

Preliminary Draft Science Plan for the Palau National Marine Sanctuary

This draft Palau National Marine Sanctuary (PNMS) Science Plan has been prepared by the Working Group as a foundation for a Plan to be developed by stakeholders and decision makers in Palau. Advancing this preliminary draft to an actionable Science Plan will require local stakeholder review and ownership to ensure the content and granularity are appropriate for the needs and capacity of those conducting the monitoring. The purpose of the Science Plan is to assess the ecological, social, and economic outcomes of PNMS implementation. Research and monitoring questions align with the following three goals and nine subgoals of the PNMS legislation:

1. **Healthy Ocean Populations and Ecosystems:** Sustaining pelagic biodiversity and marine resources that benefit Palauan livelihoods and culture and support the Palauan economy. This includes:
 - Rekindle Palauan societal connection to and appreciation for Palau’s offshore environments and resources. Create the next generation of Palauan leadership to manage Palau’s open ocean resources.
 - Protect pelagic populations and preserve marine biodiversity in Palau’s waters.
 - Support sustainable fisheries by replenishing Palau’s fishing zones and adjacent areas.
2. **Food Security:** Ensuring a sustained, safe, and nutritious supply of seafood for Palauan citizens. This includes:
 - Increase the availability of and access to domestic pelagic fish according to standard guidelines for health and nutrition for all Palauan residents.
 - Reduce fishing pressure on reef fish for the sustained cultural and socioeconomic benefit to Palauans.
3. **Sustainable Development:** Developing a sustainable domestic pelagic fishing industry and supporting ecotourism initiatives. This includes:
 - Enhance the contribution of the DFZ to economic development, food security, and the conservation of the coral reef fish and invertebrate populations.
 - Support Palau’s brand as a high-value ecotourism destination.
 - Support long-term health and wellbeing for Palauan residents.
 - Support long-term economic sustainability in Palau.

The draft PNMS Science Plan addresses the most pressing knowledge gaps put forth by PNMS decision makers and stakeholders. The below Science Plan is a compilation of these research questions¹, associated methodological information, potential partners or collaborators already collecting data, and connections to the United Nations Sustainable Development Goals (SDGs) or wellbeing elements from Sterling et al. (in prep)². Recommendations for coordination among Palauan, regional, and international agencies and entities are included yet not exhaustive.

Goal 1. Healthy Ocean Populations and Ecosystems for Palau: Sustaining pelagic marine resources that benefit Palauan livelihoods and drive the Palauan economy

Subgoal 1: Rekindle Palauan societal connection to and appreciation for Palau’s offshore environments and resources. Create the next generation of Palauan leadership to manage Palau’s open ocean resources.

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
What are the historical and current attitudes, perceptions and connections of Palauans toward the pelagic environment and how do they change through time?	public perception survey to key demographic groups; maritime anthropology - e.g. oral histories	PCS	Palauan elders; Bob Johannes	wellbeing elements A.9, D.1, D.6; E.1, E.9
What is the level of support for PNMS legislation and regulations among stakeholder groups and the public?	surveys of stakeholder groups;	TNC, PCS		
What capacity do the institutions involved in managing the no-take and domestic fishing zones have and how is it likely to evolve?	surveys, institutional assessment and needs assessment. Pipeline analysis	PICRC or PCS		SDG 17.9

¹ In some cases, baseline data needs are also identified after the monitoring questions for each subgoal. Baseline data are intended to be collected at the beginning of implementing the Science Plan but not necessarily questions that need to be regularly monitored.

² Sterling et al., “Navigating Multidimensional Measures of Sustainability and Well-Being Across Scales,” *prep*, pp. 1–33.

