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A policy framework for climate resilience

in fisheries and aquaculture in Thailand

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Supported by

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Disclaimer

The views in this report are those of the authors and do not necessarily reflect the views of the government officials and experts interviewed, nor the views of the Foreign, Commonwealth & Development Office (FCDO) that commissioned this study.

Terms of Reference (Brief)

Source: TERMS OF REFERENCE, Climate Resilience in Fisheries and Aquaculture in Thailand and Laos, Below EU Threshold ITT - Volume 2, V1.0 September 2020

This study was conducted in response to the call "Climate Resilience in Fisheries and Aquaculture in Thailand and Laos" by the Foreign, Commonwealth & Development Office (FCDO), Government of United Kingdom. The aim is to identify entry points, approaches and recommendations that could be piloted and discussed with respective in-country partners. The study addresses the following:

1. Analysis of the key linkages between climate change, aquatic ecosystem change, food supplies (food security) and social/economic well-being.
2. Analysis of current legal, policy, institutional and financial arrangements for climate-resilient fisheries and aquaculture and gaps therein. Where possible, this should be linked to the country's climate goals.
    a. Development of a comprehensive policy framework to conserve and protect aquatic ecosystems (e.g. river basin, coastal, marine ecosystem), to support adaptation efforts and to create sustainable food production systems, responding to climate change. This should include specific analysis of the opportunities to adapt, relevant risk reduction approaches and the policy environment needed to take advantage of the adaptation opportunities / to implement risk reduction approaches.

While the study should be primarily focused on Thailand, relevant lessons learnt from this study would be useful for understanding of relevant issues in the context of Laos and future approaches or interventions in Lao PDR.

The primary recipient of this review will be British Embassy Bangkok, British Embassy Vientiane and the South Asia Research Hub within FCDO's Research and Evidence Directorate. However, the outputs will be in the nature of global public goods, and will be available to the wider policy and research community.

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Acronyms and abbreviations

CPUE	Catch Per Unit Effort
EEZ	Exclusive Economic Zone
ENSO	El Niño-Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
IPCC	Intergovernmental Panel on Climate Change
IUU	Illegal, Unreported and Unregulated fishing
MSY	Maximum Sustainable Yield
RCP	Representative Concentration Pathway
SST	Sea Surface Temperatures
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

This report develops a policy framework for enhancing climate resilience in fisheries and aquaculture in Thailand. The foundations are provided by an overview of the sector, a review of what is known about climate impacts, risks and responses, and an evaluation of the climate content and sensitivity of key policies, programs, and laws. Thus, the study is based on analysis of secondary data, interviews with experts and officials, surveys done by the authors in a previous project, published peer-reviewed literature, as well as grey literature from reputable organizations. The emphasis is on evidence from Thailand; where this was not available, sources from other comparable regions in the world were used to fill gaps.

Farmed and wild fish are an important source of nutrition and income in Thailand. Production, measured as officially reported catches, from marine fisheries has been stagnant since a sharp decline in 2008. Production changes are complex to interpret, given changing contributions from catches outside the country's exclusive economic zone by the Thai fleet. Catch per unit effort, according to trawler surveys in the Gulf of Thailand, declined from around 300 kg hr^{-1} in 1961 to 20 kg hr^{-1} in the early 90s and around which it has fluctuated since. Overfishing and habitat degradation are among the main reasons for these trends. Trends in inland fisheries are less well documented, but rivers and wetlands are impacted by draining, pollution, and water infrastructure. Aquaculture production has also stagnated after decades of growth, with competitiveness and disease being key factors, but also concerns with sustainability of fisheries used to make feeds, habitat degradation, and contributions to water pollution. In all systems, climate change is emerging as another significant stressor.

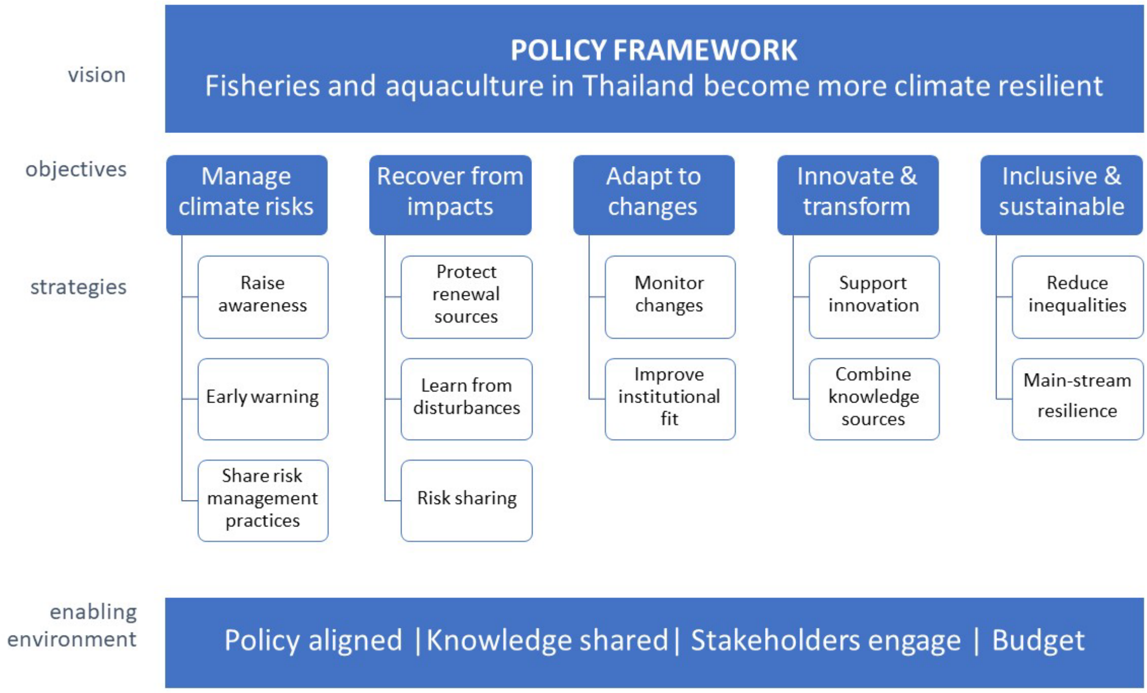
Climate-related risks to production or profitability of fish and shrimp farms, include abrupt changes in temperature, heat waves, cold spells, intense rainfall events, floods, and droughts. The relative importance of such risks varies with site geography, water management, and rearing system. Sea level rise, storms, ocean acidification, and changes in sea surface temperatures are important risks for marine capture fisheries. For freshwater fisheries, changes in flood regimes from interactions between water infrastructure operations, habitat lost, and climate change are growing in importance.

