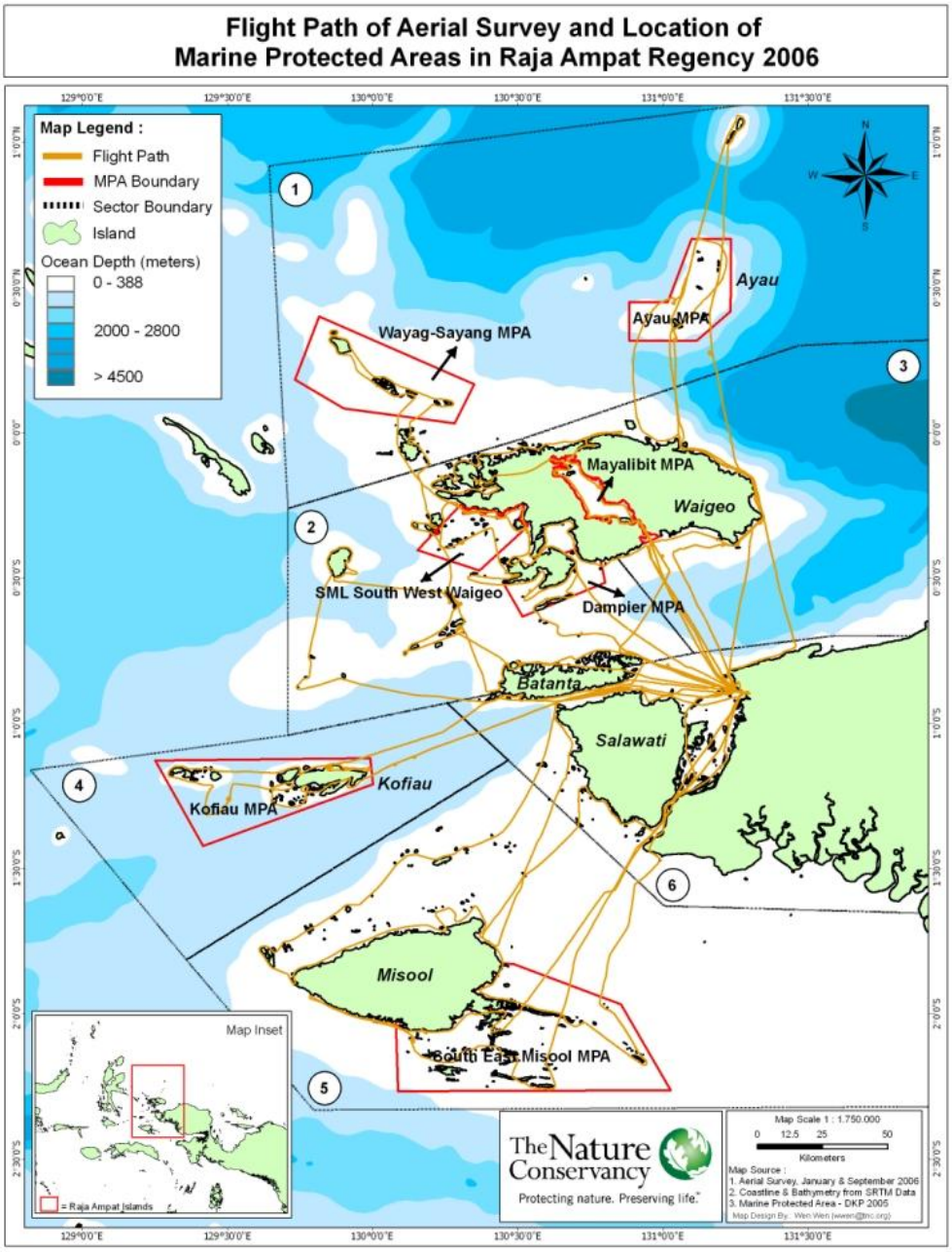

Figure 1. **)**. It is important to note that the flight path and survey methods were developed to allow maximum coverage of the near-shore reef areas of Raja Ampat and to maximize the area covered by the survey to obtain information on the distribution and type of activities and biota in Raja Ampat. Obtaining accurate estimates of marine mammal populations was not an objective of this survey.

On each flight the team consisted of 5 people - one team leader who recorded GPS positions and took photos of all observations, two fishery/biota observers (one port, one starboard) (vessels, fixed fishing structures, and large marine biota) and two people mapping reefs (one port, one starboard). Observers

recorded data describing the observation based on categories in Table 1 and GPS position onto prepared data sheets (Appendix A). Upon return to the office, all data were then transferred to an excel spreadsheet and GIS database.

All vessels were classified according to the type of vessel, its size, the type of engine and its activity at the time of observation. 'Fixed gear' is defined as man-made structures which have been built or deployed in the marine area. These include some 'bagan' or lift net vessels which are not self-powered, fish aggregating devices (FADs), fish cages used to temporarily store live fish, and fish shelters which are temporary shelters or huts of various sizes used by fishermen when fishing in an area which is too far from their village to return home each evening.

Table 1. Categories of vessels, fixed gear and marine biota recorded during aerial surveys in Raja Ampat, 2006

Vessel type	**Vessel size**	**Vessel Engine**	**Vessel Activity**	**Fixed Gear**	**Biota**
Fishery	Small canoe	No engine	Anchoring	Bagan	Whales/dolphins
Passenger	Canoe/dinghy	Ketinting	Fishing	FAD	Mantas
Live-aboard	Small <10m	Outboard	Gleaning	Fish Cage	Turtles
Freight	Med 10-20m	Inboard	Moving	Fish Shelter	Shark
Industrial	Large 20-50m	Unknown	Unknown	Other	Bait school/Tuna
Other	V. large >50m				Dugongs
Unknown					Fish Spawning Aggregation
					Birds

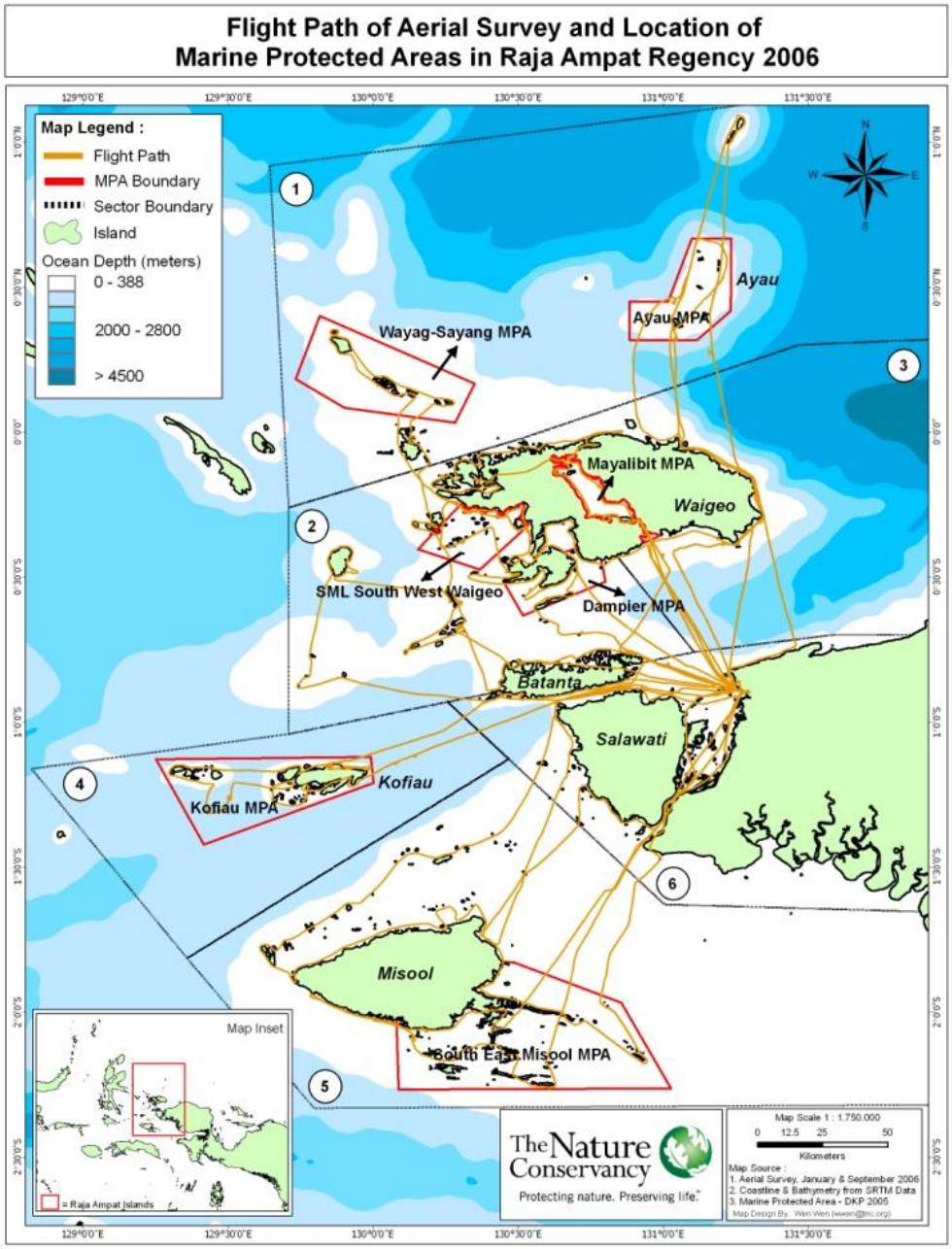

Figure 1. Flight path and boundaries of MPAs and sectors of interest

2.2 DATA ANALYSIS & MAPPING

For the purpose of analysis, Raja Ampat Regency was divided into six sectors **(Figure 1)** to allow for an analysis of the spatial distribution of vessels, fixed gear and large marine biota. MPA boundaries as

defined in 2006 were also identified (

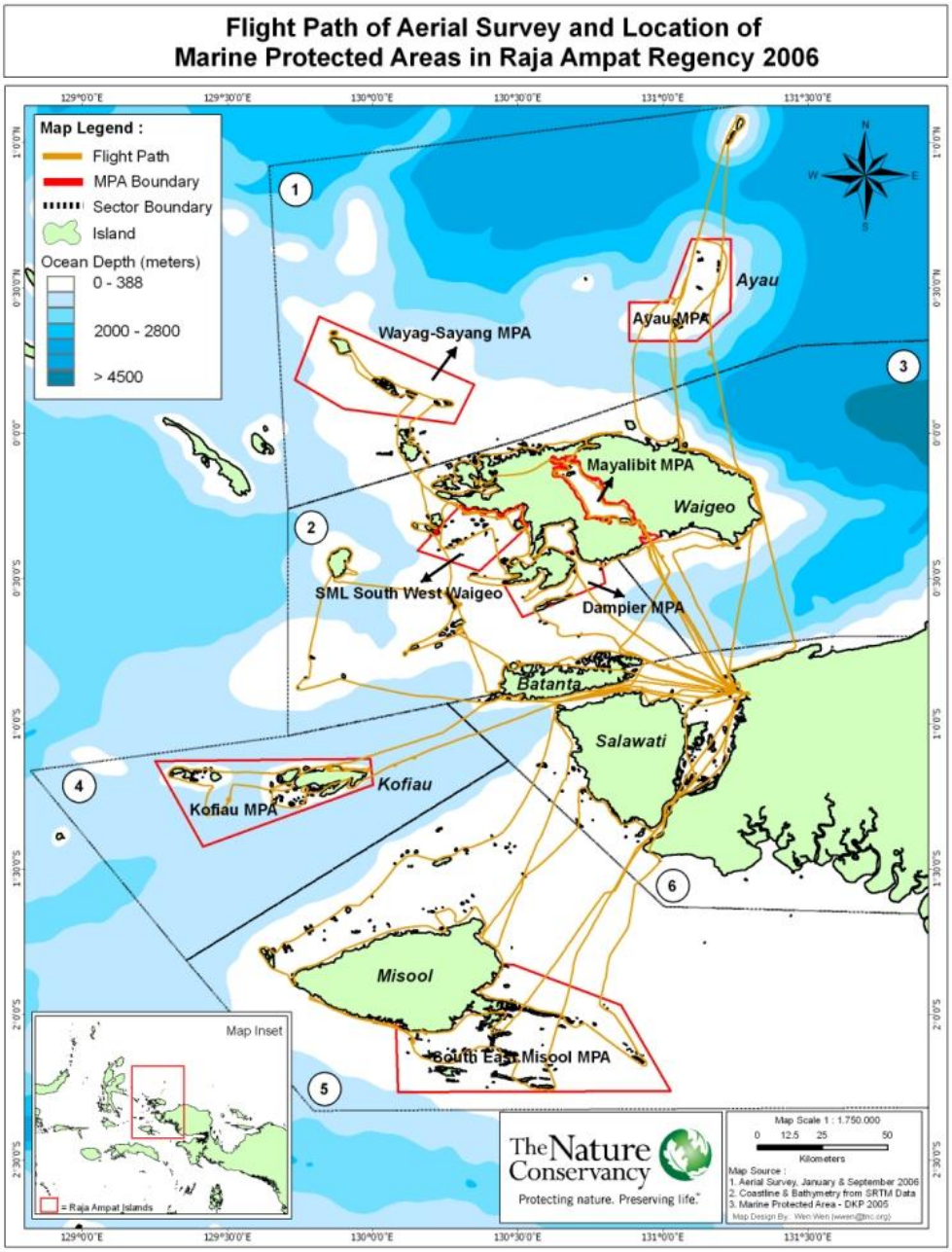

Figure 1. **)**. Data were analyzed using ArcGIS and Excel on the basis of both sectors and MPA boundaries for surveys in January and September 2006. These data are presented for each category of observation in maps and graphically. Maps which show the distribution of resource users by categories were produced using ArcGIS. Graphs were also used to compare the total number of observations in each category by sector and MPA in January and September 2006.

A CD was produced showing all photos of Raja Ampat linked to their GPS position. The CD is set up in html format showing a map of Raja Ampat overlaid with a number of red and blue dots (red for January, blue for September). Clicking on these dots will link to the relevant photo taken at that position.

3 RESULTS

3.1 GENERAL OVERVIEW

Aerial surveys proved to be an effective method for Regency wide surveys of vessels, fixed structures and large marine biota. A total of 3761 observations were made during the two surveys (January and September 2006). The distribution of vessels, fixed structures and large marine fauna in Raja Ampat Regency varied significantly among sectors, MPAs and between survey times. The majority of vessels observed during these surveys were small fishing vessels with few large commercial vessels observed. The number of fixed structures increased from January to September, and the location of many of these structures had changed. Manta rays, whales and dolphins was significantly more abundant with more than twice the number of individuals seen in January compared to September with most located in the region between Sorong, Salawati Island and Dampier Strait.

3.2 VESSELS

A total of 1748 vessels were recorded during both surveys. Fishery vessels which included all vessels used for fishing – from small canoes to large commercial vessels - were the most frequently sighted of all vessels in Raja Ampat. A total of 1322 fishing vessels were recorded representing 75% of all vessels observed **(Figure 2)**. The number of fishery vessels recorded in September (777) was somewhat higher than in January (545) likely due to the usually strong westerly winds prevalent in January which may restrict the movements of small vessels.

Most fishery vessels were small with approximately 70% classified as small canoes or dinghies **(Figure 5)** with either no engine or 'ketinting' engines. There were very few large fishery vessels recorded during these surveys. This demonstrates the high percentage of local subsistence fishers and the high reliance on reefs and coastal areas for fisheries for the survival and livelihoods of local people. Reefs and coastal areas which are sheltered and close to villages are the most accessible fishing areas for local people using small boats. Most fishing vessels were concentrated around the coral reefs and islands in the region of Sorong, Salawati Island (Sector 6) and Dampier Strait/southern Waigeo (Sector 2) **(Figure 7** and **Figure 8)**. Very few vessels were recorded in the far northern part of Raja Ampat (Sector 1) **(Figure 5, Figure 7**, **Figure 8)**. No fishing was observed on either survey in the Kawe MPA which has been declared as a protected area by local traditional owners since 2008. The MPAs with the highest vessel activity were Dampier Strait, Kofiau and SE Misool, with SE Misool **(Figure 6, Figure 8)**. SE Misool was the only MPA where fishing vessels larger than 10m long were recorded.

On average approximately 50% of vessels in Raja Ampat were actively fishing at the time of the surveys with the remainder mostly anchored or moving **(Figure 7)**. However there are large differences among Sectors and MPAs in % of vessels actively fishing and differences between January and September. **Figure 9** shows that at Ayau in January, 80% of vessels were fishing compared to only 10% in SE Misool and around 8% in Teluk Myalibit. There were also differences among surveys. For example in Teluk Myalibit MPA the percentage of vessels fishing increased from 8 to 60% from January to September. Increases in percentage of vessels actively fishing also increased in Dampier MPA and SW Waigeo MPA but decreased in Ayau and Kofiau. Percentages of vessels fishing in SE Misool MPA remained low in both surveys at 10-15%. This indicates that fishing activities are seasonal among MPAs and regions and also that for some MPAs and seasons the main fishing activity occurs at night.

Passenger and tourism

Passenger vessels are the main method of transport between the islands for local people and vary in size from canoes/dinghies to large vessels. In January, passenger vessels were only seen in sheltered straits around Salawati Island perhaps due to the bad weather during January. During September they were more widespread in Raja Ampat with vessels seen around Waigeo Island, in Dampier Strait and in SE Misool **(Figure 2, Figure 3, Figure 6, Figure 7).**

In 2006, a total of 14 sightings of tourism vessels were made including dive live-aboard vessels and other smaller dinghies or support vessels. They were distributed as far north as Wayag and as far south as SE Misool and also in the Dampier Strait and northern coast of Waigeo **(Figure 2, Figure 3, Figure 6, Figure 7)**.

Freight and Industrial

Freight and industrial ships were most frequently observed in the Salawati Straits, in shipping lanes and associated with the oil rig located between Misool and Salawati Island. There were also large vessels observed at NW Waigeo and SE Misool. Unsurprisingly, most of the large and very large vessels recorded during the surveys were freight and industrial ships but there were also some large fishery vessels observed in SE Misool MPA.

Others and Unknown

The 'Others' and 'Unknown' categories together comprise 12% of all observations made during these surveys and was due to difficulties of identifying small objects or vessels or their location being at the edge of the observers field of view **(Figure 2, Figure 3, Figure 8, Figure 9)**.