How are stakeholders engaged in dissemination of PNMS-related information and decision making?				wellbeing element B.1, C.5, C.6, C.7, C.8
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Second Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
What curricula exist at secondary and tertiary education levels to educate Palauans about the pelagic environment and the PNMS legislation? How can curricula be modified to include, and foster interest in, the pelagic environment?	surveys	PCS	NSF training (ROV, etc.)	SDG 12.8
How does citizen science participation impact the attitudes and behaviors of the public?	surveys of stakeholder groups at regular intervals;			wellbeing element F.8
How is conflict about the management of, or access to, the no-take and domestic fishing zones addressed?	stakeholder meetings and interviews; speaking with specific individuals	PICRC		wellbeing elements C.16

Data necessary for establishing a baseline³ for Subgoal 1:

First Priority

Questions	Methods / Tools	Palauan Institution	Collaborators / Existing data	Connection to SDGs / Wellbeing Elements
Who are the key stakeholders?	interviews; self-elected	use current stakeholder group and build from there	Build from existing stakeholder group and facilitate via trusted local community leader	
What are the public's perceptions of current and future diversity of uses, interests, and values associated with Palau's pelagic waters?	surveys		facilitate via trusted local community leader	

Subgoal 2: Protect pelagic populations and preserve marine biodiversity in Palau's waters.

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
How does primary production change through time (including species composition)?	remote sensing and plankton tows; Continuous Plankton Recorder (CPR)		Voyage of Discovery for baseline data; foreign partnerships may aid in data collection	wellbeing elements A.7
What is the current biodiversity within Palau's open ocean and how does it change through time?	CPR, eDNA, and use existing monitoring networks		Voyage of Discovery for baseline data; foreign partnerships	wellbeing elements A.2

³ Data need to be collected in initial stages of carrying out the Science Plan but not regularly monitored

			may aid in data collection; Stanford / Collin Closek	
How does bycatch amount and composition change through time?	observer program		FFA	wellbeing elements A.2
Determine distribution and abundance of different life states of mammals, reptiles, seabirds, and invertebrates within habitats over time to gain insight into how marine ecosystems function and the importance of different habitats and seasons for key species across their life cycles.	tagging data		SPREP; Glenn McKinlay; NOAA; Birdlife international; IUCN; Voyage of Discovery for baseline data; foreign partnerships may aid in data collection	wellbeing elements A.2, A.7
Monitor sea temperature, salinity, and water quality.	CTD and pH measurements		SPC; NOAA (any pelagic monitoring group); Voyage of Discovery for baseline data; foreign partnerships may aid in data collection	SDG 14.3

Second Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
How do connectivity patterns change through time as well as home ranges for reef and open ocean species?	drifters, satellite tagging and otolith microchemistry, current models, literature review	PICRC	Voyage of Discovery for baseline data; foreign partnerships	wellbeing elements A.7

			may aid in data collection	
What is the distribution, abundance, life stage, fertility state, and size and weight of pelagic fish through time?	hydroacoustic surveys, fisheries independent surveys; maturation status, fish measurements both in terms of length and weight (as well as age - otolith)	TNC; PICRC and other local institutions conducting reef research	Voyage of Discovery for baseline data; foreign partnerships may aid in data collection; Pristine Seas; SPC	wellbeing elements A.2
What does population connectivity look like for species of interest?	genetics		Existing data with University of Hawaii and possibly University of the South Pacific; Voyage of Discovery for baseline data; foreign partnerships will aid in data collection	wellbeing elements A.1
What are the statuses of culturally important species? What are the perceptions of species' population health by stakeholders and the public? What are the levels of stakeholder knowledge of natural history in Palau's pelagic waters?				
What are compliance levels with no-take and domestic fishing zone regulations?				SDG 12.2, 14.4
How do pelagic fishes that are caught on FADs and those caught in the open ocean use reef food sources? Are there differences?	stomach content analysis (particularly with molecular tools)			

Data necessary for establishing a baseline⁴ for Subgoal 2:

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
What are the baseline patterns of energy and trophic flows within the pelagic environment?	ecosystem modelling, stable isotope analysis, stomach content	MNRET; PICRC	UBC / Colette Wabnitz, SPC	wellbeing elements A.7
What is the current size structure of target pelagic fish stocks?	fisheries sampling - catch data; community size structure	MNRET; TNC	SPC; FFA	SDG 14.4

Second Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
Map benthic environment and 3-D water column structure (e.g., eddies, currents, upwelling regions)?	multibeam sonar (but consider unintended consequences e.g., noise); drifters, ROV; some may be done using satellite monitoring as well		SPC (Fiji), NOAA	
Where are the pelagic nursery habitats for species of interest (i.e.: calving grounds or spawning aggregations) within Palau's EEZ?	underwater surveys; ethnobiological surveys		Pristine seas / Alan Friedlander	wellbeing elements A.7

⁴ Data need to be collected in initial stages of carrying out the Science Plan but not regularly monitored

What are the connectivity patterns and oceanographic mechanisms for connectivity between reefs and the open ocean environment?	stomach content, stable isotopes, conventional acoustics, satellite tags, plankton tow, larval dispersal models, genetic markers	PICRC	Pristine seas / Alan Friedlander	wellbeing elements A.7
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Subgoal 3: Support sustainable fisheries by replenishing Palau's fishing zones and adjacent areas.