Climate variables important to capture fisheries and aquaculture at different locations have varied over the decades, sometimes showing distinct long-term trends. Temperatures in Southeast Asia have increased 0.14^{o}C-0.20^{o}C per decade. Average daily rainfall intensity across Thailand has increased by 0.24-0.73 mm day^{-1} per decade, whilst the number of rain days has decreased by 1.3-5.9 days per decade. Across Thailand, the number of warm days increased by 3.4 days per decade, and of warm nights by 3.5 days per decade. Mean annual temperatures across Southeast Asia, using regional models, are projected to increase by 3^{o}C-5^{o}C by 2100, relative to 1986-2005 period under RCP8.5. Projections of precipitation under possible future climates are more uncertain than for temperatures.

In this report, climate resilience is defined as the capacity of a fishery or aquaculture system to handle climate-related risks and impacts to sustain livelihoods and food provision. Climate-related risks to the productivity and profitability of aquaculture are actively managed by fish and shrimp farmers with attention to: quality and price of feed and seed (stock); adjustments to stocking size, densities, and timing; and water management at different levels. The opportunities to manage risks to capture fisheries appear to be more limited. Important measures include adjusting fishing times, location, and gear. Comparing fisheries and aquaculture, extreme events are of relatively greater concern to aquaculture, whereas slow-onsets and long-term shifts are greater concerns for fisheries.

Existing laws, regulations, and institutions already contain many of the elements needed for an effective policy response to climate change in capture fisheries and aquaculture in Thailand. The Climate Change Master Plan, for example, makes suggestions on zoning to protect nursery habitats, use of calendars to navigate seasonal risks, and adoption of innovations – practices and strategies that would contribute to climate resilience.

The vision of the proposed framework is fisheries and aquaculture in Thailand become more climate resilient through enhancing capacities to manage climate-related risks, recover from disturbances, adapt to changes, and innovate to transform while becoming more inclusive. The figure below summarizes in concise form the main elements. Not shown are the specific project and program suggestions under each strategy.



Capacities to manage climate-related risks, for example, could be enhanced by supporting the development of early warning and risk information systems (Strategy 2). Capacities to recover from impacts or disturbances, in the case of fisheries, might be enhanced by the establishment and protection of refugia and natural nursery habitats (Strategy 4). Capacities to adapt in response to changes in climate could be strengthened with monitoring (Strategy 7). Capacities to handle climate changes may depend on innovation when existing options for adaptation are insufficient (Strategy 9). Finally, inequalities in access to resources, and the benefits arising from use of those resources, are obstacles to climate resilient fisheries and aquaculture, and thus need to be addressed (Strategy 11).

While focused on Thailand, this report also provides some initial insights into conditions and needs in Laos. Three suggestions are made for next steps. First, existing studies in Laos should be reviewed for insights important for policy responses to climate change, starting with those about management of climate-related risks. Second, climate change working groups should be established to facilitate sharing of knowledge and good practices. Third, the policy framework proposed in this report could be used as a starting point for a policy development initiative for climate resilience in fisheries and aquaculture in Laos.

Enhancing resilience to climate is not the only policy objective important to the development of fisheries and aquaculture. Food security, employment, foreign exchange earnings from exports, international competitiveness, profitable returns on investment, sustainable livelihoods, and conservation are others.

There are three main recommendations for initial action by government stakeholders in the fisheries and aquaculture sectors in Thailand. First, to convene a climate resilience working group at the level of the Department of Fisheries. Second, to reduce knowledge gaps with investments in research. Third, use the policy framework developed in this report as a starting point in building climate resilience.