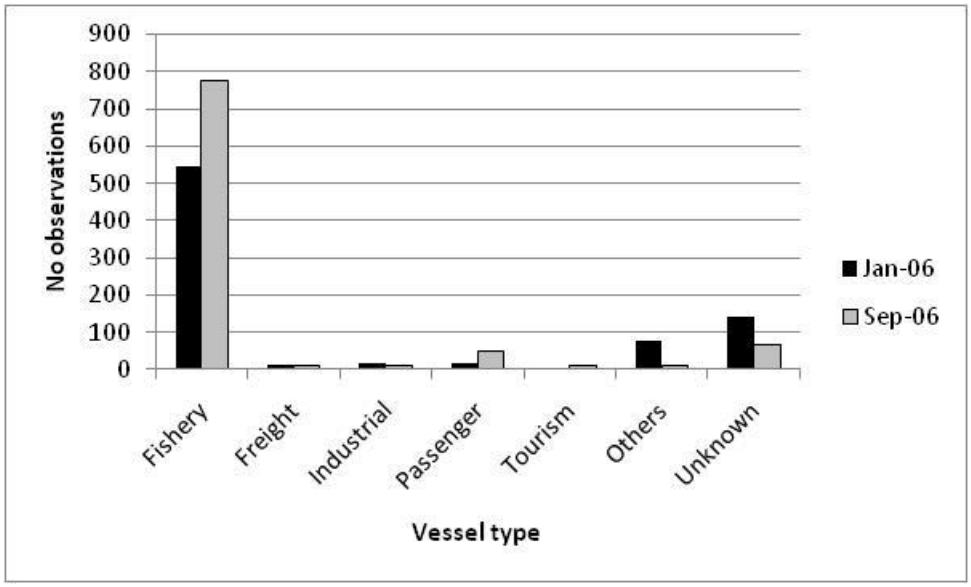

Figure 2. Frequency of observations of vessels by type in Raja Ampat in 2006 from aerial surveys.

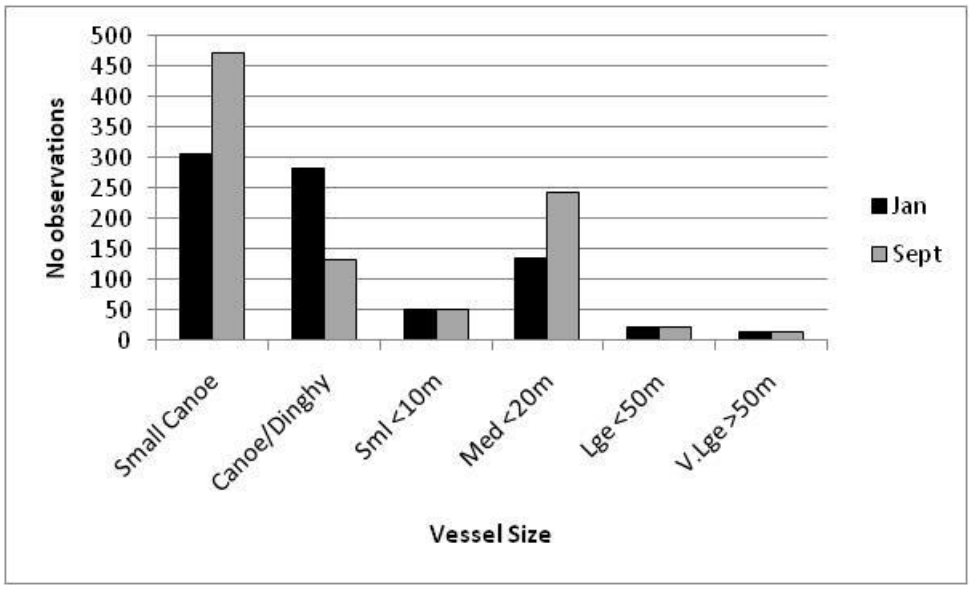

Figure 3. Frequency of observation of vessels by size in Raja Ampat Regency in 2006 from aerial surveys.

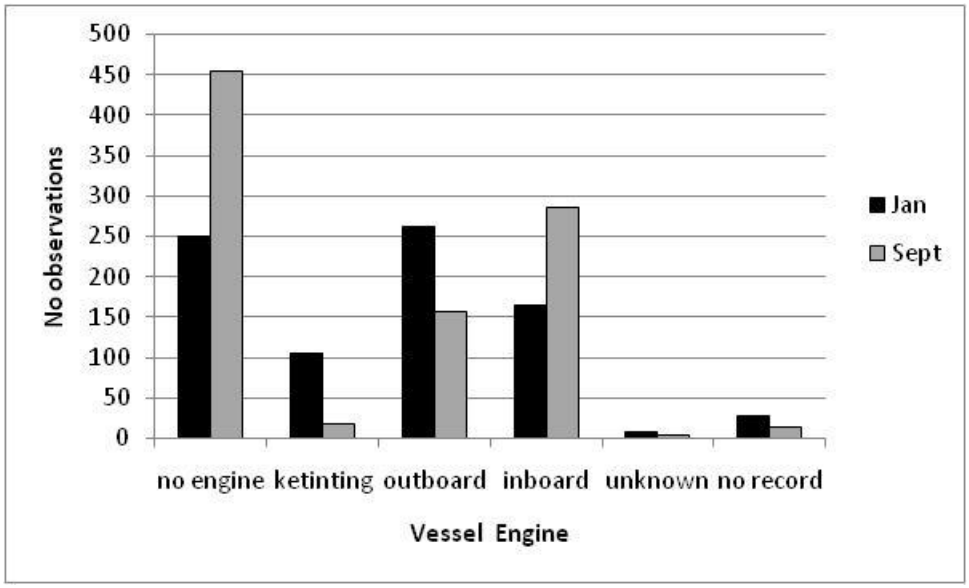

Figure 4. Frequency of observations of vessels by engine type in Raja Ampat Regency in 2006 from aerial surveys.

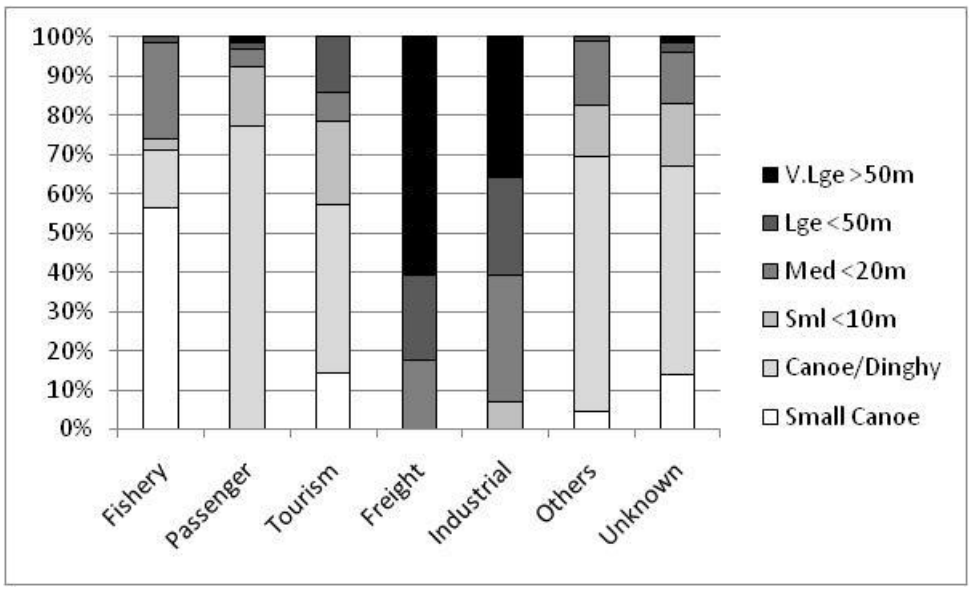

Figure 5. Relative proportion of vessel size for each category of vessel type in Raja Ampat Regency in 2006 from aerial surveys (January and September).

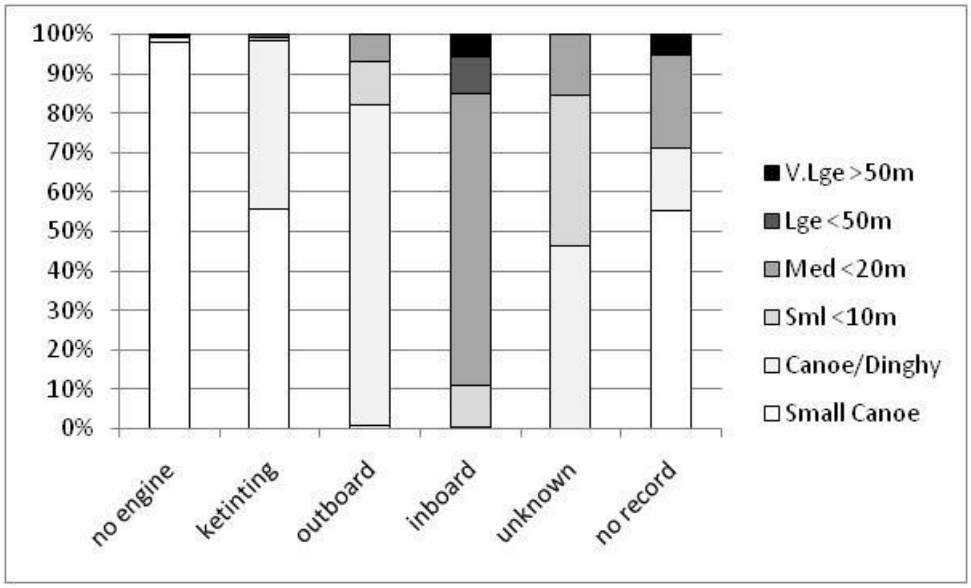

Figure 6. Relative proportion of vessel size for each category of engine type in Raja Ampat Regency in 2006 from aerial surveys (January and September).

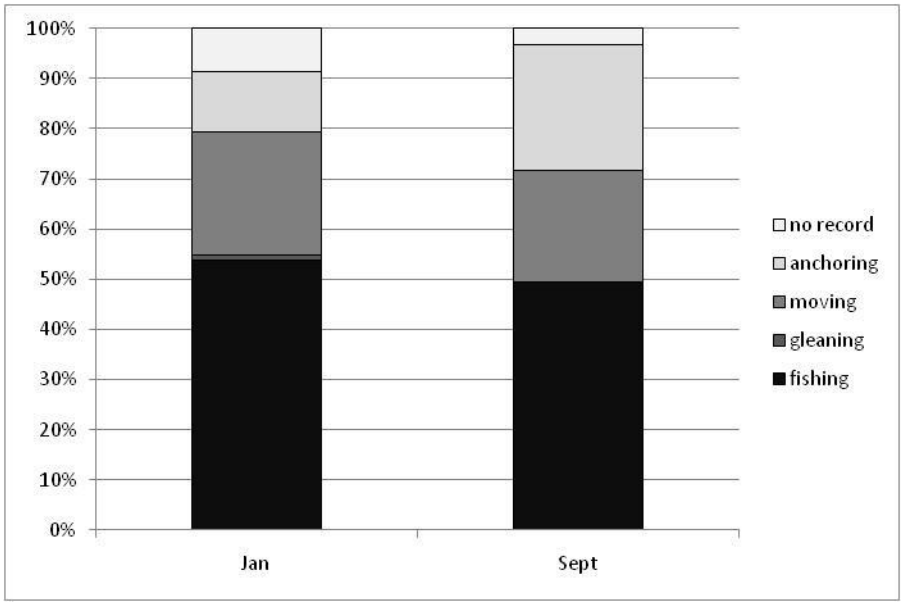

Figure 7. Relative proportion of activities for fishing vessels observed in Raja Ampat Regency in 2006 by aerial surveys.

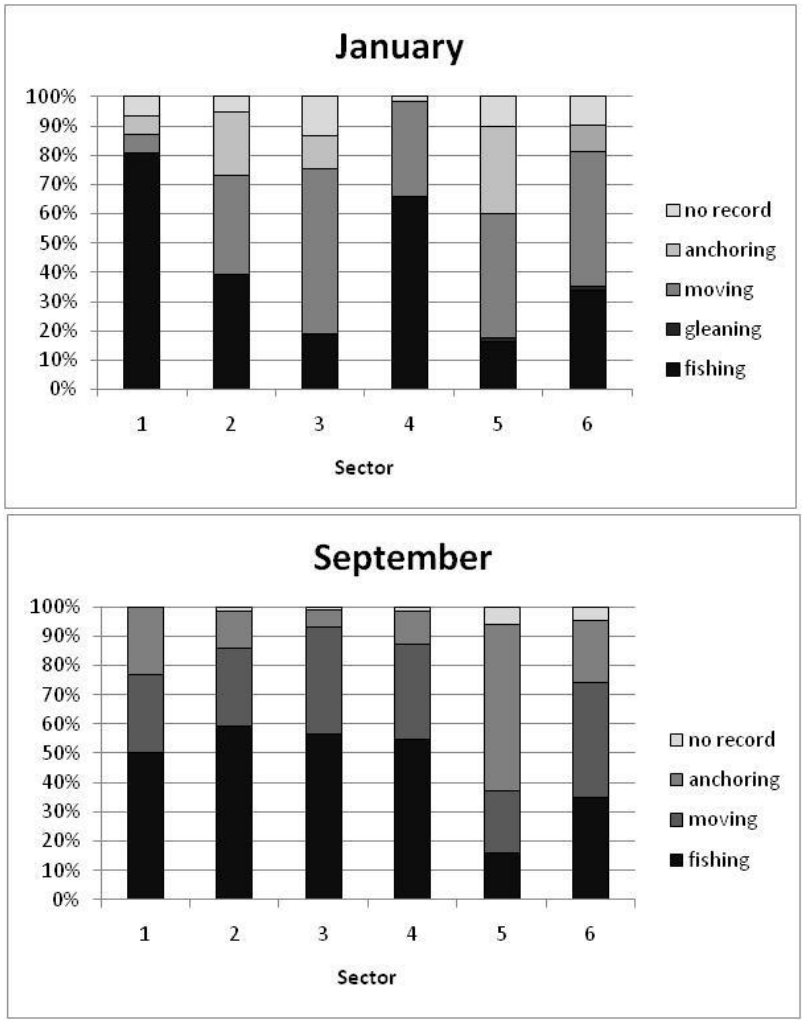

Figure 8. Relative proportion of activities for fishing vessels observed in each sector of Raja Ampat Regency in 2006 by aerial surveys.

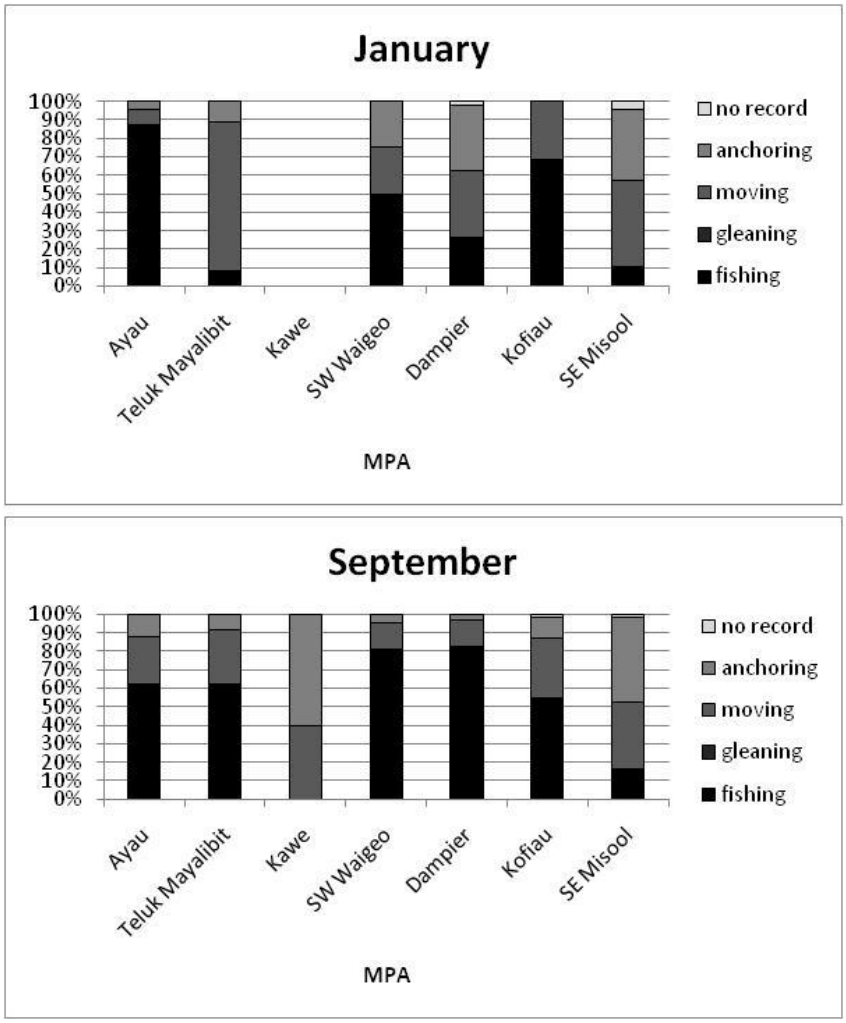

Figure 9. Relative proportion of activities for fishing vessels observed in each MPA of Raja Ampat Regency in 2006 by aerial surveys.