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
What are the demographics of pelagic fish populations of commercial interest?	experimental fishing, hydroacoustic surveys, fisheries independent surveys, tagging; fisheries-independent methods		use community participation in experimental fishing data collection; SPC; Voyage of Discovery for baseline data; foreign partnerships may aid in data collection; Pristine Seas	
How do catch volumes, rates, and composition change through time?	creel and market surveys (including where catch is from and how it was caught); fisheries dependent methods		SPC; TNC	
How do imports and exports of seafood, including fish not landed in Palau, change through time?			Ministry of Finance / Customs (as they collect data on some of these metrics)	

What proportion of fishing trips for both the purse seine and longline fleets have observers on board?	surveys		FFA, SPC, WCPFC website for Palau's AR Part I & II (where bycatch data are presented)	
How is fishing effort for all sectors changing through time?	AIS data; VMS; change in CPUE		NCEAS; FFA; SPC	SDG 8.3, 12.2
How have spatial and temporal fishing patterns changed in Palau's waters? For example, have exemptions been granted and to whom? How does this affect catch, revenue, and fish stocks?	targeted surveys to government officials, tracking revenue through MOF		MOF, MOJ, FFA	
How are FADs being used over time? What are the factors affecting use?			CI (GEF project-Lindsay Chapman-existing data); Johann Bell	

Second Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
How is the PNMS legislation affecting bilateral and multilateral agreements?	surveys		PNA; SPC; FFA	
What is the ratio of catch from each fishing zone through time?				

Goal 2. Food Security for Palau: Ensuring sustained, nutritious, and safe supply of food for Palauan residents

Subgoal 1: Increase the availability of and access to domestic pelagic fish according to standard guidelines for health and nutrition for all Palauan residents.

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
What are the nutrient levels of reef and pelagic fish?	test fish		UBC / Colette Wabnitz	SDG 2.1. SDG 2.2; wellbeing element G.1
Availability: What volume and species composition are residents consuming now and how does this change through time? What are the geographic and demographic profiles of residential consumers?	surveys every five years with census; possibility for higher frequency		HIES (SPC) - POC Michael Sharp; TNC; existing data from Staci and Kirsten, Colette data	SDG 2.1. SDG 2.2; wellbeing element G.1
Access: How does catch, price, and source of fish at markets change through time? What are the sources of fish (e.g., pelagic offshore, pelagic nearshore, reef)?	creel surveys		TNC; SPC	
What are the mercury levels of pelagic fishes available in local markets?	test fish; use FAO or EPA guidelines for mercury levels		The Japanese are likely doing this; so there is potential to develop the capacity locally	SDG 2.1. SDG 2.2; wellbeing element G.1
What is the amount of (both pelagic and reef) fish leaving Palau as part of the (informal) cooler trade now? How does this change through time?		Customs, airport, TNC		SDG 12.2

Second Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
How does agricultural production change through time, particularly with regard to climate change? Are there shifts in agriculture production that correspond with changes in fish landings?				SDG 12.2

Subgoal 2: Reduce fishing pressure on reef fish for the sustained cultural and socioeconomic benefits to Palauans.

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
How do reef fish populations change through time?	PICRC existing surveys		PICRC reef surveys	SDG 12.2
What are the size of coolers exported and the species, number, and size composition of seafood inside each cooler?				
What is reef fish catch per unit effort (CPUE) and how does it change through time?	creel surveys		TNC	SDG 12.2
What is the local demand for reef and pelagic fish over time (before and after a local-sustainable brand is in effect)?			TNC	

What are the historical and current cultural uses of reef fishes, and to what extent would individuals be willing or consider it culturally appropriate, to substitute these for pelagic fishes?	ethnobiological surveys	PCS		
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Second Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
What is the abundance, size, and number of fishes caught for cultural use? How do these factors impact those species' long-term sustainability?				