บทสรุปผู้บริหาร

รายงานฉบับนี้ได้จัดทำกรอบนโยบายเพื่อเพิ่มความสามารถในการรับมือต่อการเปลี่ยนแปลงสภาพภูมิอากาศ (climate resilience) ในการประมงและการเพาะเลี้ยงสัตว์น้ำในประเทศไทย โดยใช้ข้อมูลพื้นฐานมาจากการทบทวนข้อมูลเกี่ยวกับผลกระทบจากการเปลี่ยนแปลงสภาพอากาศ ความเสี่ยงและการตอบสนอง และการประเมินเกี่ยวกับสภาพอากาศและความอ่อนไหวของนโยบายและกฎหมายที่สำคัญ

การศึกษานี้ใช้การวิเคราะห์ข้อมูลทุติยภูมิและสถิติ การเก็บรวบรวมข้อมูลจากการสัมภาษณ์ผู้เชี่ยวชาญและเจ้าหน้าที่จากหน่วยงานที่เกี่ยวข้อง ข้อมูลเชิงคุณภาพจากโครงการที่ดำเนินการก่อนหน้านี้ บทความตีพิมพ์ในวารสารระดับนานาชาติ รวมถึงข้อมูลและรายงานจากองค์กรที่น่าเชื่อถือ โดยเน้นข้อมูลจากประเทศไทย และใช้ข้อมูลจากภูมิภาคอื่น ที่เทียบเคียงได้กับประเทศไทยเพื่อเติมเต็มข้อมูลส่วนที่ขาดไป ในกรณีที่ไม่มีข้อมูล

การประมงและการเพาะเลี้ยงสัตว์น้ำเป็นแหล่งอาหารและรายได้ที่สำคัญของประเทศไทย ผลผลิตซึ่งพิจารณาจากรายงานการจับสัตว์น้ำอย่างเป็นทางการจากการประมงทะเลได้ลดลงอย่างรวดเร็วตั้งแต่ปี พ.ศ. 2551 การเปลี่ยนแปลงของผลิตนั้นมีความซับซ้อนในการวิเคราะห์ เนื่องมาจากการเปลี่ยนแปลงการจับสัตว์น้ำนอกเขตเศรษฐกิจจำเพาะโดยเรือประมงของประเทศไทย ผลจับต่อหน่วยการลงแรงประมง (CPUE) จากการสำรวจเรืออวนลากในอ่าวไทยพบว่าปริมาณสัตว์น้ำลดลงจากประมาณ 300 กิโลเมตรต่อชั่วโมง ในปี พ.ศ. 2504 เหลือ 20 กิโลเมตรต่อชั่วโมง ในช่วงทศวรรษที่ 90 และได้ลดลงเหลือเพียง 6 กิโลเมตรต่อชั่วโมง ในปี พ.ศ. 2558 แต่อาจจะมีการเพิ่มขึ้นในปัจจุบัน โดยมีสาเหตุหลักมาจากการทำประมงเกินขนาด และการเสื่อมโทรมของแหล่งที่อยู่อาศัย

ข้อมูลผลผลิตจากประมงน้ำจืดไม่ได้มีการเก็บรวบรวมที่สมบูรณ์ แต่มีข้อมูลแม่น้ำหรือพื้นที่ชุ่มน้ำที่ได้รับผลกระทบจากการระบายน้ำ มลพิษ และโครงสร้างพื้นฐานของน้ำ การเพาะเลี้ยงสัตว์น้ำชะงักหลังจากการเติบโตมาหลายสิบปีเนื่องจากความสามารถในการแข่งขันและโรคที่เป็นปัจจัยสำคัญ รวมถึงปัจจัยความยั่งยืนของการประมงที่ใช้ในการผลิตอาหารสัตว์ ความเสื่อมโทรมของแหล่งที่อยู่อาศัย และการเพิ่มมลพิษทางน้ำ การเปลี่ยนแปลงสภาพภูมิอากาศก็ถือเป็นปัจจัยกดดันที่สำคัญอีกอย่างหนึ่ง

ความเสี่ยงที่เกี่ยวข้องกับการเปลี่ยนแปลงสภาพภูมิอากาศต่อการผลิตหรือความสามารถในการทำกำไรของเกษตรกรผู้เพาะเลี้ยงสัตว์น้ำ ได้แก่ การเปลี่ยนแปลงของอุณหภูมิอย่างกะทันหัน คลื่นความร้อน อากาศเย็น เหตุการณ์ฝนตกหนัก น้ำท่วม และภัยแล้ง โดยความสำคัญจากความเสี่ยงดังกล่าวจะแตกต่างกันไปตามบริบทของแต่ละพื้นที่ การจัดการน้ำ และระบบการเลี้ยง ในขณะที่การเพิ่มขึ้นของระดับน้ำทะเล พายุ ความเป็นกรดของน้ำทะเล และการเปลี่ยนแปลงของอุณหภูมิพื้นผิวน้ำทะเลเป็นความเสี่ยงที่สำคัญต่อการทำประมงในทะเล สำหรับการประมงน้ำจืด การเปลี่ยนแปลงของเหตุการณ์น้ำท่วม รวมถึงโครงสร้างพื้นฐานด้านการจัดการน้ำ การสูญเสียแหล่งที่อยู่อาศัย และการเปลี่ยนแปลงสภาพภูมิอากาศได้มีความสำคัญมากขึ้น

ตัวแปรสภาพภูมิอากาศที่มีความสำคัญต่อการเพาะเลี้ยงสัตว์น้ำและการประมงในสถานที่ต่างๆ มีความแตกต่างกันตลอดหลายทศวรรษที่ผ่านมา ซึ่งบางครั้งก็แสดงให้เห็นถึงแนวโน้มในระยะยาวที่แตกต่างกันออกไป อุณหภูมิในเอเชียตะวันออกเฉียงใต้เพิ่มขึ้น 0.14°C-0.20°C ต่อทศวรรษ และปริมาณน้ำฝนเฉลี่ยรายวันทั่วประเทศไทยเพิ่มขึ้น 0.24–0.73 มิลลิเมตรต่อวัน ต่อ