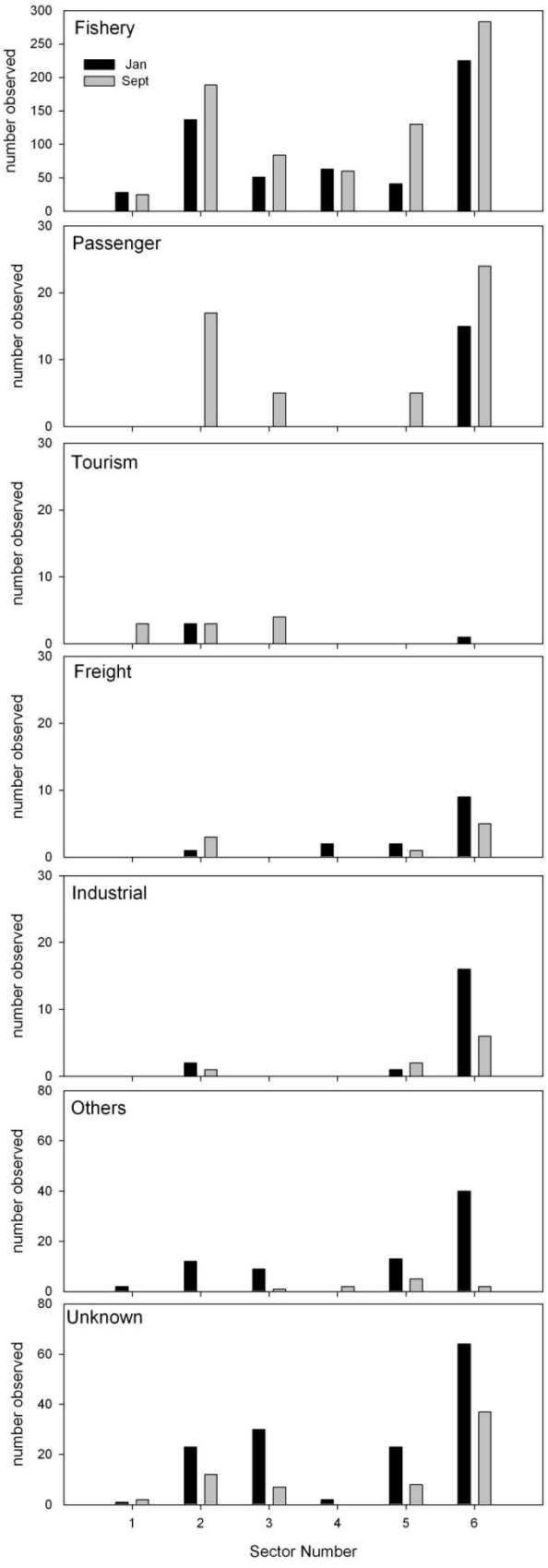

Figure 10. Frequency of vessels by type in each sector of Raja Ampat Regency 2006.

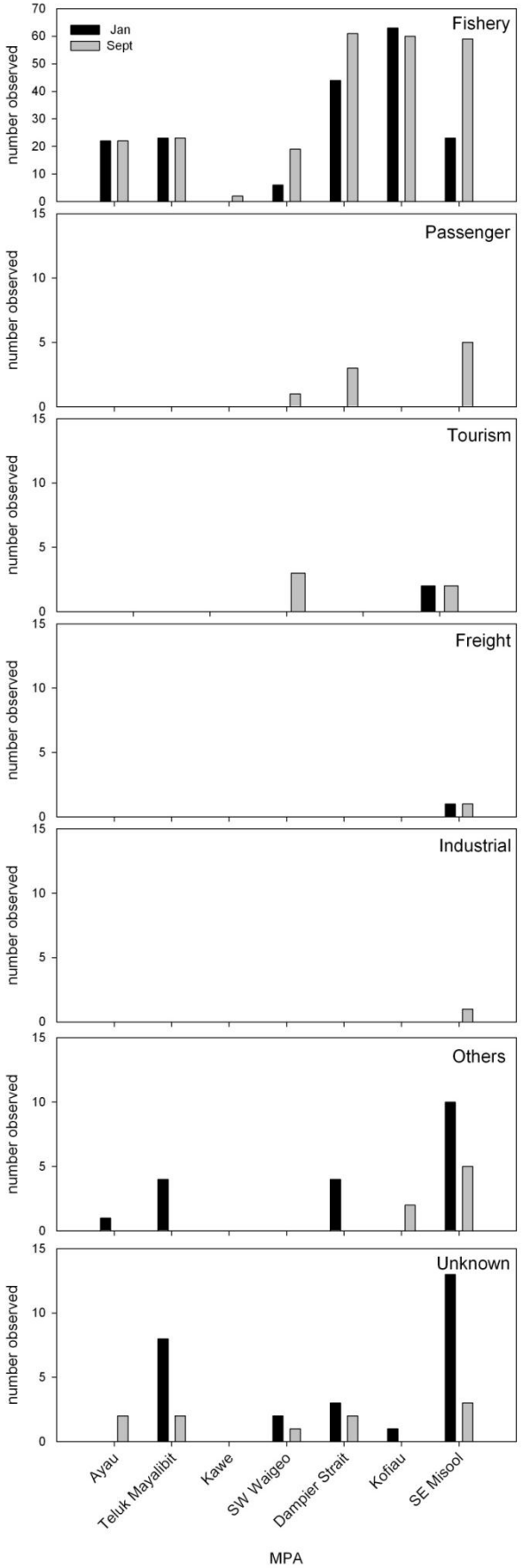

Figure 11. Frequency of vessels by type in each MPA in Raja Ampat 2006.

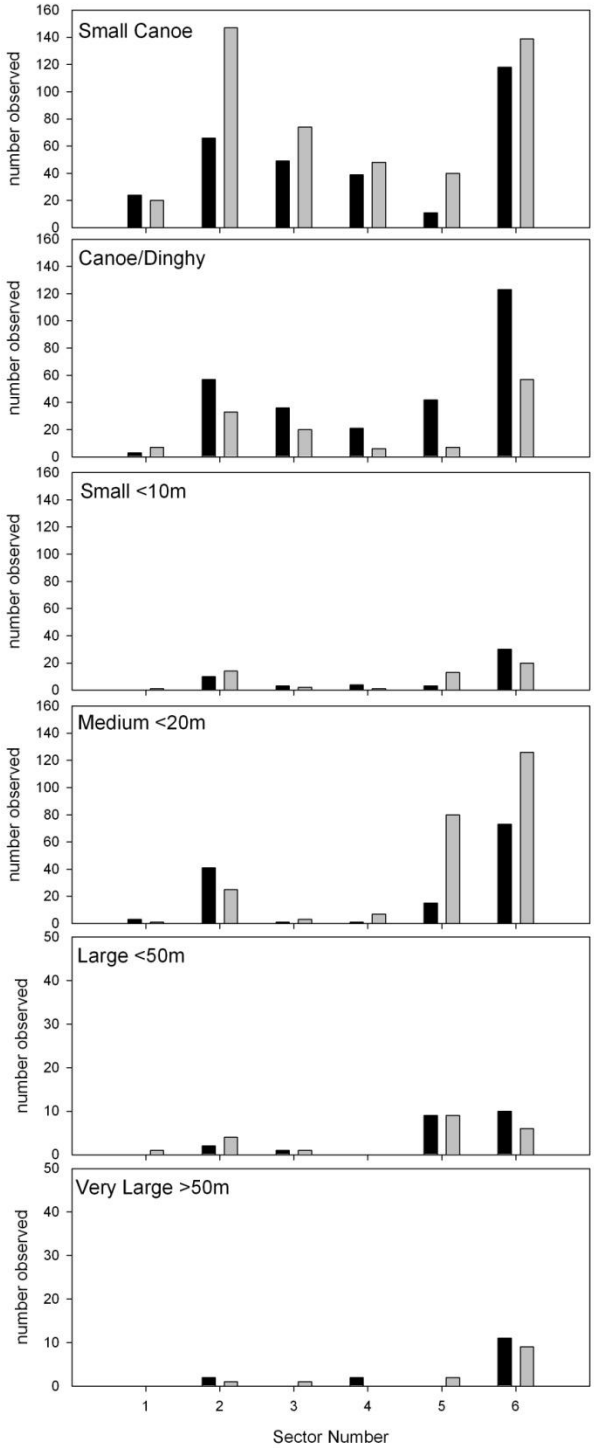

Figure 12. Frequency of vessels by size in each sector of Raja Ampat 2006.

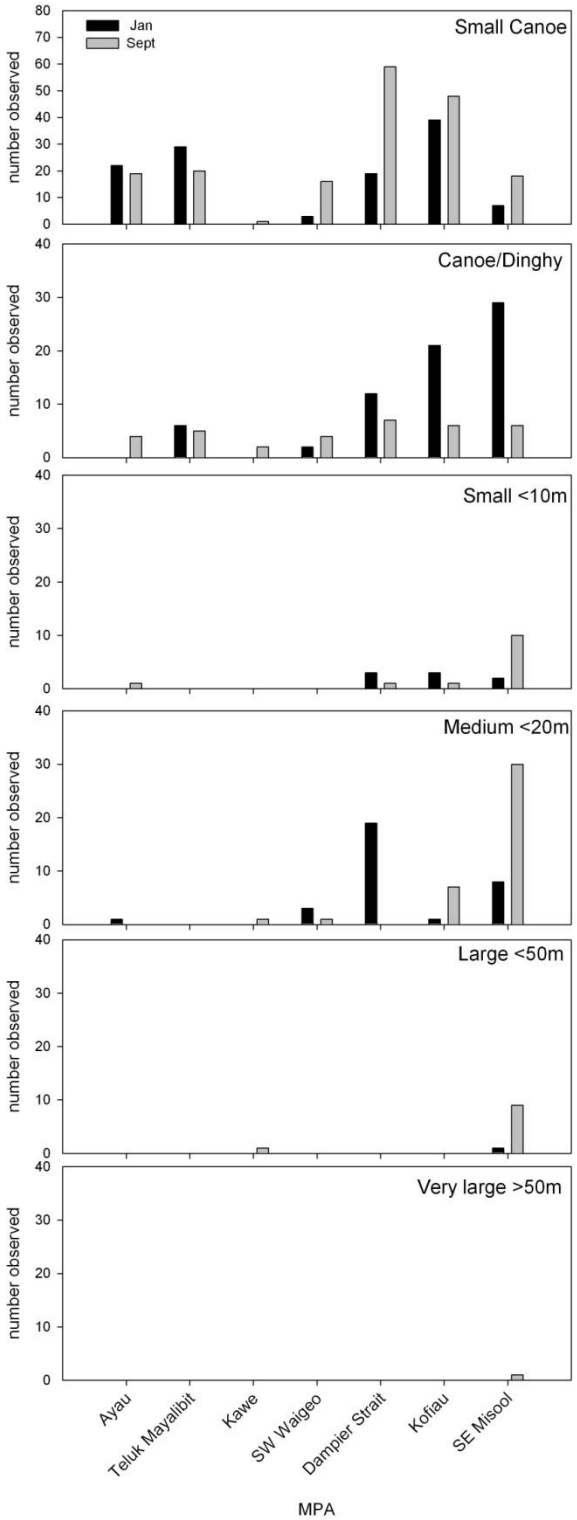

Figure 13. Frequency of vessels by size in each MPA in Raja Ampat 2006.

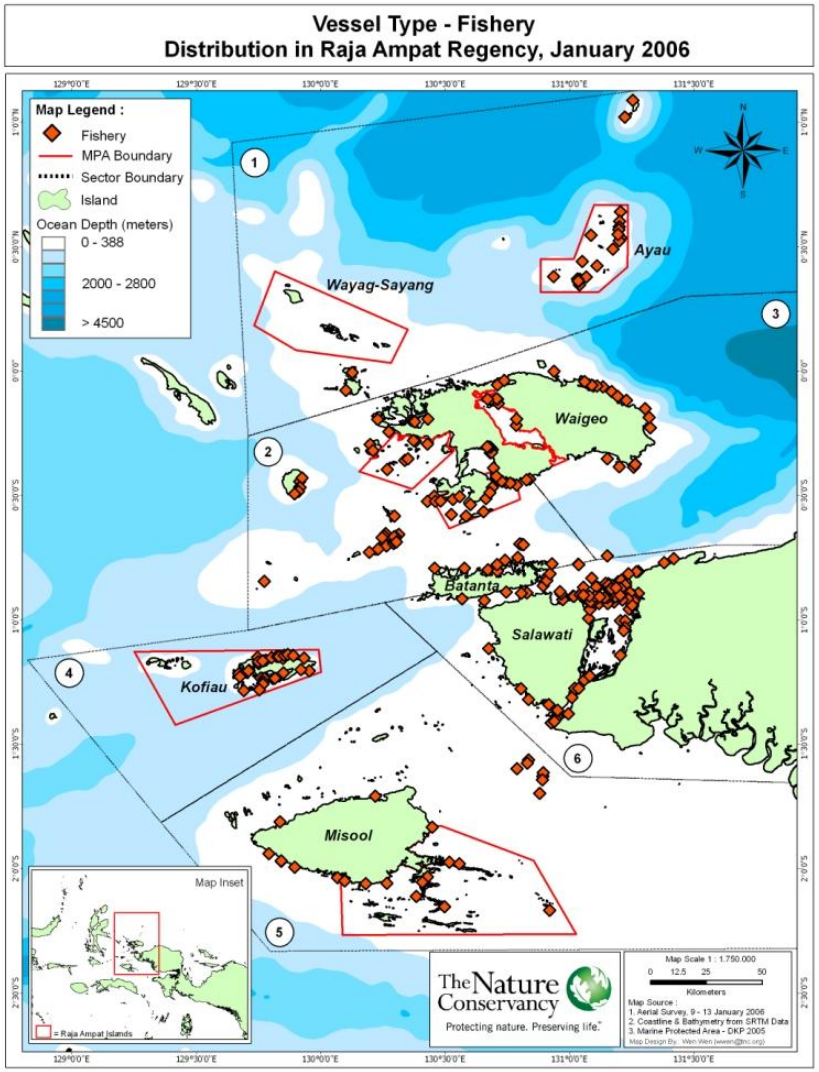

Figure 14. Distribution of all fishery vessels in Raja Ampat Regency, from aerial surveys in January 2006.

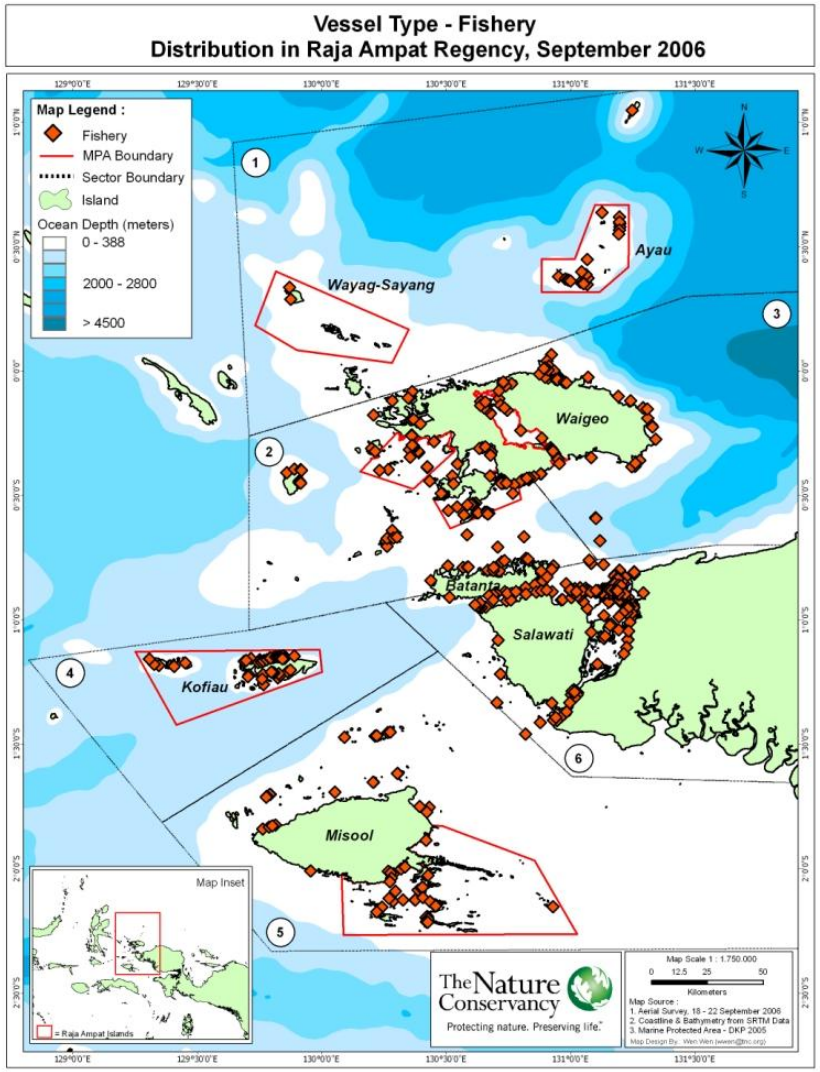

Figure 15. Distribution of all fishery vessels in Raja Ampat Regency, from aerial surveys in September 2006.

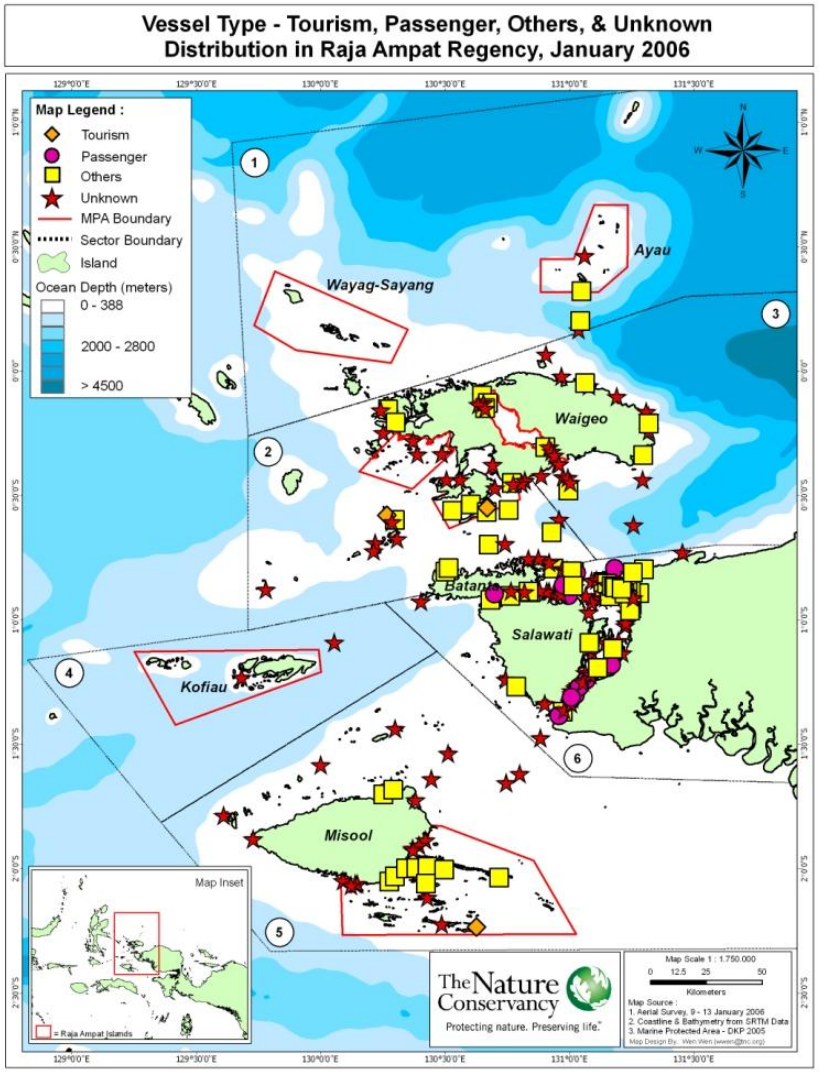

Figure 16. Distribution of tourism, passenger and other vessels in Raja Ampat Regency, from aerial surveys in January 2006.