Goal 3. Sustainable Development for Palau: Developing a domestic pelagic fishing sector and supporting existing sustainable tourism initiatives

Subgoal 1: Enhance the contribution of the Domestic Fishing Zone to economic development, food security and the conservation of the coral reef fish and invertebrate populations.

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
How effective are Fish Aggregating Devices (FADs) at increasing fishing efficiency?				
What type of FADs are currently in place, what is their condition, and are other FAD materials or configurations likely to be more effective?		MNRET, TNC, (PICRC?)	SPC from regional experience, GEF (Lindsay Chapman), Johann Bell (CI), World Fish (Solomon Islands), Alan Friedlander's tagging data	
Who funds the FADs? Who deploys and maintains them? Where are they located?				
How many fishers use the FADs? How frequently are FADs visited?	observer program, socioeconomic census, creel surveys, e-monitoring	MNRET, TNC, (PICRC?)	TNC e-monitoring	
What are the costs of operating on a FAD (e.g., fuel cost) versus benefits of operating on a FAD (e.g., efficiency of catch compared to non-FADs, price of catch).				

How many fishers are engaged in the DPF?	observer program, socioeconomic census, creel surveys, e-monitoring	MNRET, TNC, (PICRC?)	TNC e-monitoring	
How does income change through time for pole and line fishers? What are their operating costs and how much do they sell their catch for?	observer program, socioeconomic census, creel surveys, e-monitoring	MNRET, TNC, (PICRC?)	TNC e-monitoring	
What are the most viable business plans for developing a DPF? What infrastructure investments (e.g., fleet, processing, marketplace) for fisheries development are being considered?	surveys, OECD database	DOF, PICRC, Dept of Statistics	FFA, JICA re: Japanese investment, others; SPC (cost benefit analysis)	SDG 8.3
What training opportunities are being provided to fishers for engaging in the DPF? What is the investment in safety training and equipment for those fishers?	surveys, OECD database	DOF, PICRC, Dept of Statistics	FFA, JICA re: Japanese investment, others; SPC (cost benefit analysis)	SDG 8.3

Second Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
Where does pelagic catch enter the marketplace and how is it distributed?	creel survey		TNC; related to data collected in SPC Tufman database	wellbeing element H.9
What is the proportion of fisheries products imported from overseas (e.g., canned tuna), compared to locally sourced seafood?	review of customs imports	DOF, Customs		

Subgoal 2: Support Palau’s brand as a high-value ecotourism destination.

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
How is the PPEF distributed throughout the economy?		MOF		
How does the “Pristine Paradise Palau” branding influence Palau’s appeal to tourists with regard to the open ocean environment? What proportion of tourists said that they visited Palau as a result of the establishment of the PNMS?	entry & exit interviews, surveys for tour operations (national and international), surveys of tourism perceptions;	PVA	Staci Lewis and Kirsten Oleson data (re: if PNMS is a draw)	SDG 8.9
Where do tourists spend money?				SDG 8.9

Second Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
How is the PNMS messaging being used to promote tourism?				SDG 8.9

Subgoal 3: Support long-term health and wellbeing for Palauan residents.

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
What does wellbeing mean to Palauan residents?	surveys	PCS	WCS	connection to Sterling et al. wellbeing elements
What are the cultural effects of PNMS implementation on Palauans?	surveys	PICRC; PCS		wellbeing element D.14

Second Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
What is the proportion of Palauan residents that present non-communicable diseases and how does it change through time?		Ministry of Health	SPC	SDG 3.4
What are the community effects of the no-take and domestic fishing zones on Palauan residents?				wellbeing element D.14

Subgoal 4: Support long-term economic sustainability in Palau.

First Priority

Monitoring Questions	Methods / Tools	Palauan Institution	Collaborators / Existing Data	Connection to SDGs / Wellbeing Elements
How do jobs and employment distribution (e.g., gender, age) in ecotourism change through time?	surveys	MOF		SDG 8.9, 12.B
How do jobs and employment distribution (e.g., gender, age) in fisheries and fishing-related operations change through time?	surveys	MOF	Statistics from MOF/MNRET	
How does the PNMS legislation support Palauans beyond fishing and tourism (e.g., new jobs in monitoring, research, administration, etc.)?	surveys	PICRC; PCS		