ทศวรรษ ในขณะที่จำนวนวันที่ฝนตกลดลง 1.3-5.9 วันต่อทศวรรษ ในประเทศไทยจำนวนวันที่อากาศร้อนในช่วงกลางวันเพิ่มขึ้น 3.4 วันต่อทศวรรษ และในช่วงกลางคืนเพิ่มขึ้น 3.5 วันต่อทศวรรษ อุณหภูมิเฉลี่ยทั้งปีทั่วทั้งเอเชียตะวันออกเฉียงใต้โดยใช้แบบจำลองระดับภูมิภาคคาดว่าจะเพิ่มขึ้น 3°C-5°C ภายในปี พ.ศ. 2643 เมื่อเทียบกับช่วงปี พ.ศ. 2529-2548 ภายใต้ RCP8.5 การคาดการณ์ปริมาณน้ำฝนภายใต้สภาพอากาศที่อาจจะเกิดขึ้นในอนาคตนั้นมีความไม่แน่นอนมากกว่าอุณหภูมิ

ในรายงานนี้ การรับมือต่อการเปลี่ยนแปลงสภาพภูมิอากาศ (climate resilience) ถูกกำหนดอย่างกว้างๆ ว่าเป็นความสามารถของระบบในการจัดการความเสี่ยงที่เกี่ยวข้องกับสภาพอากาศ การฟื้นตัวจากความแปรปรวนที่เกี่ยวข้องกับสภาพภูมิอากาศ การปรับตัวให้เข้ากับสภาพอากาศที่แปรปรวนหรือเปลี่ยนแปลงไป หรือการประยุกต์และเปลี่ยนแปลงเพื่อตอบสนองต่อสภาพอากาศที่เปลี่ยนแปลง

ความเสี่ยงที่เกี่ยวข้องกับสภาพภูมิอากาศต่อผลผลิตและความสามารถในการทำกำไรของการเพาะเลี้ยงสัตว์น้ำได้รับการจัดการอย่างจริงจังโดยเกษตรกรผู้เพาะเลี้ยงสัตว์น้ำ โดยให้ความสำคัญกับ คุณภาพและราคาของอาหารสัตว์และลูกพันธุ์สัตว์น้ำ การปรับเปลี่ยนขนาด ความหนาแน่น และระยะเวลาในการเลี้ยง และการจัดการน้ำในระดับต่างๆ ส่วนการจัดการความเสี่ยงในการประมงจะมีข้อจำกัดมากกว่า โดยมีมาตรการสำคัญได้แก่ การปรับเวลาทำการประมง สถานที่และอุปกรณ์ เมื่อเปรียบเทียบการประมงและการเพาะเลี้ยงสัตว์น้ำพบว่า เหตุการณ์ที่รุนแรงเป็นเรื่องที่น่ากังวลมากกว่าสำหรับการเพาะเลี้ยงสัตว์น้ำ ในขณะที่การเปลี่ยนแปลงอย่างช้าๆ และการเปลี่ยนแปลงในระยะยาวเป็นเรื่องที่น่าวิตกสำหรับการประมง

ปัจจุบัน กฎหมาย ระเบียบข้อบังคับ และหน่วยงาน มีองค์ประกอบหลายอย่างที่จำเป็นสำหรับการตอบสนองนโยบายอย่างมีประสิทธิภาพต่อการเปลี่ยนแปลงสภาพภูมิอากาศในการประมงและการเพาะเลี้ยงสัตว์น้ำในประเทศไทย ยกตัวอย่าง แผนแม่บทการเปลี่ยนแปลงสภาพภูมิอากาศ ให้คำแนะนำเกี่ยวกับการแบ่งเขตเพื่อเป็นแหล่งอนุบาลสัตว์น้ำ การวางแผนการเลี้ยงเพื่อลดความเสี่ยงตามฤดูกาล และการใช้นวัตกรรมซึ่งเป็นแนวปฏิบัติและกลยุทธ์ที่จะส่งผลต่อการรับมือต่อการเปลี่ยนแปลงสภาพภูมิอากาศ

วิสัยทัศน์ของกรอบนโยบายที่เสนอคือ การส่งเสริมให้การประมงและการเพาะเลี้ยงสัตว์น้ำในประเทศไทย สามารถรับมือต่อการเปลี่ยนแปลงภูมิอากาศได้มากขึ้น โดยการเพิ่มขีดความสามารถในการจัดการความเสี่ยงที่เกี่ยวข้องกับสภาพอากาศ การฟื้นตัวจากความแปรปรวนที่เกี่ยวข้องกับสภาพภูมิอากาศ การปรับตัวให้เข้ากับการเปลี่ยนแปลง และพัฒนานวัตกรรมเพื่อการเปลี่ยนแปลง รวมถึงเพิ่มความครอบคลุมให้มากขึ้น รูปด้านล่างสรุปองค์ประกอบหลักของกรอบนโยบาย แต่ไม่ได้แสดงตัวอย่างโครงการ หรือข้อเสนอแนะในแต่ละยุทธศาสตร์