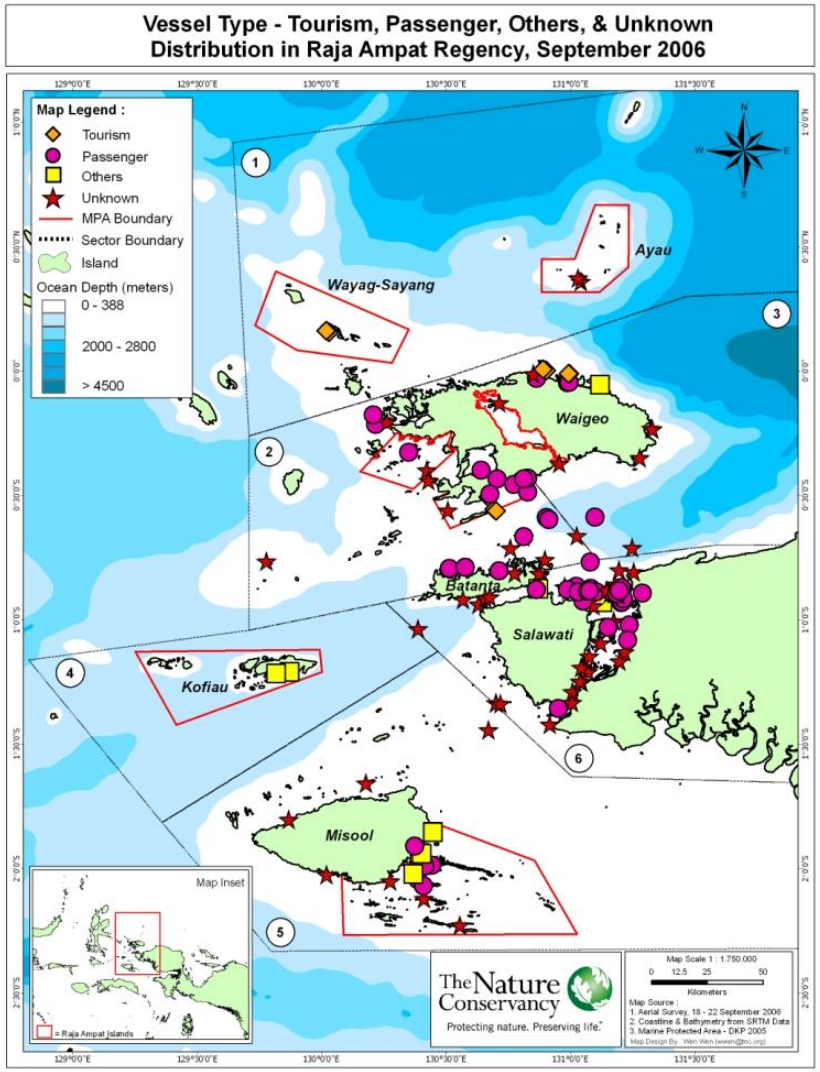

Figure 17. Distribution of tourism, passenger and other vessels in Raja Ampat Regency, from aerial surveys in September 2006.

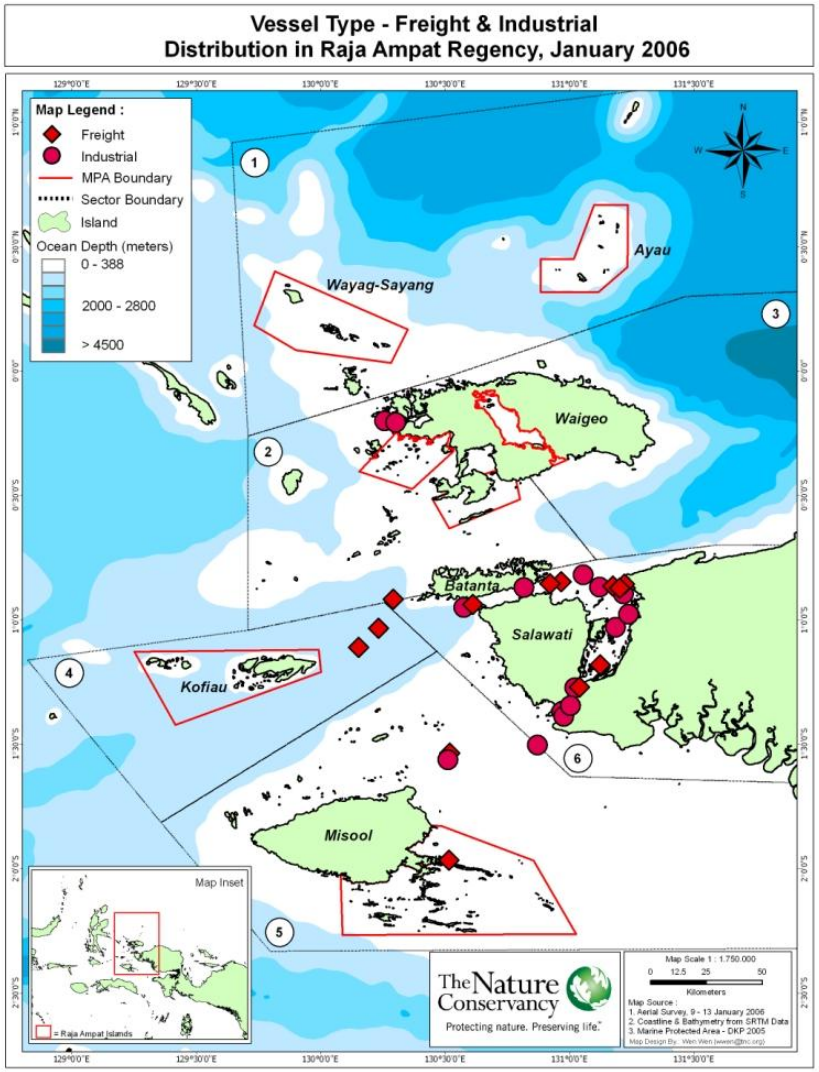

Figure 18. Distribution of freight & industrial vessels in Raja Ampat Regency, from aerial surveys in January 2006.

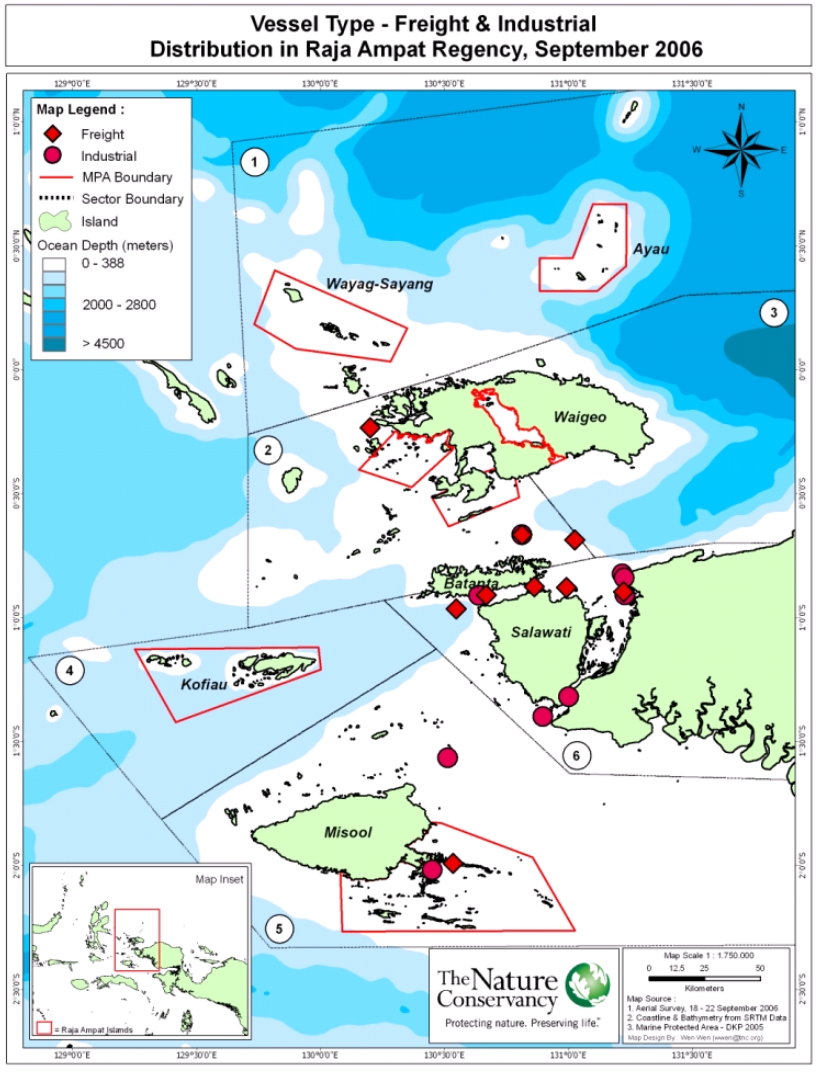

Figure 19. Distribution of freight & industrial vessels in Raja Ampat Regency, from aerial surveys in September 2006.

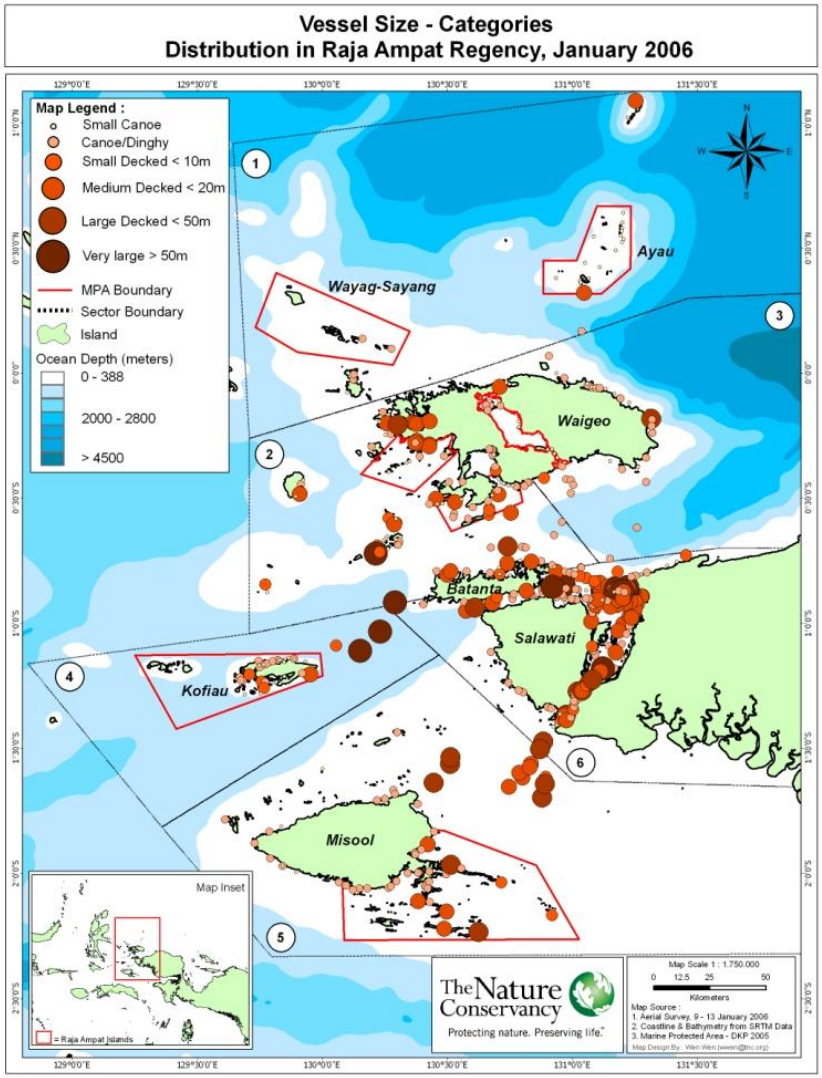

Figure 20. Distribution of vessels of different size in Raja Ampat Regency, from aerial surveys in January 2006.

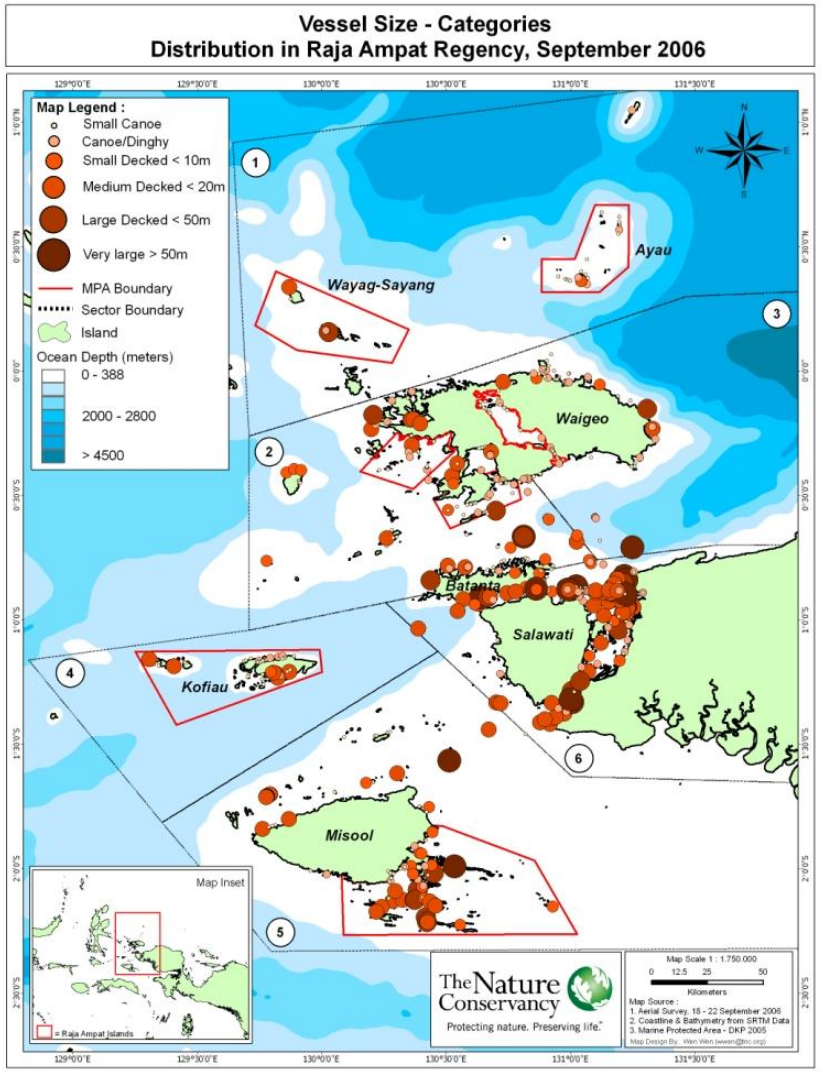

Figure 21. Distribution of vessels of different size in Raja Ampat Regency, from aerial surveys in September 2006.

3.3 FIXED STRUCTURES

Fixed fishing structures recorded during this survey include some types of 'bagan' or lift nets, fish aggregating devices (FADs), fish cages and fishing shelters. 'Other' fixed structures included pearl farms, navigation buoys and oil and gas rigs. Fish shelters and fish cages were the most abundant fixed gears observed during these surveys **(Figure 22)**. The number of fixed structures in Raja Ampat increased by approximately 35% from January to September 2006. It is not possible to determine if the increase reflects a seasonal difference or a general increase in construction of fixed gears.

Bagan

Bagans or lift nets are used in Raja Ampat to target squid or small sardines (or 'Ikan Tri') which are sold either for human consumption or used as bait for other fisheries. The bagan vessels noted under the fixed gear category are floating bagans associated with tuna fishing vessels which use the bagan catch as bait. As such they are not true fixed structures as they can be towed by other vessels to suitable areas as needed. As the bagan method uses light to attract the fish or squid, they operate at night so the position of the observation from daytime aerial surveys is more likely to reflect where the vessel was anchored or its home base. Bagans were seen in the regions of the Dampier Strait, SE Misool and Salawati Straits **(Figure 23, Figure 24, Figure 25, Figure 26)**. Few bagans were recorded in MPAs with the exception of SE Misool **(Figure 24, Figure 25, Figure 26)**. Bagans were more often seen in September than January.

Fish aggregating devices (FAD)

Fish aggregating devices are floating 'rafts' of material which attract and concentrate fish. They are deployed to make it easier for fishermen to catch fish. The location of FADs varied between surveys. In January FADs were concentrated around western Salawati Island with one or two distributed south of Ayau, in Wayag-Sayang, Kofiau and SE Misool **(Figure 23, Figure 24, Figure 27, Figure 28)**. In September, most FADs were seen in SE Misool and Kofiau

'Fish' shelters

Fish shelters are huts built on the beach or on coral reefs and are used as temporary shelters by local fishermen for overnight stays and also as a platform to dry fish. Some shelters are also used as a base for workers on coconut plantations and as storage for coconuts/copra particularly in Kofiau. Shelters are concentrated in the Salawati Straits, Kofiau MPA, southern Waigeo and Teluk Myalibit **(Figure 23, Figure 24, Figure 27, Figure 28)**. The numbers of fish shelters increased from January to September particularly in Salawati Straits and Kofiau MPA **(Figure 23, Figure 24)**. The increase in shelters may reflect increased fishing or agricultural activities in areas remote from villages. As these structures are usually quite strong it is unlikely to reflect a seasonal difference. This may indicate depletion of resources close to the villages and a need to travel further to catch fish. The construction of shelters on top of coral reefs is likely to damage reefs in the local area through construction, shading and disposal of waste including rubbish and sewage.