การเพิ่มความสามารถในการจัดการความเสี่ยงด้านสภาพอากาศ เช่น การสนับสนุนการพัฒนาระบบข้อมูลการเตือนภัยล่วงหน้าและข้อมูลความเสี่ยง (ยุทธศาสตร์ที่ 2) การเพิ่มความสามารถในการฟื้นตัวจากความแปรปรวนที่เกี่ยวข้องกับสภาพอากาศ ในกรณีของการประมง อาจเพิ่มได้โดยการจัดทำแหล่งที่อยู่อาศัยและปกป้องแหล่งอนุบาลสัตว์น้ำตามธรรมชาติ (ยุทธศาสตร์ที่ 4) การเพิ่มความสามารถในการปรับตัวเพื่อตอบสนองต่อการเปลี่ยนแปลงของสภาพอากาศสามารถทำได้ด้วยการเฝ้าระวัง การวิจัย และประเมินผล (ยุทธศาสตร์ที่ 7) แนวทางการปรับตัวต่อการเปลี่ยนแปลงสภาพภูมิอากาศที่มีอยู่นั้นอาจไม่เพียงพอ การเพิ่มขีดความสามารถเพื่อรองรับการเปลี่ยนแปลงสภาพภูมิอากาศอาจขึ้นอยู่กับนวัตกรรม (ยุทธศาสตร์ที่ 9) สุดท้าย ความไม่เท่าเทียมกันในการเข้าถึงทรัพยากร และผลประโยชน์ที่เกิดจากการใช้ทรัพยากรเหล่านี้ เป็นอุปสรรคต่อการพัฒนาการประมงและการเพาะเลี้ยงสัตว์น้ำ ที่มีความสามารถในการรับมือต่อการเปลี่ยนแปลงสภาพอากาศ และจำเป็นต้องได้รับการแก้ไข (ยุทธศาสตร์ที่ 11)

ในขณะที่รายงานนี้มุ่งเน้นศึกษาที่ประเทศไทย ข้อมูลเบื้องต้นสามารถนำไปประยุกต์ใช้กับประเทศลาวได้ด้วย โดยมีข้อเสนอแนะเบื้องต้นสามประการดังนี้ ประการแรก ควรทบทวนการศึกษาที่มีอยู่ในประเทศลาวเพื่อหาข้อมูลเชิงลึกที่สำคัญสำหรับการตอบสนองต่อนโยบายต่อการเปลี่ยนแปลงสภาพภูมิอากาศ โดยเริ่มจากการศึกษาที่เกี่ยวกับการจัดการความเสี่ยงที่เกี่ยวข้องกับสภาพอากาศ ประการที่สอง พิจารณาจัดตั้งคณะทำงานด้านการเปลี่ยนแปลงสภาพภูมิอากาศเพื่อช่วยแบ่งปันความรู้และแนวทางปฏิบัติที่ดี ประการที่สาม กรอบนโยบายที่เสนอในรายงานนี้สามารถเป็นจุดเริ่มต้นในการพัฒนานโยบายเพื่อช่วยในการเพิ่มความสามารถในการรับมือต่อการเปลี่ยนแปลงสภาพภูมิอากาศในการประมงและการเพาะเลี้ยงสัตว์น้ำในประเทศลาว

การเพิ่มความสามารถในการรับมือต่อการเปลี่ยนแปลงสภาพอากาศไม่ได้เป็นเพียงวัตถุประสงค์เดียวของนโยบายที่สำคัญต่อการพัฒนาการประมงและการเพาะเลี้ยงสัตว์น้ำ ยังมี ความมั่นคงด้านอาหาร การจ้างงาน รายได้จากการส่งออก ความสามารถในการแข่งขันระหว่างประเทศ กำไร ผลตอบแทนจากการลงทุน การดำรงชีวิตอย่างยั่งยืน การอนุรักษ์ เป็นต้น

รายงานนี้มีคำแนะนำสามประการหลักสำหรับการดำเนินการเบื้องต้นสำหรับหน่วยงานภาครัฐที่เกี่ยวข้องในการประมงและการเพาะเลี้ยงสัตว์น้ำในประเทศไทย ประการแรก พิจารณาจัดตั้งคณะทำงานด้านการรับมือต่อการเปลี่ยนแปลงสภาพภูมิอากาศระดับกรมประมง ประการที่สอง สนับสนุนงานวิจัยที่เกี่ยวข้องกับการรับมือต่อการเปลี่ยนแปลงสภาพภูมิอากาศ ประการที่สาม กรอบนโยบายในรายงานนี้สามารถใช้เป็นจุดเริ่มต้นในการเพิ่มการรับมือต่อการเปลี่ยนแปลงสภาพภูมิอากาศ

1 INTRODUCTION

CHAPTER SUMMARY Farmed and wild fish are an important source of nutrition and income in Thailand. Climate resilience is important to the future of fisheries and aquaculture because they are important to food security, livelihoods, and economic development, while also being sensitive to climate. The purpose of this report is to develop a policy framework for enhancing climate resilience. Climate resilience is defined broadly as the capacity of a social-ecological system to handle climate-related risks and impacts to sustain livelihoods and food provision.

Understanding of the historical and potential future impacts of climate change on fisheries and aquaculture in Thailand is growing, but from a policy perspective still provides limited guidance on when, where, and how to respond. Globally, research suggests capture fisheries in the tropics are having difficulties adapting to the combination of climate changes in the marine environment with the impacts of overfishing and regulatory changes [2]. Aquaculture in the tropics would seem to provide more possibilities for active management of climate-related risks and successful adaptation, but producers face challenges related to disease outbreaks, knowledge gaps, and shifts in competitiveness in international trade markets [3].

Climate resilience is important to the future of fisheries and aquaculture in Thailand because these sectors are important to food security, livelihoods, and economic development, while also being sensitive to climate. Fish is critical to food security and nutrition [4]. Estimates of per capita consumption of fish in Thailand vary between 25 to 35 kilograms per year [5]. Inland and marine small-scale fisheries are a very important source of nutrition for poor households.

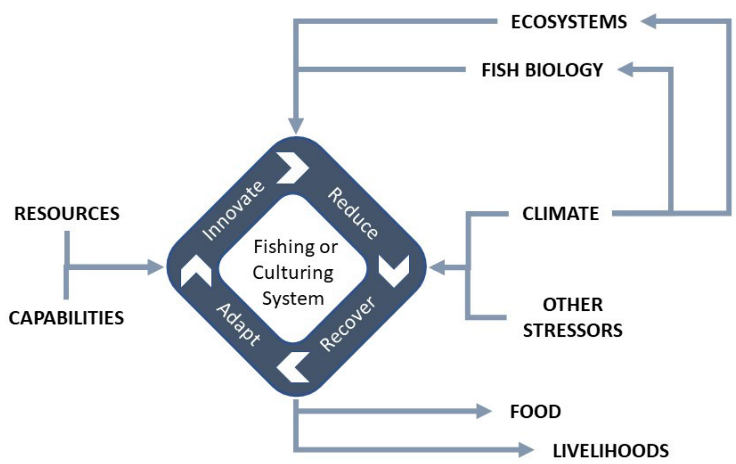
Fishing is also a significant livelihood option and a source of employment. In 2018, there were over 26,000 small scale fishing vessels registered [6]. In 2017, fisheries provided jobs for over 170,000 fishers in Thailand, over half were migrants from Myanmar or Cambodia. Fishing also provided work for about half a million people in supporting industries, mostly women [5].

Industrial areas around Bangkok are globally important for seafood processing. In 2018, tinned tuna made up 35% and shrimp 28% of the value of fisheries exports [6]. Key destinations were the USA, Japan, and EU. In 2017, export of processed shrimp and prawns was valued at about US$ 1.8 billion and tuna US$ 2.1 billion [7].

Fisheries and aquaculture are sensitive to climate. The life history of many species is seasonal and growth rates vary with climate differences between places. Extreme events, like the 2011 floods in Thailand [8], even though it occurred in the later part of the year, had a large impact on total production of tilapia and walking catfish for that calendar year (see Figure 6). High sea surface temperatures are one of the main causes of coral bleaching [9, 10] – a habitat that, alongside mangroves, is important as a nursery or refugia for species which are regularly fished.

Climate resilience is defined broadly in this report as the capacity of a social-ecological system to handle climate-related risks and impacts to sustain livelihoods and food provision. Other stressors may reduce resilience, while access to resources and capabilities may enhance it (Figure 1).

Figure 1 The impacts of climate depend on the resilience of the fishing or fish farming system. Other stressors may reduce resilience, while improved access to resources and capabilities may enhance it. A resilient system sustains livelihoods and food provision. Note the blue diamond square represents climate resilience.



Social-ecological systems contain interacting social parts – institutional, behavioral, economic, technological – and ecological parts – from tightly managed through to natural ecosystems [11]. Rearing and fishing activities undertaken by households or corporations can be thought of as social-ecological systems [12]. Coastal fisheries may for example depend on the ecosystem services provided by mangroves or coral reefs, while intensive aquaculture may depend on fish meal harvested from the ocean as a key ingredient of fish feed [13, 14]. Social components may be even more complex. Social standing and relations may strongly influence access to assistance and information, and thus adoption of better or new practices. Logistics and trade critical to inputs and outputs of fish production may be disrupted by extreme climate events. Both social and ecological parts, and their interactions, can contribute to climate resilience.

The purpose of this report is to develop a policy framework for enhancing climate resilience in fisheries and aquaculture in Thailand. This report is directed at stakeholders with interests in the fisheries and aquaculture sectors of Thailand, including government departments and agencies, but also non-state actors, for example, private businesses, industry associations, fish farmers and fishers' groups, conservation, academics, and civil society organizations.

This study is based on analysis of secondary data and statistics, 38 interviews with experts and officials (source identified by a 3-digit superscript like [005]), surveys done by the authors from earlier projects, published peer-reviewed literature, as well as grey literature from reputable organizations. The emphasis is on evidence from Thailand, where this was not available, sources from other comparable regions in the world were used to fill gaps. Information for capture fisheries and aquaculture were assessed separately, as they involve distinct risks and management opportunities.

This chapter is followed by a summary of recent fisheries and aquaculture production trends (Chapter 2), state-of-the-science reviews of what is known about climate-related risks (Chapter 3) and climate resilience (Chapter 4), a concise analysis of the policy environment (Chapter 5), and the foundations for developing a policy framework for climate resilience (Chapter 6). Possible lessons from that experience in Thailand for Laos are highlighted next (Chapter 7). The report ends with some general conclusions and recommendations for next steps in Thailand (Chapter 8).