Fish Cage

Fish cages are used to temporarily store live fish for collection by traders who supply fish such as grouper and Napoleon Wrasse to the live reef fish trade. Cages can vary from small 1-2 m^2 cages maintained by local communities to larger commercial operations. Fish cages are common around the mainland areas of Raja Ampat including Ayau with the exception of Kofiau and Wayag-Sayang **(Figure 29, Figure 30)**. The number of fish cages observed increased by 30% from January to September **(Figure 23, Figure 24)**. It was also noted that

some fish cages observed in January were not observed in September meaning they were either moved or dismantled. Fish cages were observed in four MPAs in Raja Ampat – Ayau, West Waigeo, Dampier and SE Misool **(Figure 29, Figure 30)**. This is of concern as fish cages are usually associated with the live reef fish trade which targets spawning aggregations of target fish species. Fishing of spawning aggregations is inherently unsustainable and may conflict with the conservation and sustainable fisheries objectives of the MPAs

Other Fixed Gears

'Other' fixed gear includes structures such as pearl and seaweed farms, navigation buoys, fish traps such as 'sero' traps and other infrastructure. The number of 'other' gear in January was lower than in September **(Figure 22**, **Figure 23, Figure 24)**. Given the category of 'other' makes up approximately 30% of all observations of fixed gear, it is important to further classify the main classes of fixed gear for future aerial surveys. Pearl and seaweed farms are expanding in Raja Ampat and it is important to document their location and extent. Some fixed gear such as fish traps may also become a trap for large marine species. Villagers around Dampier Strait reported that dugongs and dolphins were occasionally trapped inside the fixed gears and were likely consumed by the locals or sold to outsiders (Rotinsulu, pers. comm.).

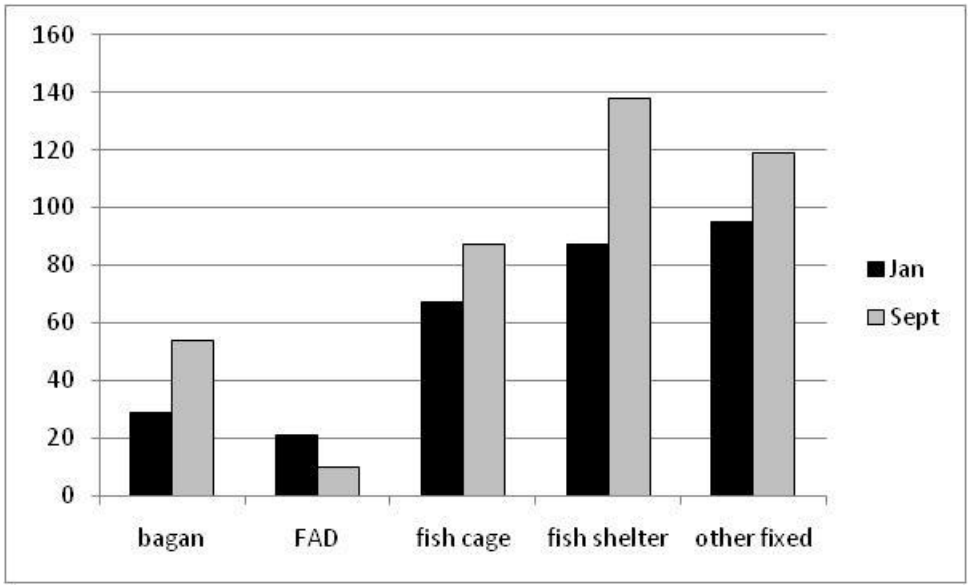

Figure 22. Frequency of observations of fixed structures in Raja Ampat in 2006 from aerial surveys.

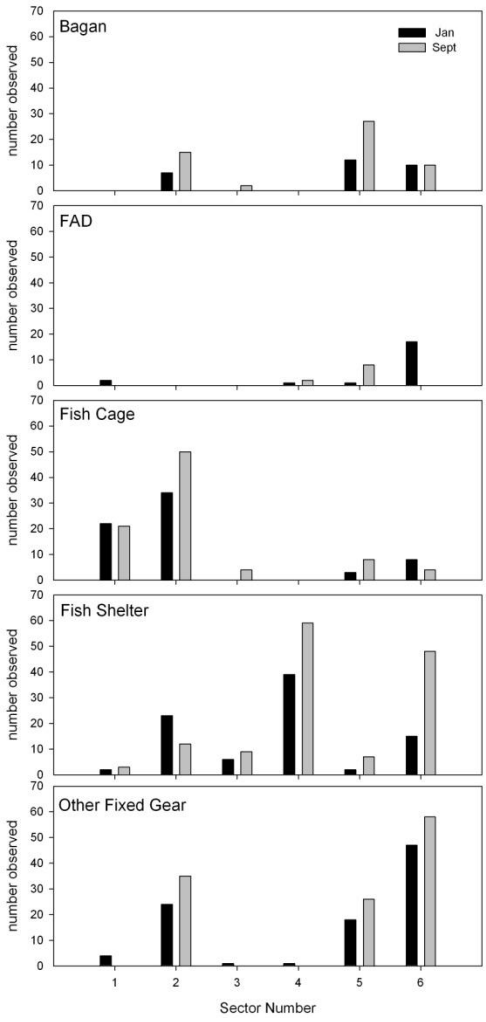

Figure 23. Frequency of fixed gears in each sector of Raja Ampat 2006.

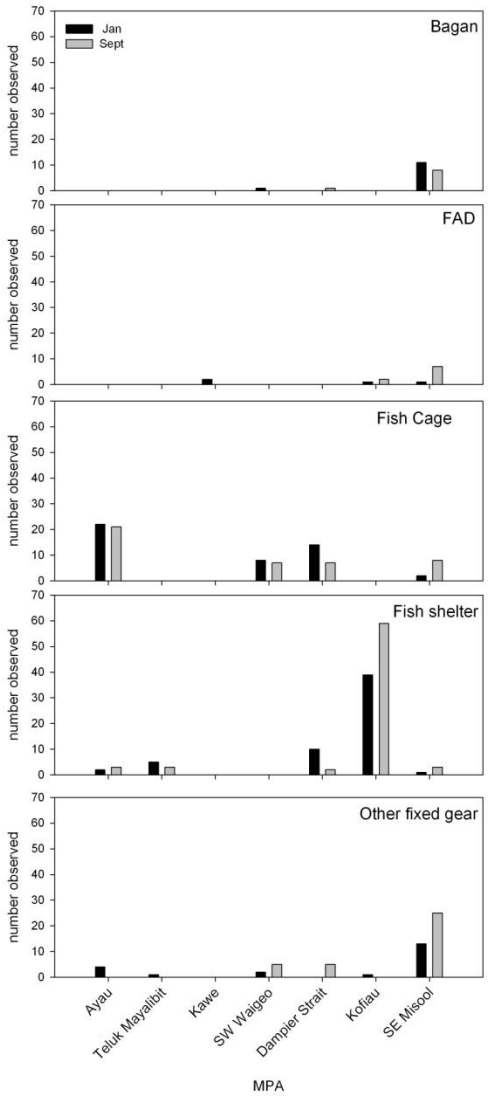

Figure 24. Frequency of fixed gears in each MPA in Raja Ampat 2006.

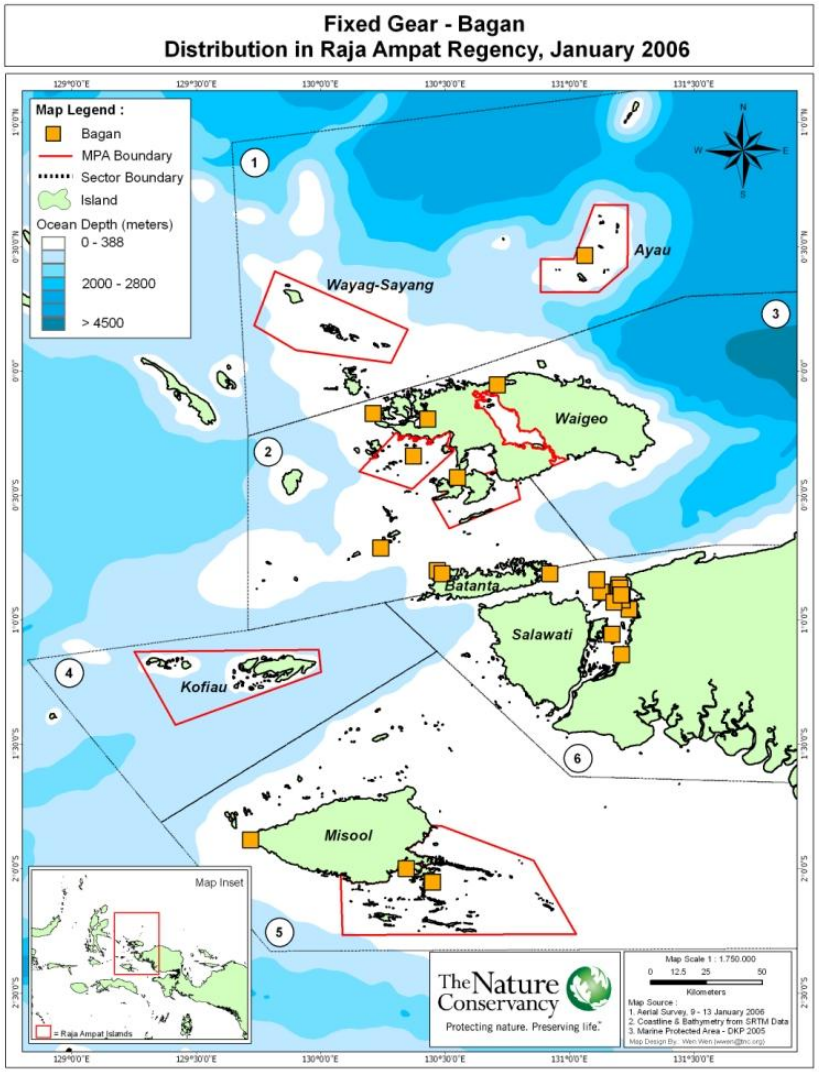

Figure 25. Distribution of bagan in Raja Ampat Regency, from aerial surveys in January 2006.

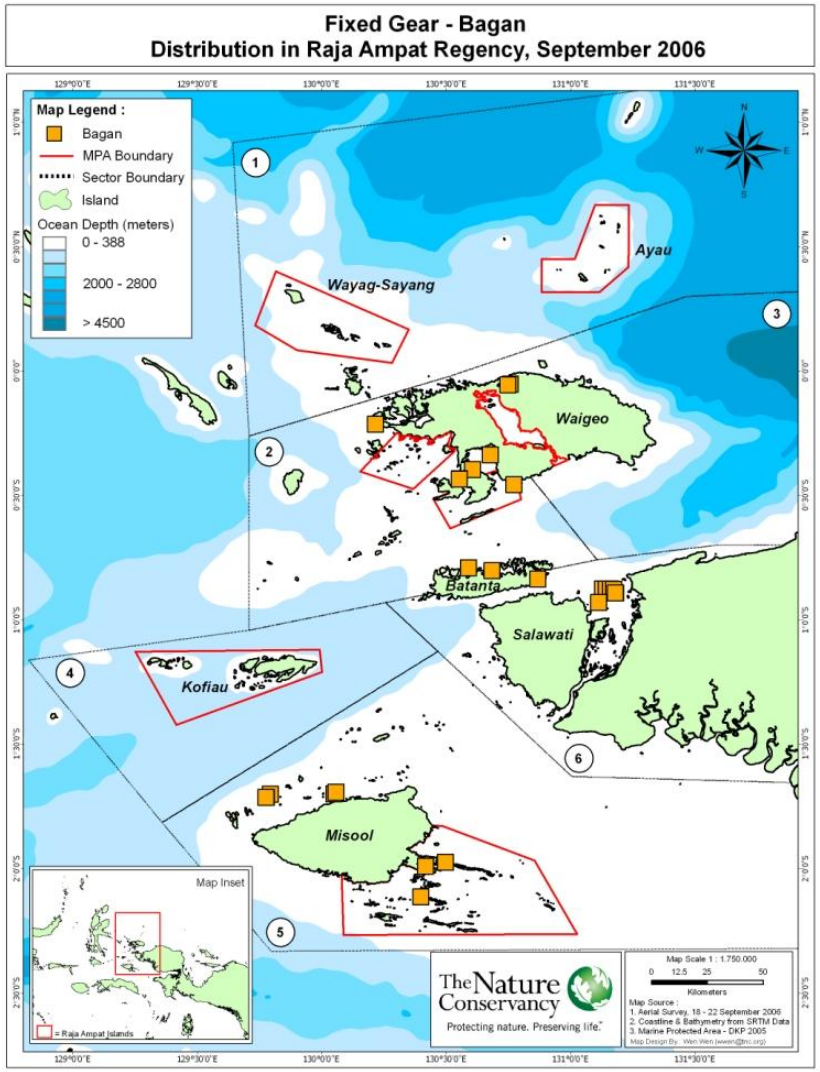

Figure 26. Distribution of bagan in Raja Ampat Regency, from aerial surveys in September 2006.

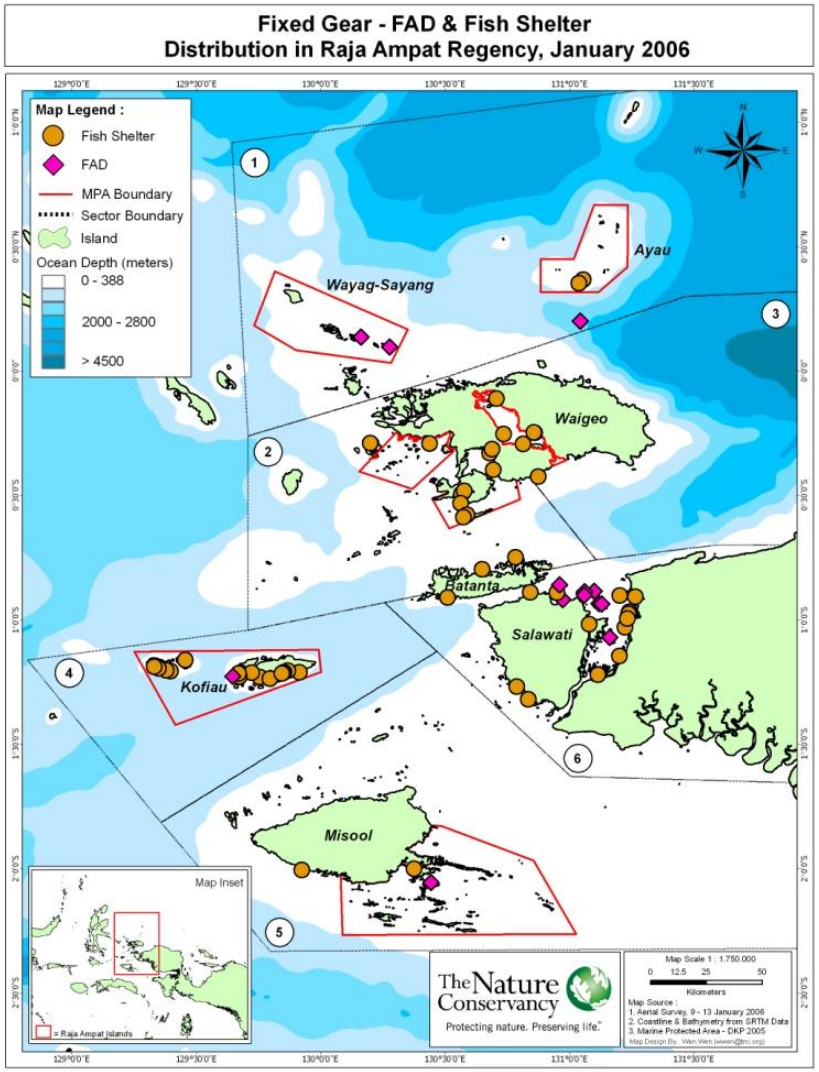

Figure 27. Distribution of FAD (fish aggregating devices) and fish shelters in Raja Ampat Regency, from aerial surveys in January 2006.

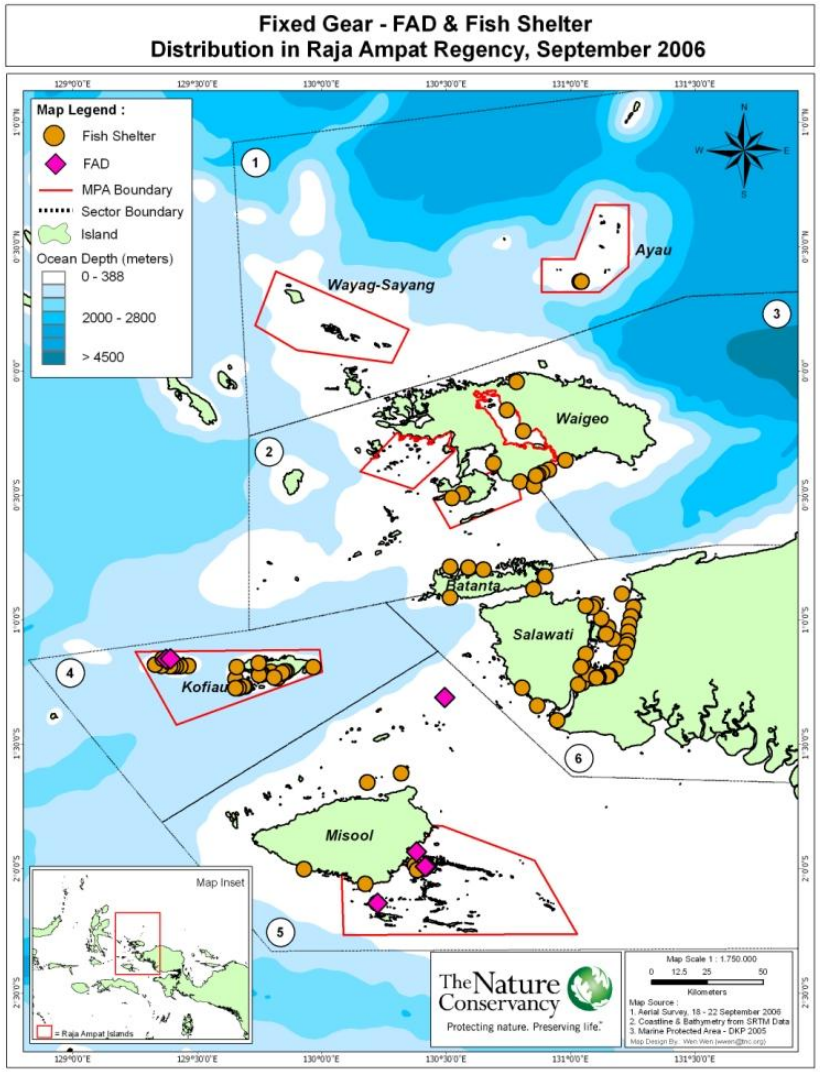

Figure 28. Distribution of FAD (fish aggregating devices) and fish shelters in Raja Ampat Regency, from aerial surveys in September 2006.