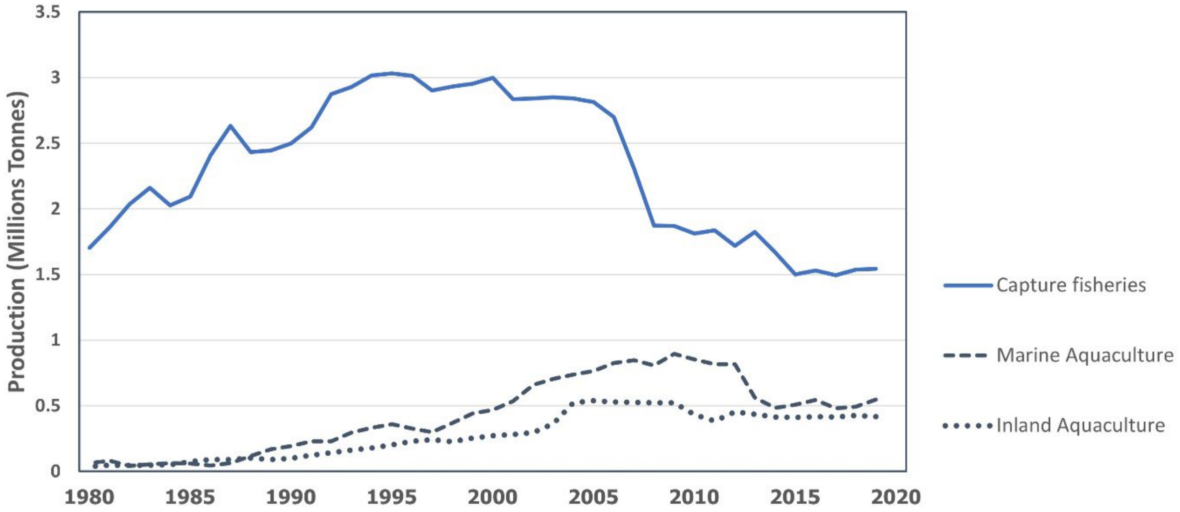
2 FISHERIES AND AQUACULTURE

CHAPTER SUMMARY Efforts to enhance climate resilience are taking place in fisheries and aquaculture sectors that is increasingly regulated and becoming more sustainable. Production from capture fisheries peaked in the mid-90s and aquaculture a decade later. Overfishing is suggested by decades of declines in catch per unit effort by trawlers in both the Gulf of Thailand and the Andaman Sea.

2.1 PRODUCTION TRENDS

Recent production trends are an important part of the context in which efforts to enhance climate resilience will take place. Capture fisheries and aquaculture production levels have stagnated since about 2015, at levels well below earlier plateaus (Figure 2). As late as 2007 it looked as if aquaculture production would soon be higher than those from capture fisheries, but that never happened. In last five years (2015-2019) capture fisheries annually contributed 61-63% of total production.

Figure 2 Total annual capture fisheries and aquaculture production in Thailand (1980-2019). All aquatic organisms. Live weight. Inland = freshwater. Marine = brackish or marine. Data Source: FAO [15]

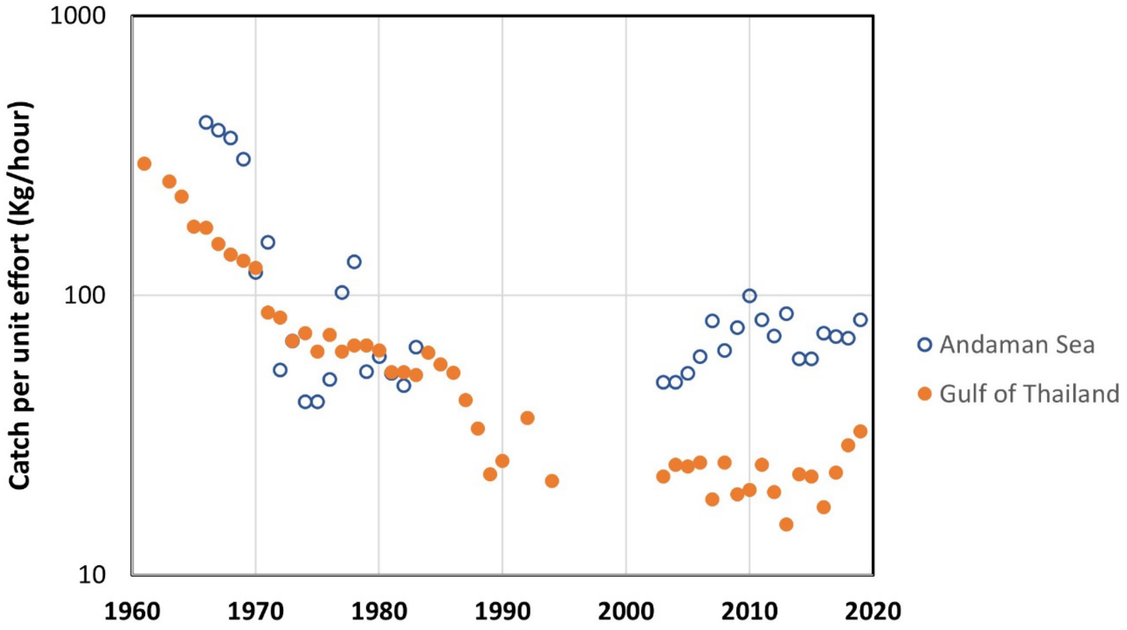


2.2 MARINE FISHERIES

In 2008, Malaysia and Indonesia closed their fishing grounds to Thai fishers [6], causing a sharp reduction in production (Figure 2). Prior to this the Thai fishing fleet regularly fished in the exclusive economic zone (EEZ) of other nearby coastal countries [16], including the South China Sea, an area in which it has no EEZ territorial claim [17]. The current Marine Fisheries Management Plan (2020-2022) continues to promote expansion into deeper waters and to fishing grounds outside Thailand [6].