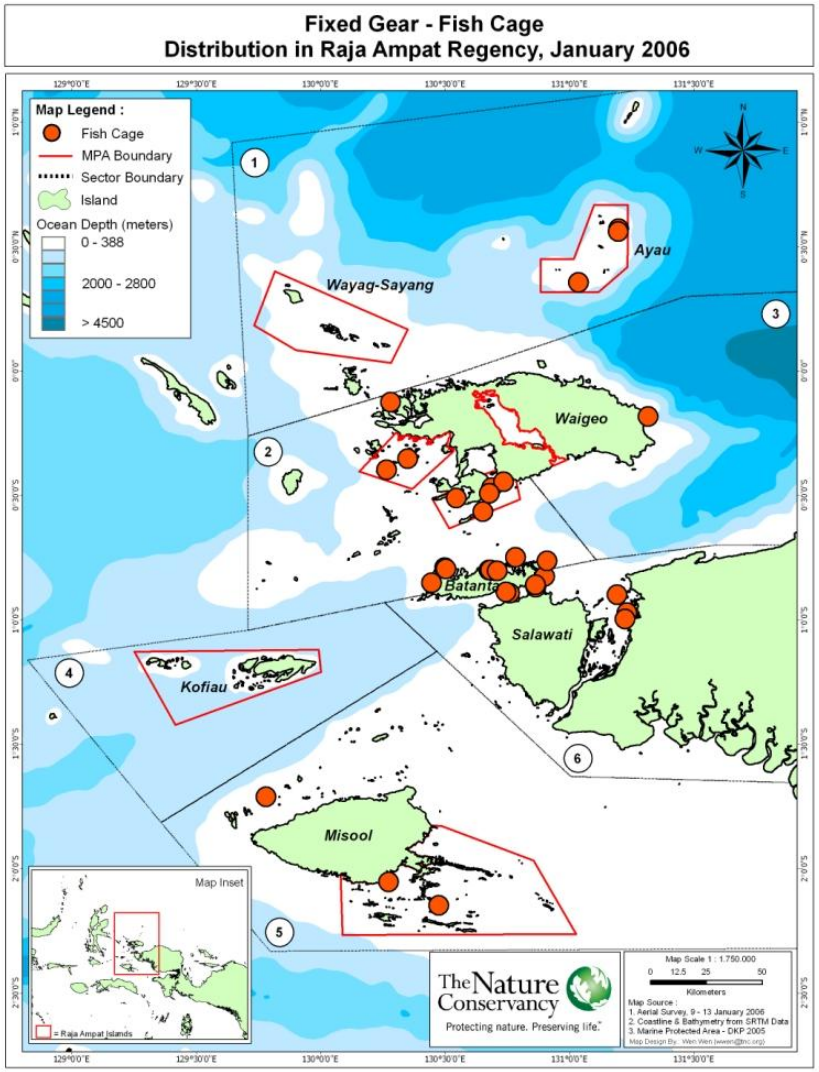

Figure 29. Distribution of fish cages in Raja Ampat Regency, from aerial surveys in January 2006.

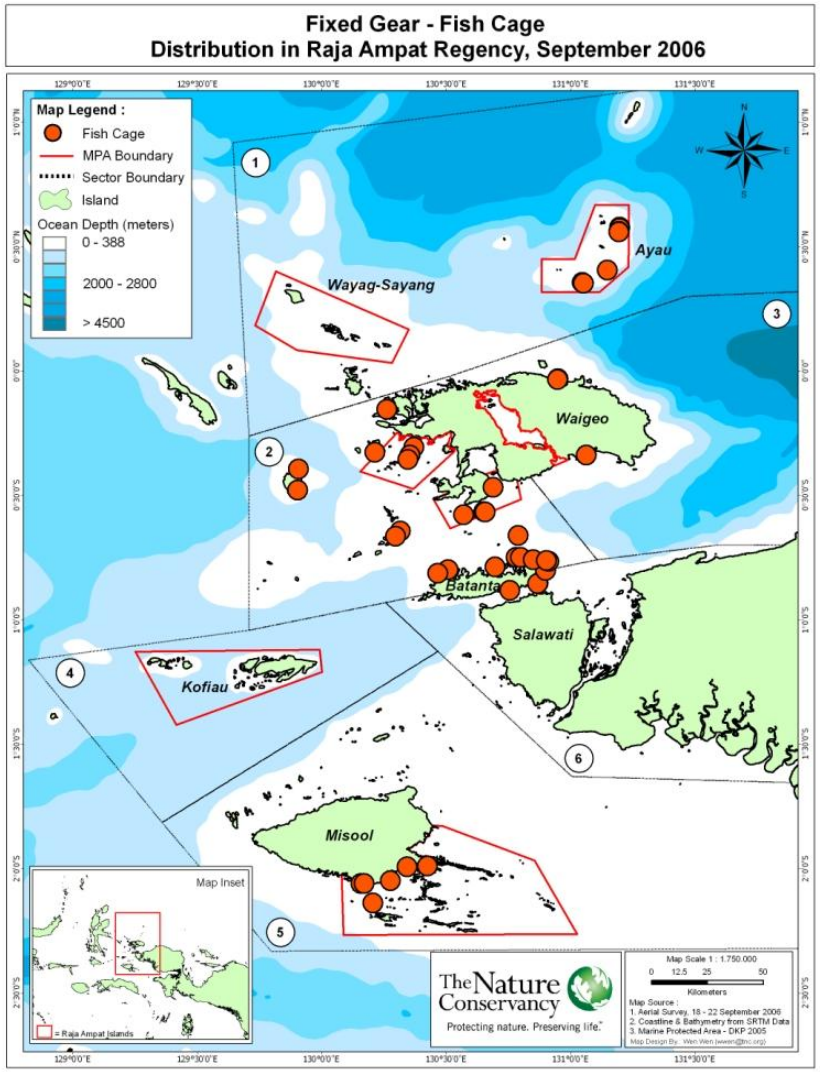

Figure 30. Distribution of fish cages in Raja Ampat Regency, from aerial surveys in September 2006.

3.4 BIOTA

Large marine biota recorded during aerial surveys included whales, dolphins, dugongs, manta rays, turtles and sharks. In addition, aggregations of sardines/pilchards or 'bait balls' were noted and were often associated schools of tuna or aggregations of birds which were feeding on them. The number observed and the distribution of the main taxa are reported, however it should be noted that these surveys are not designed for, nor intended to provide population estimates for large marine biota. These data do show that Raja Ampat is an important region for a diverse assemblage of large marine biota many of which are vulnerable or endangered and identify particular areas and seasons which are particularly important **(Figure 31- Figure 44)**. However large marine biota are highly mobile and their occurrence in a particular place may be related to tidal factors or ephemeral upwellings or areas of high productivity. Therefore the distributions shown in the maps should be considered in that context.

Whales/Dolphins

Whales/dolphins were widespread throughout Raja Ampat with concentrations around southern Waigeo Is, the straits between Salawati and Batanta Islands, Kofiau and small islands off the north coast of Misool Island **(Figure 31 - Figure 34)**. The number of whales and dolphins sighted in January (629) was much higher than for September (241) and the largest pods were seen in January **(Figure 33, Figure 34)**. This strong seasonality in cetacean numbers indicates Raja Ampat is used by cetacean species as a migratory pathway, and or seasonal feeding or breeding ground. The strongest seasonal trend is seen at Kofiau MPA which had the highest count of whales/dolphins of all MPAs in January but no sightings in September. As whales and dolphins were recorded as a single category, it is not possible to analyze these data further to separate whales from dolphins or identify specific species consistently throughout the data set. However details in the 'comments' section of the data base and from aerial photos taken during the surveys indicate the presence of Indo-Pacific humpback dolphins and killer or false killer whales in Raja Ampat. This information can be used as a basis to develop hypotheses or further more detailed studies of the cetaceans of Raja Ampat.

Mantas

Manta rays were seen in a few specific locations in Raja Ampat around Ayau, Dampier Strait and southern Misool. Numbers were higher in January (113) than September (19) and the largest aggregation of approximately 50 animals was seen in Dampier MPA in January **(Figure 31, Figure 32, Figure 35, Figure 36)**. In September more than half the manta rays observed were seen in Ayau MPA **(Figure 36)**. Manta ray aggregations are highly ephemeral as they respond to tidal currents and areas of upwelling/high productivity.

Dugongs

Dugongs were relatively widely distributed around the main islands of Raja Ampat with similar numbers seen in January (30) and September (31) **(Figure 31, Figure 32, Figure 37, Figure 38)**. Dugongs were commonly seen close to the coast around Salawati and Batanta Islands, east Waigeo Island, Dampier Strait and northern Misool. One dugong was seen at Kofiau MPA in September 2006. The larger groups of dugongs (5-10 animals) were seen in eastern Waigeo and western Salawati Islands.

Turtles

Turtles were seen in coastal regions throughout Raja Ampat from Asia atoll in the north to SE Misool MPA in the south. Turtles were usually solitary or in small groups of 2-5. Numbers were higher in January (68) than September (20) **(Figure 31, Figure 32, Figure 39, Figure 40)**.

Sharks

A total of 17 sharks were seen during the aerial surveys but it is not expected that aerial surveys are an effective method for detecting and counting sharks. Approximately half the sightings were made in Ayau MPA in September with the remainder around Salawati and Batanta Islands, SW Waigeo and eastern Waigeo **(Figure 31, Figure 32, Figure 41, Figure 42)**.

Bait School /Tunas

Schools of bait fish and associated predators such as tuna were seen throughout Raja Ampat with higher numbers of bait schools seen in January (92) than September (40) **(Figure 31, Figure 32, Figure 43, Figure 44)**. In January, bait schools were concentrated in central Dampier Straits and South-west Waigeo Island and southern Raja Ampat around Misool Island and waters between Misool and Salawati Island). In September most bait schools were seen along the coastline in the eastern, southern and western sides of Waigeo Island.

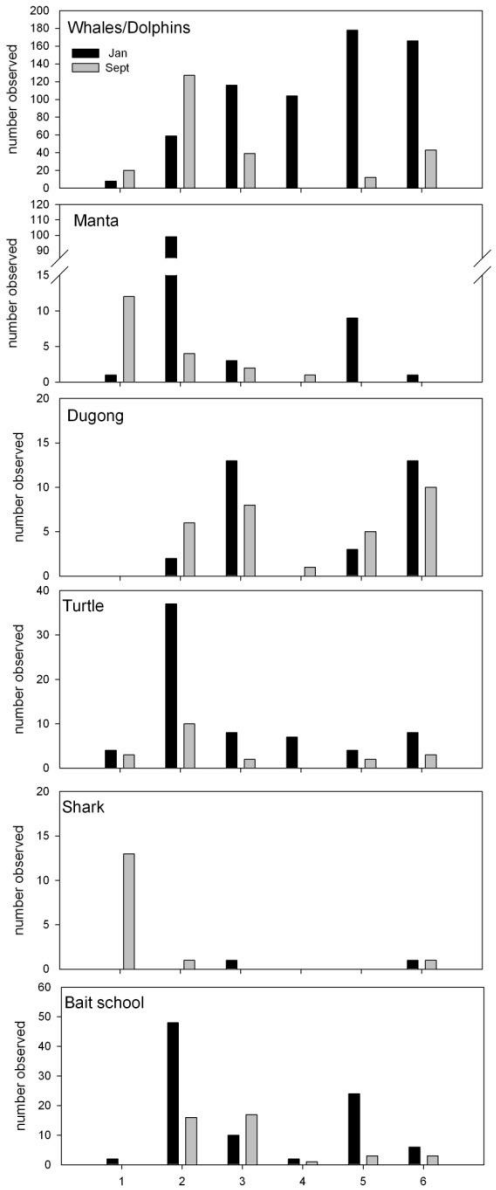

Figure 31. Numbers of all biota per sectors

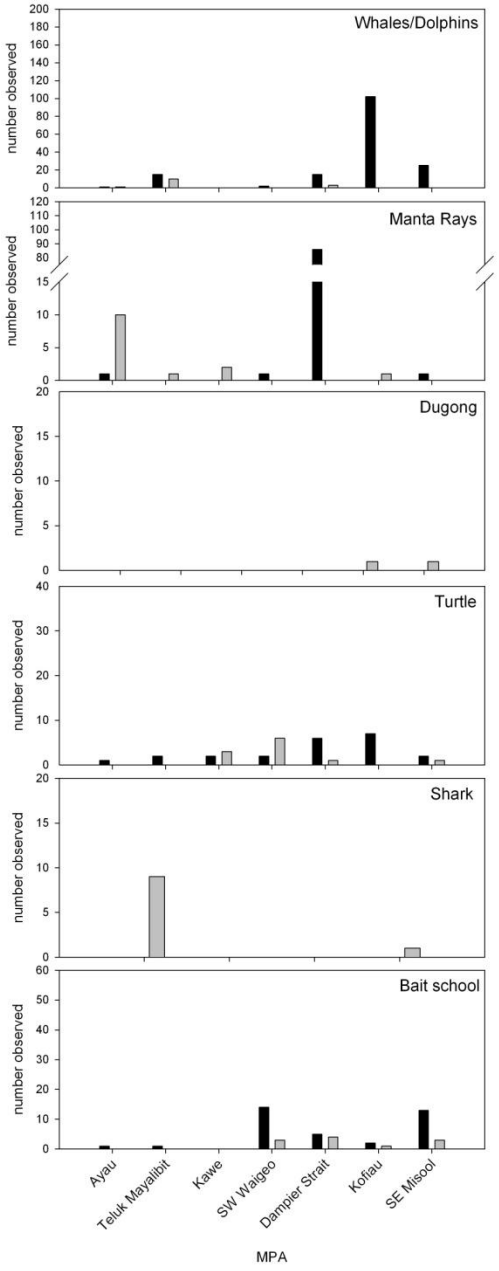

Figure 32. Numbers of all biota per MPAs

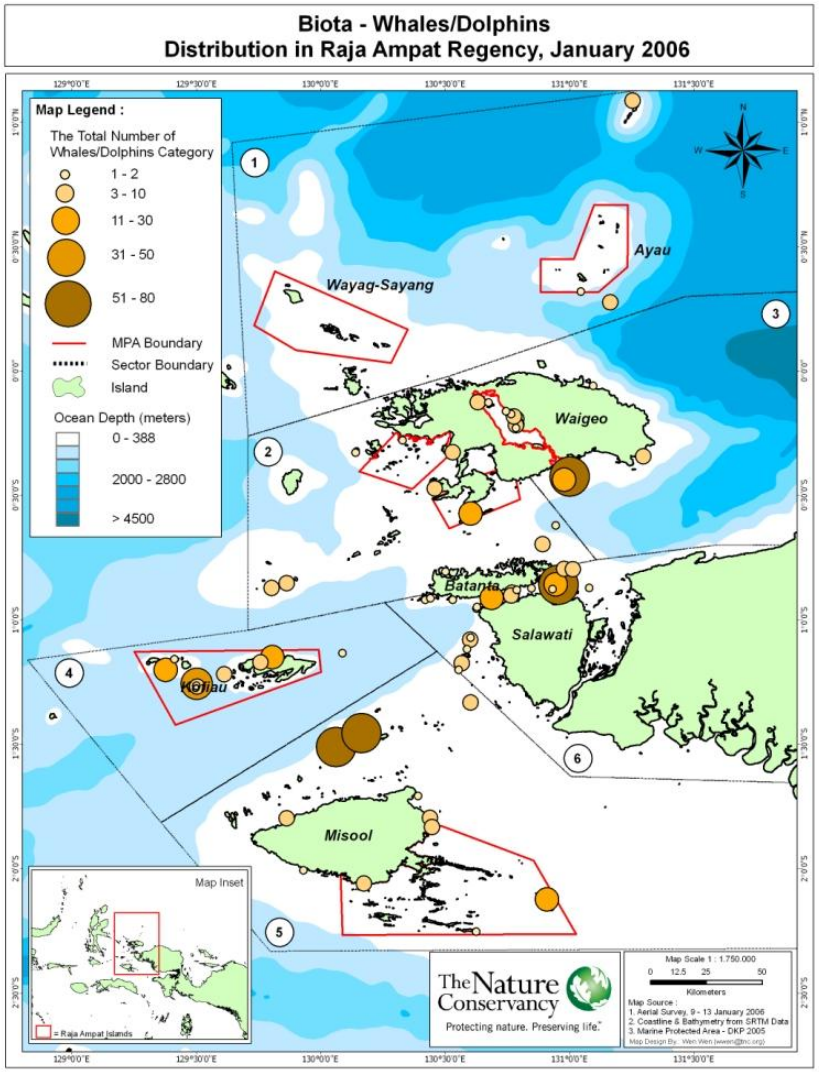

Figure 33. Distribution of whales and dolphins in Raja Ampat Regency, from aerial surveys in January 2006

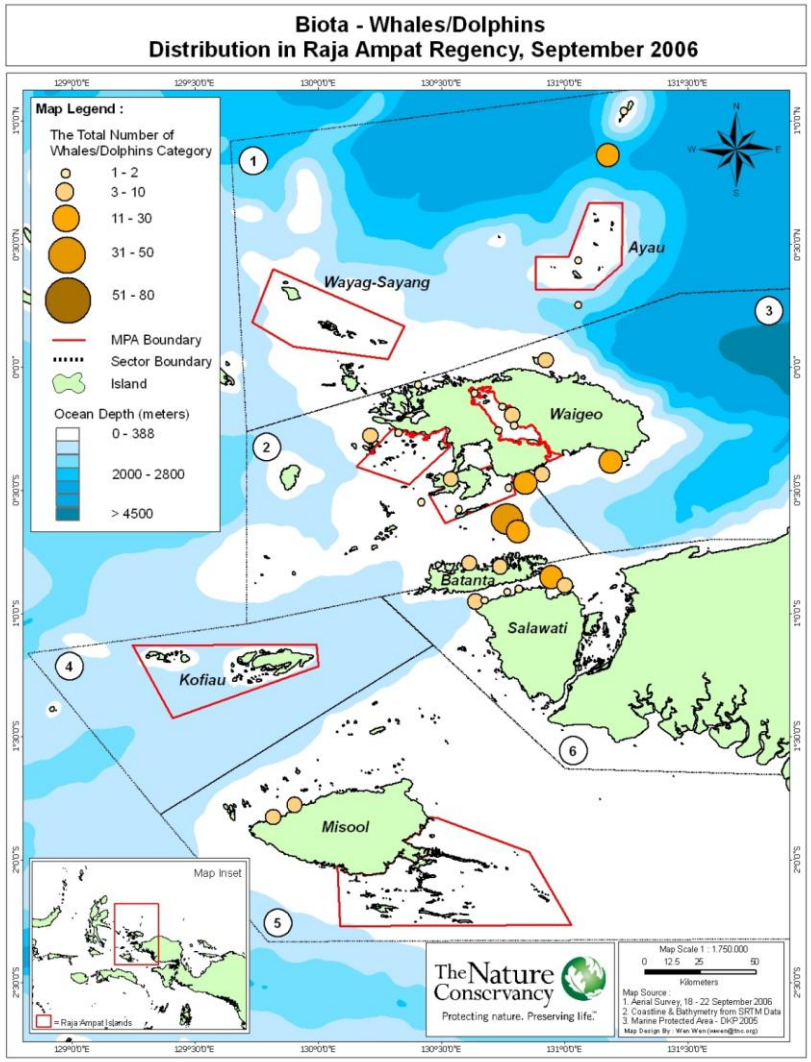

Figure 34. Distribution of whales and dolphins in Raja Ampat Regency from aerial surveys in September 2006

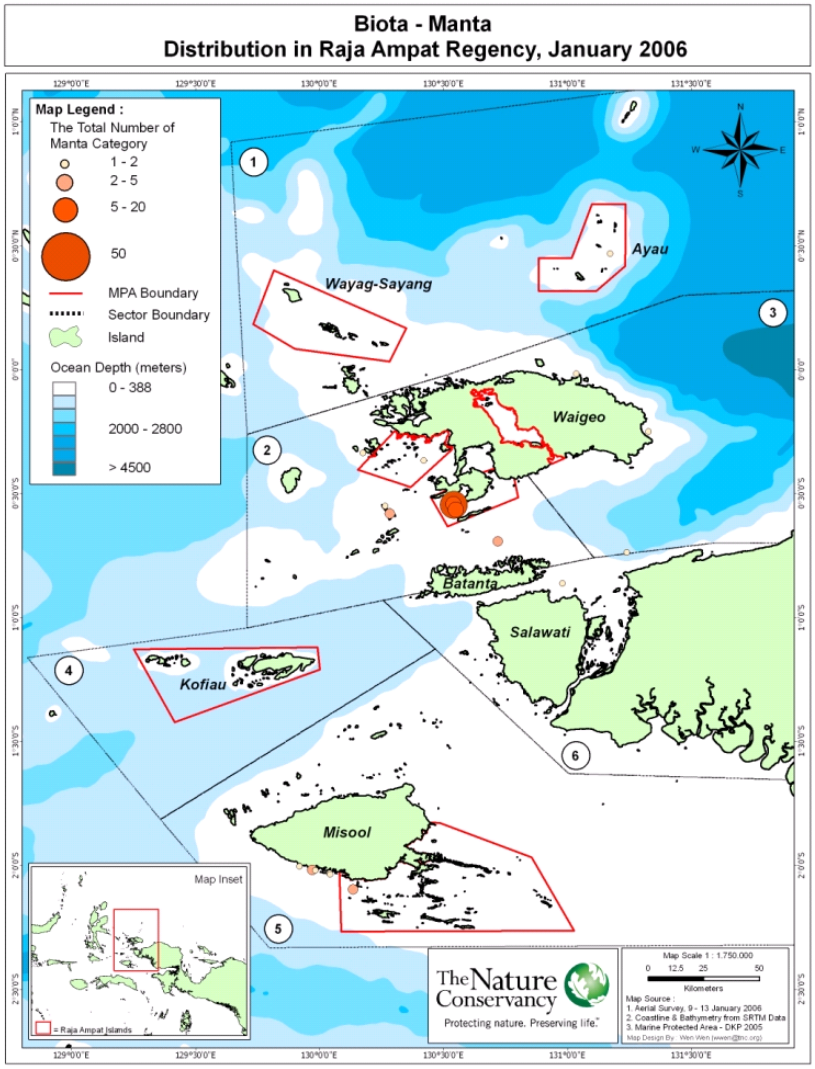

Figure 35. Distribution of manta rays in Raja Ampat Regency from aerial surveys in January 2006

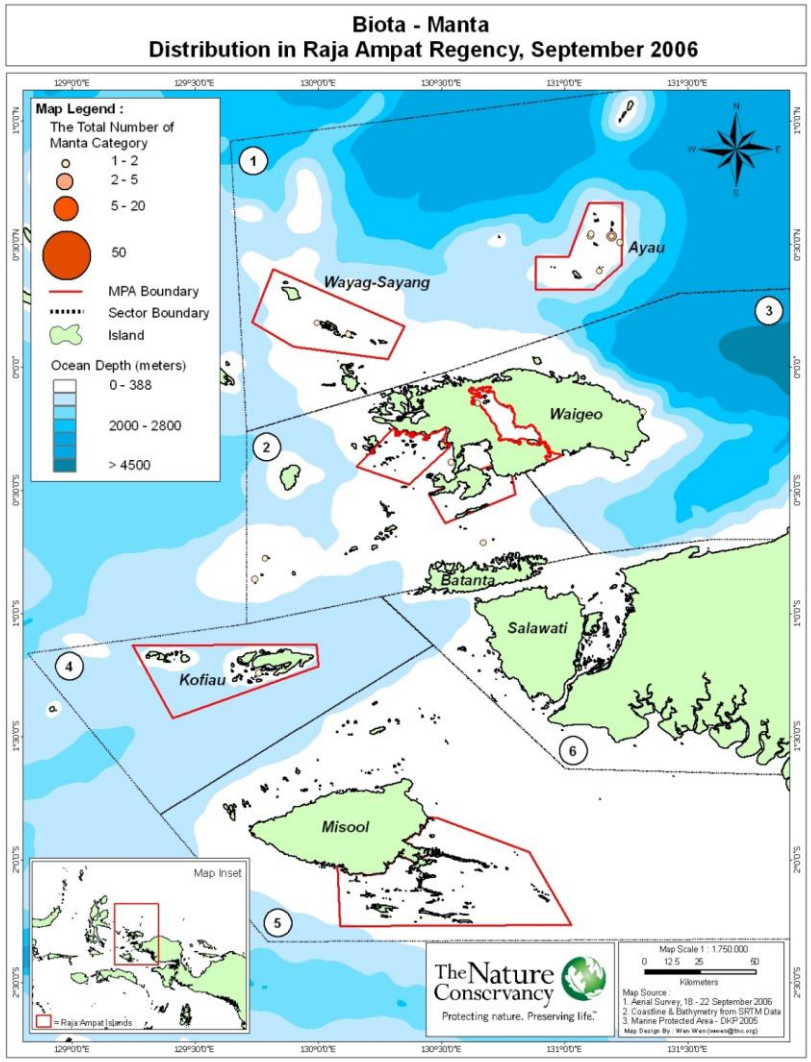

Figure 36. Distribution of manta rays in Raja Ampat Regency from aerial surveys in September 2006

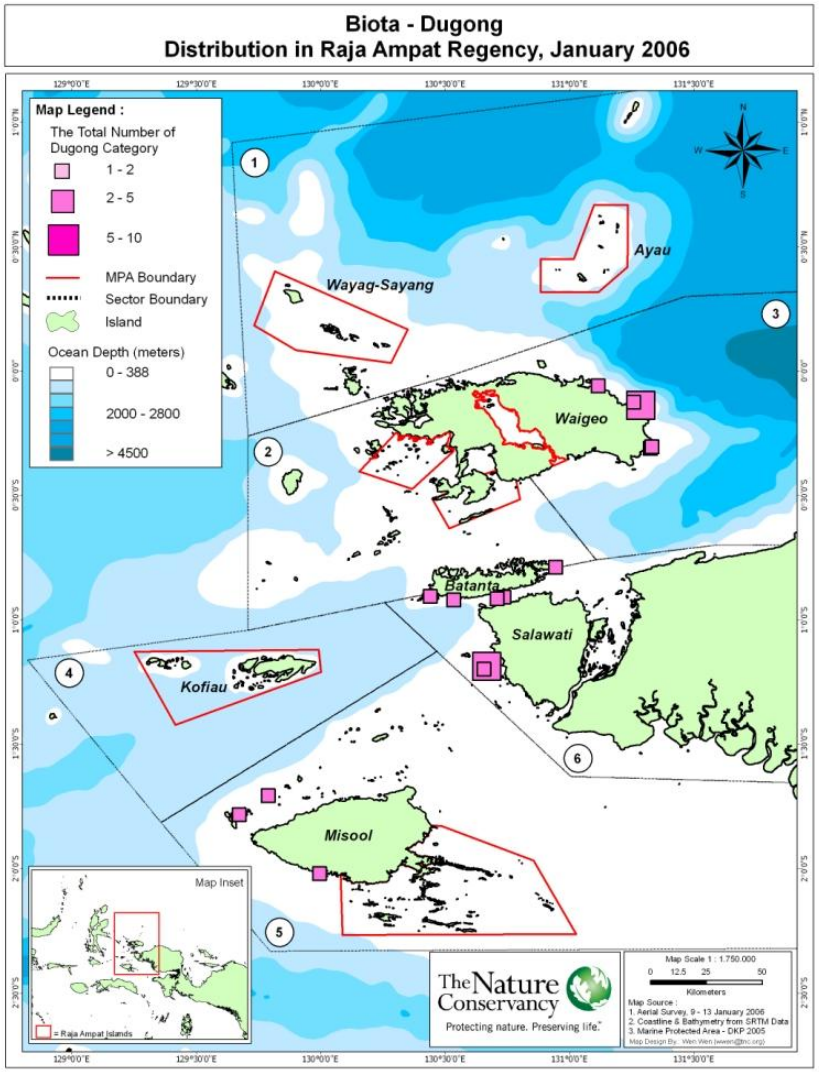

Figure 37. Distribution of dugong in Raja Ampat Regency from aerial surveys in January 2006

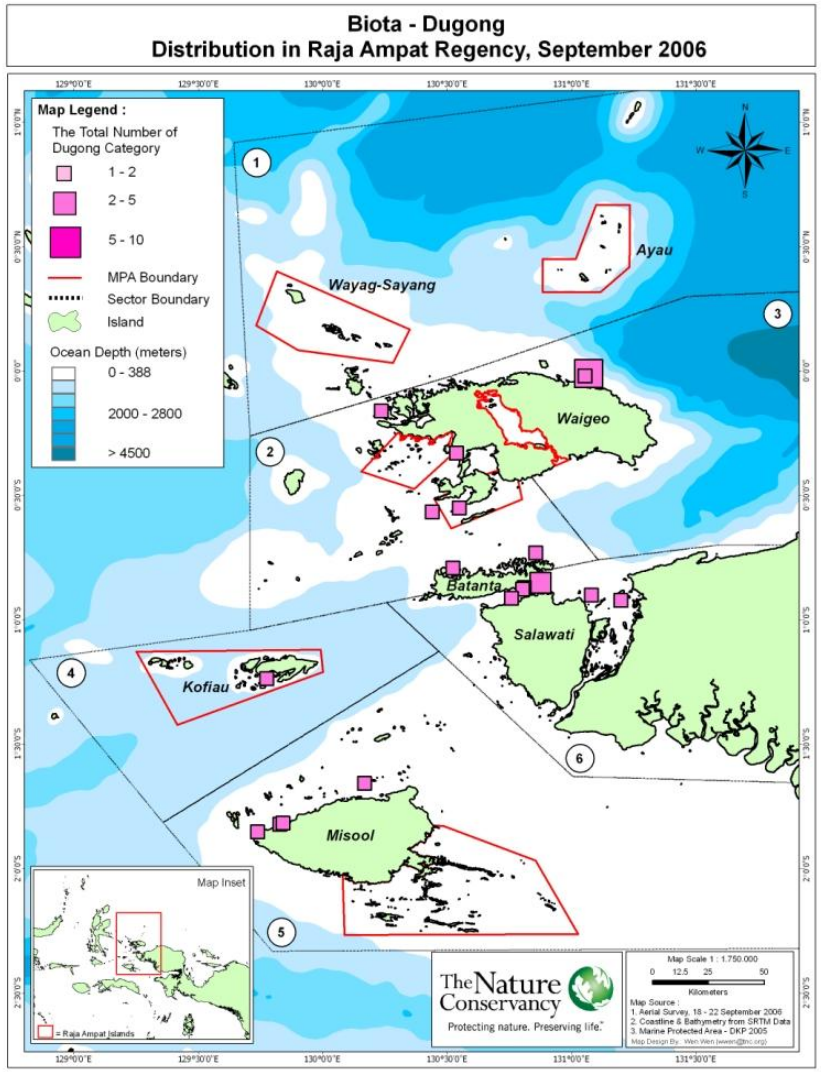

Figure 38. Distribution of dugong in Raja Ampat Regency from aerial surveys in September 2006

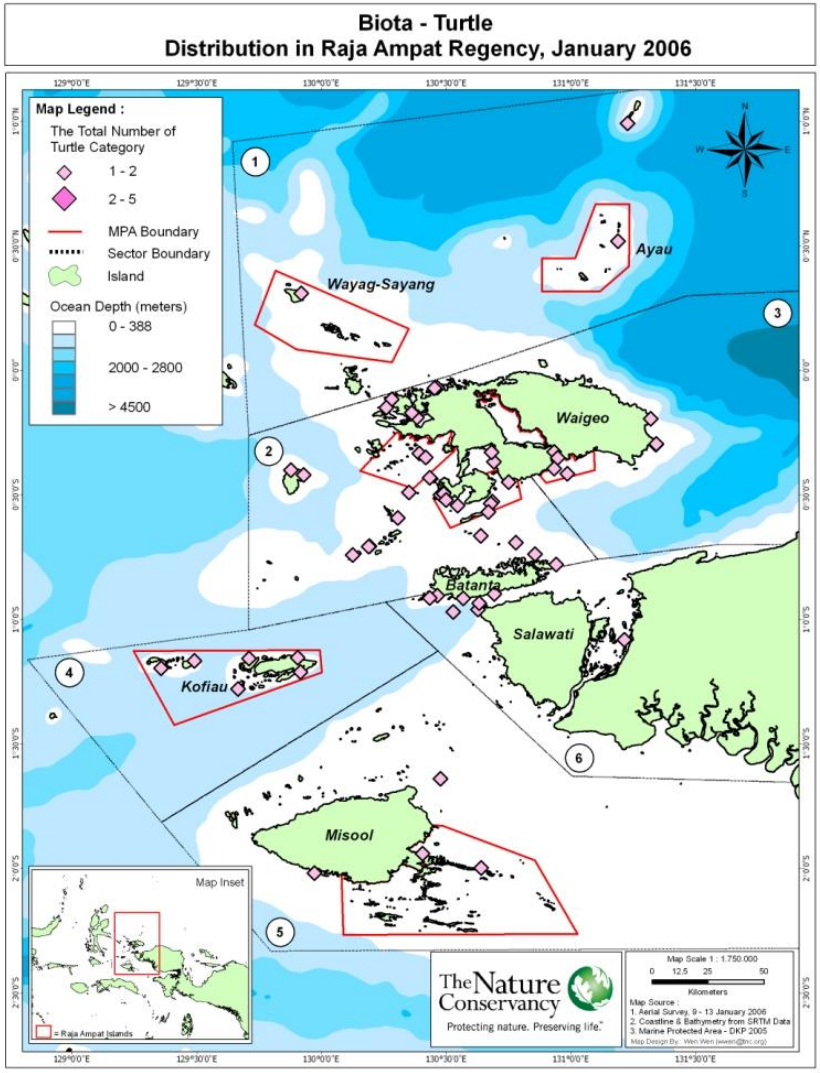

Figure 39. Distribution of turtles in Raja Ampat Regency from aerial surveys in January 2006

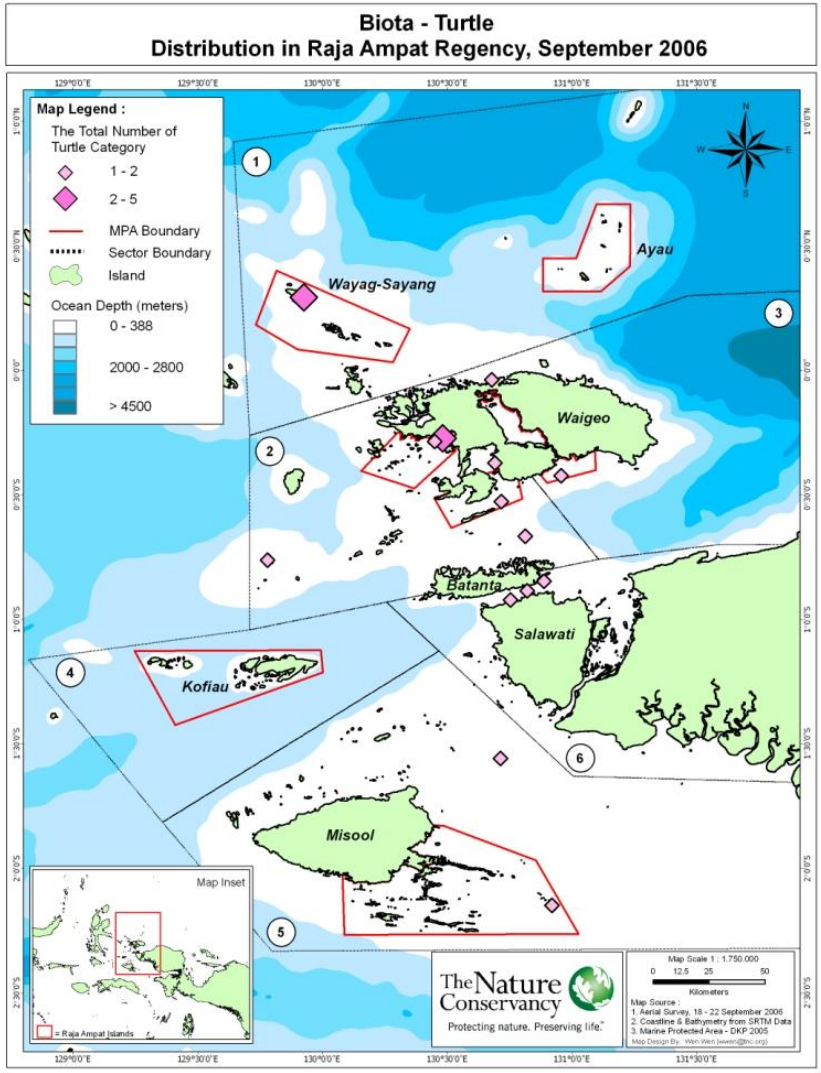

Figure 40. Distribution of turtles in Raja Ampat Regency from aerial surveys in September 2006

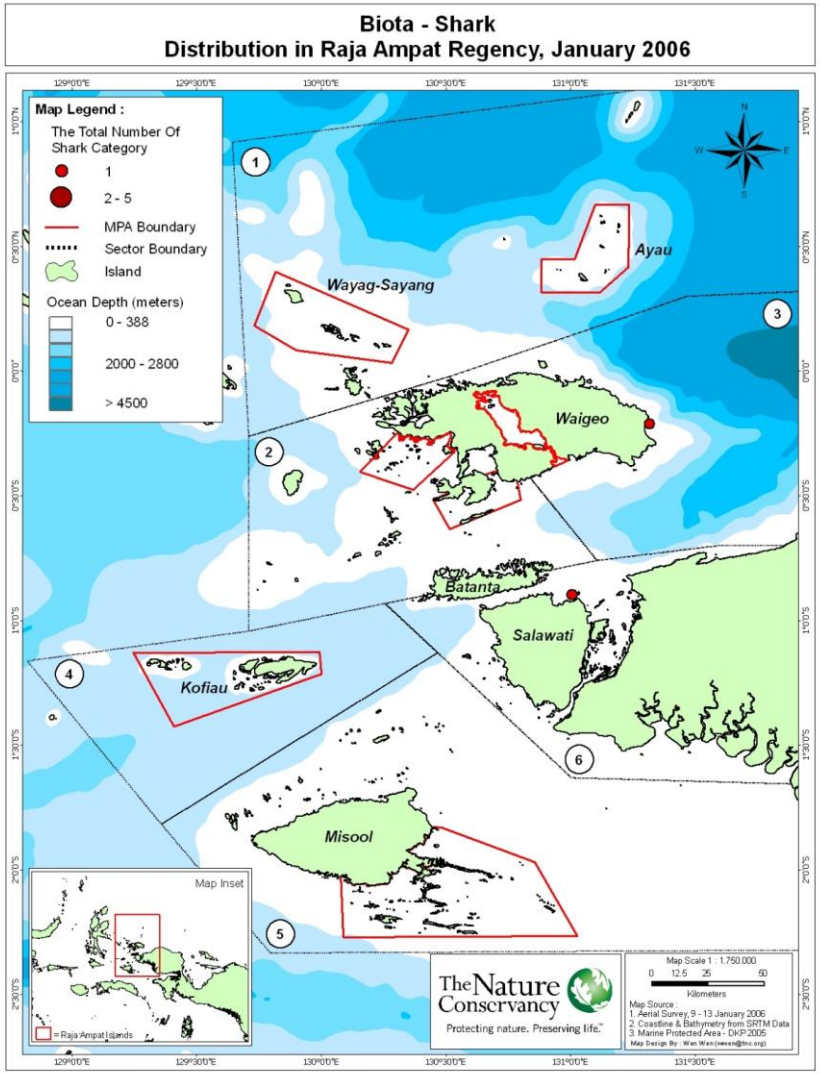

Figure 41. Distribution of shark in Raja Ampat Regency from aerial surveys in January 2006

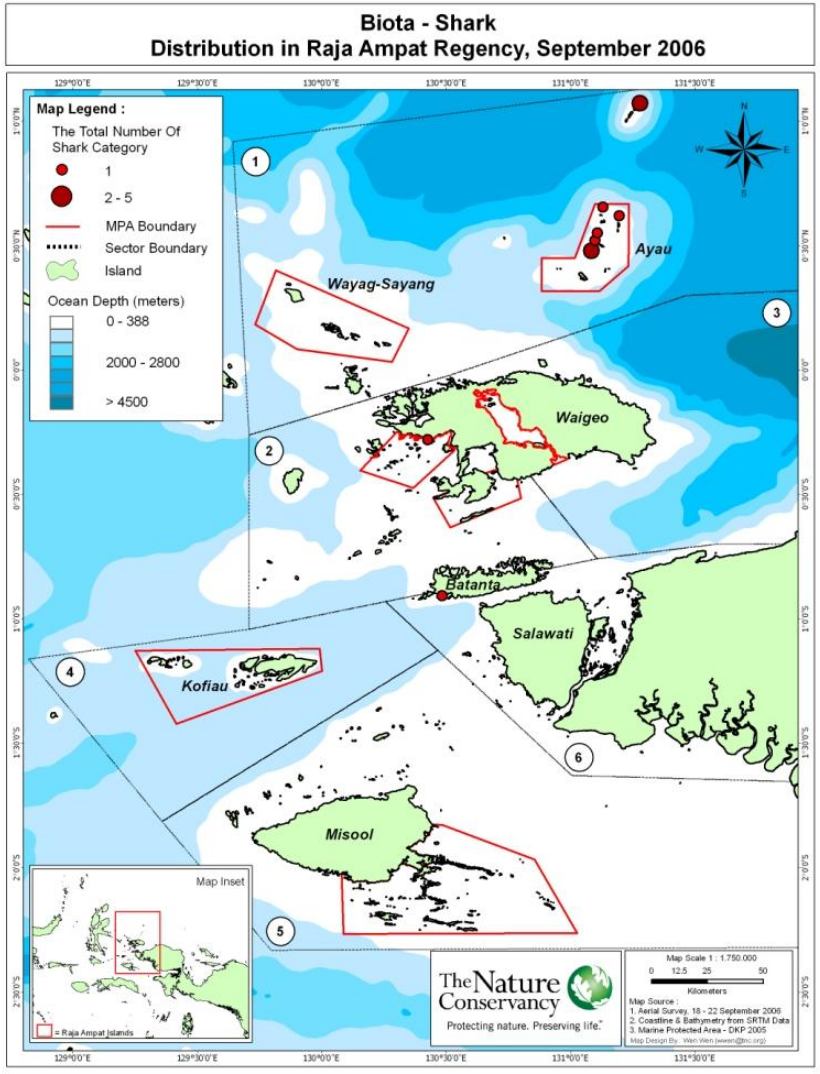

Figure 42. Distribution of shark in Raja Ampat Regency from aerial surveys in September 2006

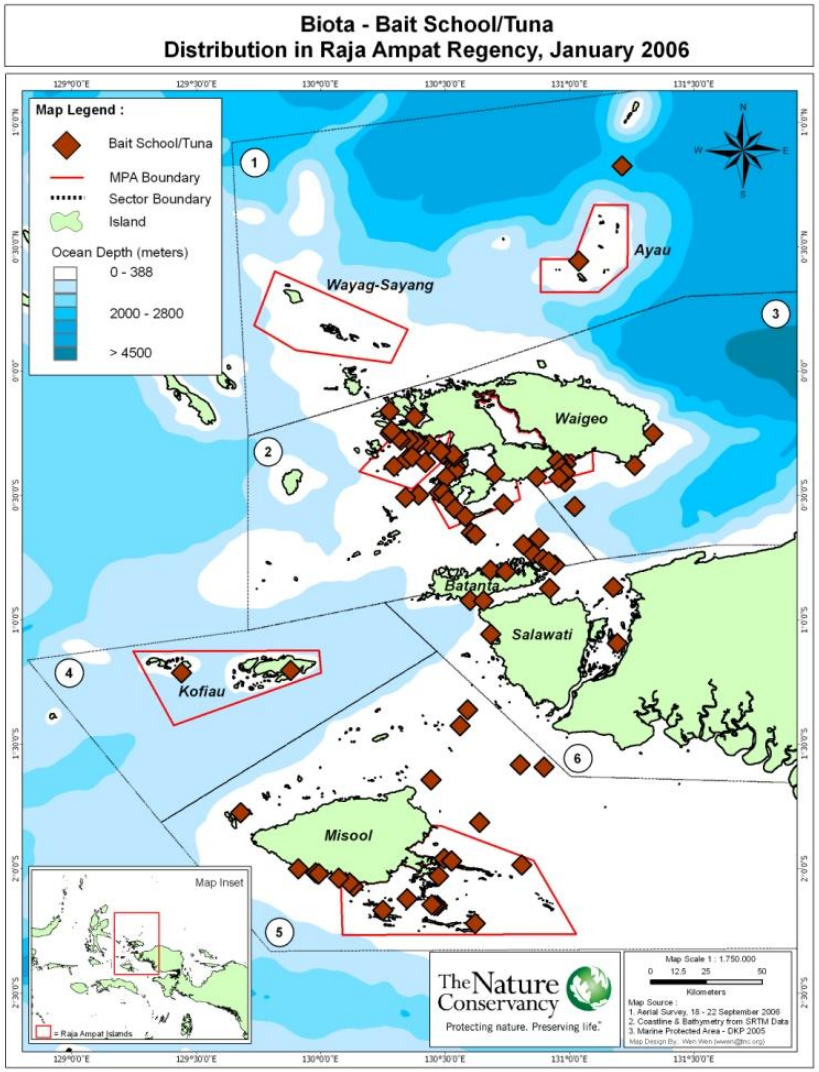

Figure 43. Distribution of bait schools in Raja Ampat Regency from aerial surveys in January 2006

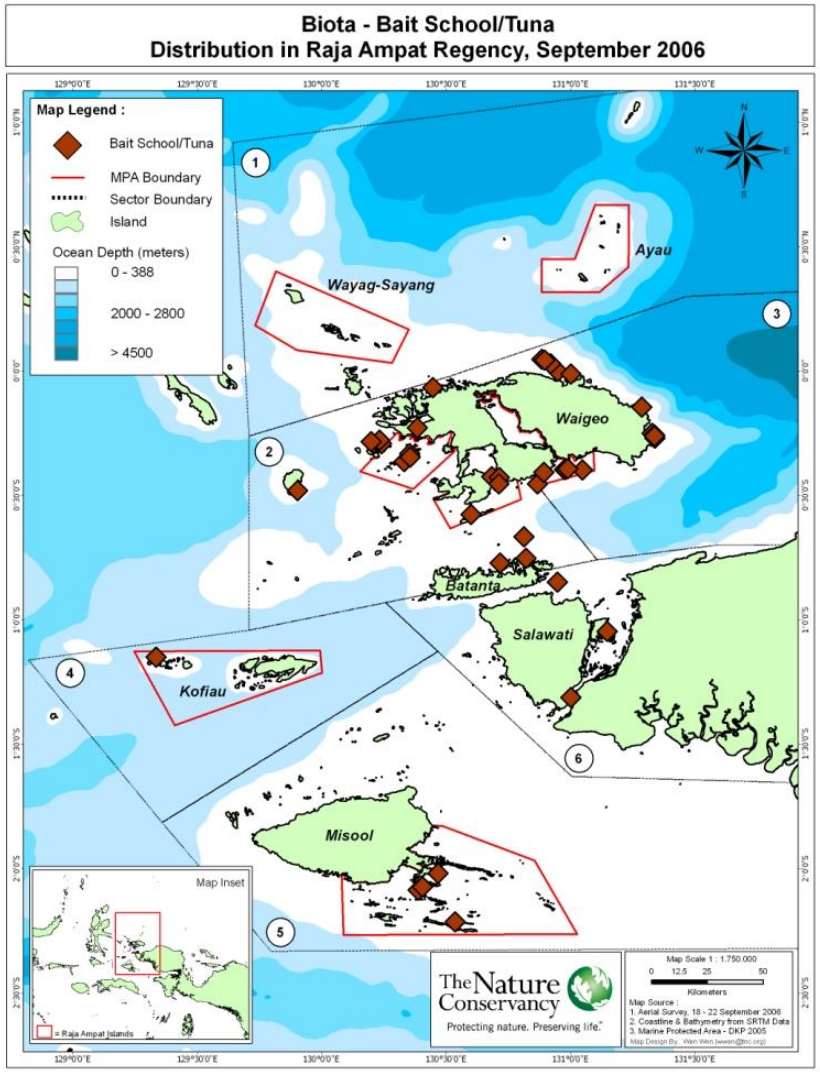

Figure 44. Distribution of bait schools in Raja Ampat Regency from aerial surveys in September 2006

4 DISCUSSION

This study has shown that aerial surveys are an effective method for obtaining detailed information on patterns of resource use including vessels operating in the area, fixed structures associated with fishing and aquaculture, and large marine fauna across a large remote area. The flight path for this study focussed on the coastal areas, islands, offshore reefs and marine protected areas where it was anticipated most use would occur. These observations in January and September 2006 provided the first comprehensive snpashot of coastal resource use throughout Raja Ampat. It is difficult to determine if differences between January and September are due to seasonal patterns, weather/tidal conditions at the time of the surveys or longer terms trends.

These surveys provided valuable information on the distribution and characteristics of resource users and their location both inside and outside MPA boundaries as at 2006. This information has been used in the development of MPA management and zoning plans, marine spatial plans, fisheries strategies and coastal management plans.

Marine resource use was described by the size, type and activity of vessels. In most cases, small canoes could be seen clearly and counted accurately. In 2006, the majority (>75%) of vessels seen were small fishing boats – canoes with small or no engines. This demonstrates a high level of use of coastal marine resources by local communities for artisinal fisheries. Boat based surveys in Raja Ampat of resource users in Kofiau MPA however show that while local fishers comprise the majority of participants in the fisheries (up to 90%), the majority of the catch (up to 80%) is taken by a few large boats which are usually originate from other areas of Indonesia especially Maluku and Sulawesi (Muljadi et al. 2009). Therefore assessment of the patterns of size and activities of vessels is important as small increases in the number of large vessels is likely to mean a significant increase in fish catches with little benefit to local communities.

The area with the highest number of large fishing vessels recorded during this survey (not counting Sorong Harbour) was western Waigeo and Dampier Strait and waters around Misool reflecting their proximity to the main centers of population. The MPA with the largest number of large fishing vessels is SE Misool. Local field teams and communities report that the area is often used by illegal long line fishing vessels who come from Maluku to the south and often with the permission of local communities but without required licences from the local fisheries agency. Local teams are now working closely with local communities and enforcement agencies to patrol the area more frequently.

In 2006, relatively low numbers of dive live-aboards were recorded in Raja Ampat but over the past five years, the number of dive live-aboards operating in Raja Ampat has increased significantly. In 2010 there were more than 20 dive live-aboard operators working regularly or permanently in Raja Ampat.

Most of the fixed gear structures recorded in this survey are fishing gears (FADs, fish cages, traps, bagan) or support fishing activities (fish shelters). Exceptions to this are infrastructure associated with aquaculture and oil and gas industries. The gears associated with fishing are largely unregulated i.e. they do not require a permit. However a significant amount of fish are likely to be caught by these structures or using these structures as support for fishing activities in remote areas (Bailey et al. 2008). Understanding the number, location and type of fixed gears is important in understanding the true amount of fishing effort in Raja Ampat and can be used as a basis for any future licencing or quota system to regulate these fishing gears. It

also serves as a baseline against which to compare future survey data. The number of all fixed structures except FADs increased between January and September. It is not known if this is a seasonal pattern or indicative of a longer term general increase in these structures in Raja Ampat but demonstrate the potential risk of expansion of these unregulated fishing gears and therefore increases in fishing effort

The observations of large marine fauna including dolphins, whales, dugongs, turtles and manta rays have significantly increased our understanding of the occurrence and distribution of these species in Raja Ampat. While the surveys was not designed to obtain population estimates of these species, the sightings have identified important aggregation areas and migratory pathways for particular species. These areas can then be targetted for further studies in the future. These observations have further confirmed that Raja Ampat is an important area for a diverse assemblage of cetaceans and other large fauna including species listed as endangered and threatened (Kahn, 2007, IUCN 2010). The relatively large number of sightings of dugong in Raja Ampat has increased the known range of important habitats in West Papua for dugongs (Iongh et al. 2009) and demonstrated that Raja Ampat is potentially an important region for dugongs. It also highlighs the importance of protecting seagrass beds particularly around Waigeo and Batanta where most dugong observations were made.

This study has also demonstrated that the 2006 boundaries of the MPA network, with the exception of Kofiau, do not capture the majority of important areas for large marine fauna. The extension of Dampier Strait MPA in 2008 increased MPA coverage over the habitat of large fauna. However, it is recommended that management recommendations relevant to the protection of large marine fauna are applied to areas both inside and outside MPAs including consideration of regulation on fishing gears to prevent bycatch or disturbance of cetaceans and coastal development to prevent sedimentatoin/reclamation of seagrass beds and other important coastal habitats.

The advantages of using fixed wing aircraft for aerial surveys are that long range surveys can be undertaken safely, that up to 5 observers can record data and photos simultaneously in a comfortable environment, and that surveys are not badly affected by weather conditions. The disadvantages include high cost, relatively fixed schedule and lack of maneuverability of the plane.

Aerial surveys in Raja Ampat are now being undertaken using an ultra light drifter float plane based in the Dampier Straits. This plane has an open cockpit and 2 seats. The advantages of this method is that it is relatively cheap, schedule is highly flexible and the plane is very maneuverable allowing the plane to quickly return over an area to confirm fauna sightings or look more closely at vessels or infrastructure. The disadvantages include small range, susceptibility to bad weather and difficulty of recording by one person in an open cockpit.

This study has shown that aerial surveys are a highly useful method to survey resource use and large marine fauna in remote and extensive areas. There is great potential to combine aerial surveys with vessel activities to assist in enforcement patrols and alert authorities to illegal activities. It is also an excellent method to assess the number, type and distribution of unregulated structures such as fishing traps and shelters.

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Appendix A – Aerial survey data recording forms

Synchronize your watch with GPS receiver --- If the record relates to a group of similar objects, indicate group size in remarks.--- Record all vessels, except the ones at home or on the beach

Name	**Date**	**Position:** 0 Starboard (*kanaan*) 0 Port (*kiri*)

		Vessel Type							**Vessel Size**						**Vessel Engine**					**Activity**				**Fixed gear**					**Biotic**				
Record ID	Time (hh:mm:ss)	Passenger	Freight	Industrial	Tourism	Fishery	Others	Unknown	Small canoe	Canoe, dinghy	Small (decked. <10m)	Medium (decked, < 20m)	Large (decked, < 50 m)	Very large (> 50m)	No engine	Ketinting	Outboard	Inboard	Unknown	Moving	Anchored	Fishing	Unknown	Fish cage	Fish shelter	FAD	Bagan	Other fixed gear	Whales / dolphins	Manta	Dugong	Bait school / tuna	Remarks