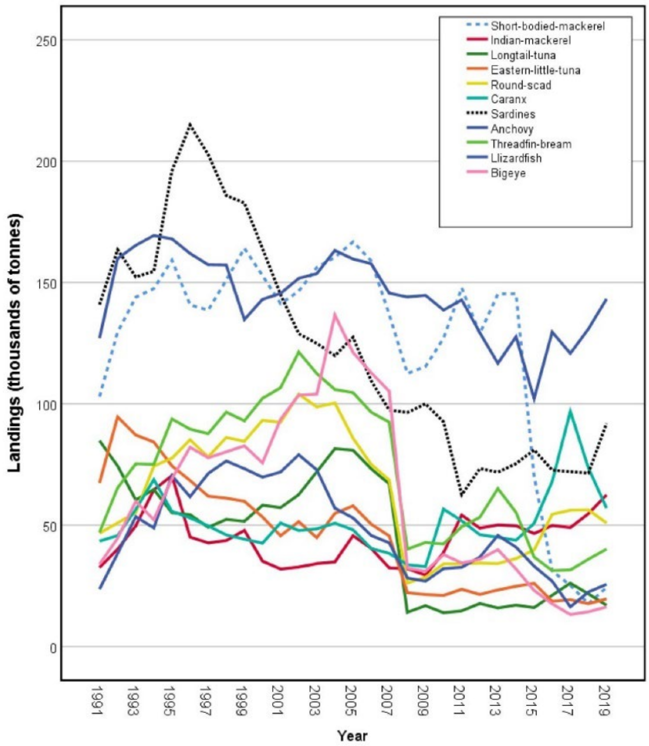
Production statistics are often complex to interpret given changing contributions from catches outside Thailand's EEZ, as well as changes to data collection procedures and classifications. Nevertheless, several lines of evidence point to a history of overexploitation of marine resources in the Gulf of Thailand and the Andaman Sea. Trawling expanded greatly in Thailand in the mid-1960s, based on technologies developed in the Philippines transferred by German experts [17]. Trawler surveys in the Gulf of Thailand show a decline in catch per unit effort (CPUE) from around 300 kg hr^{-1} in 1961 to 20 kg hr^{-1} in the early 90s [18], and which it has remained thereabouts (Figure 3). In the Andaman Sea, levels fell from over 400 kg hr^{-1} in 1966 to around 50 kg hr^{-1} in 1975, with a hint of increase in the last two decades (Figure 3).

Figure 3 Catch per unit effort 1960-2019 in the Andaman Sea and the Gulf of Thailand trawler fisheries. Note logarithmic scale and gap in observations. Re-drawn by authors based on figures in a policy document from the Department of Fisheries, Thailand [6].



Published studies have commented on trends in the marine fish catch. One analysis found that between 1995-2015 production declined by half from 2.8 million tonnes to 1.3 million tonnes, with no major shifts in the taxonomic composition of the catch [19]. Some variability among years in the dominant species groups, however, was visible in our analysis (Figure 4).

Figure 4 Landings of most common species of marine fish 1991-2019. Drawn by the authors based on official landing statistics from the Department of Fisheries, Thailand.



The decline in overall production was attributed to higher fuel prices, restrictions on access to EEZ of other countries, overfishing, and illegal fishing [19]. The apparent halt in declining production post-2015 (Figure 2) is consistent with increased regulation and efforts to reduce fishing towards levels needed to achieve maximum sustainable yields [19].

2.3 INLAND FISHERIES

Important inland fisheries in Thailand include the mainstem, tributaries, and wetlands of the Mekong River Basin in Northeast Thailand, and Songkhla Lake in Southern Thailand. In the Sebok River, a tributary of the Mun River in the Northeast, for instance, hydropower and irrigation dams adversely impacted fisheries based on migratory species in the tributaries [20]. In general, the production, and hence importance of inland small-scale fisheries beyond the mainstem of the Mekong River is often underestimated.

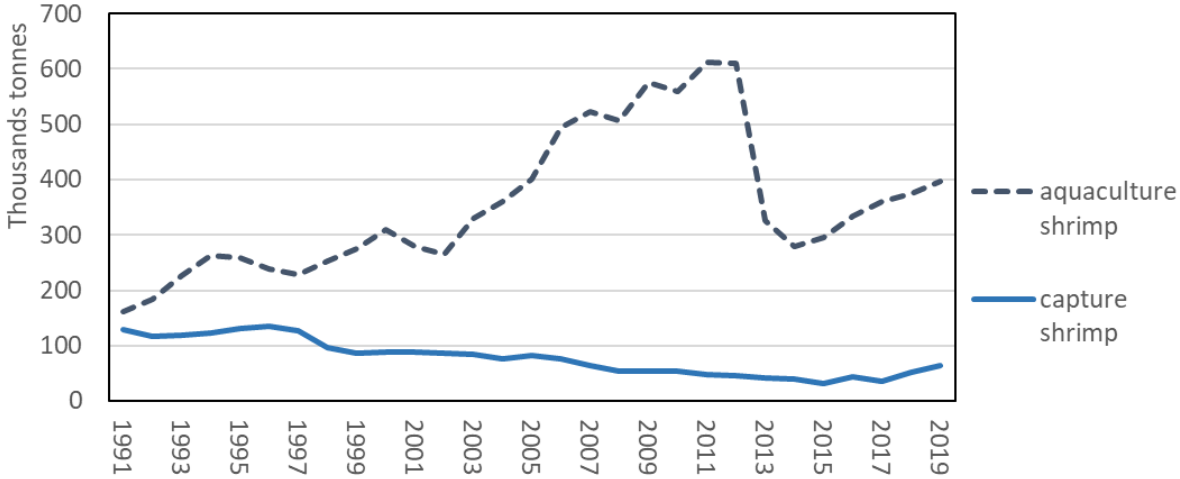
In Thailand, there is a history of stock enhancement programs, including the release of culture fish and shrimp into reservoirs and natural water bodies to improve the productivity of fisheries. These systems are therefore a hybrid between fisheries and aquaculture. Inland fisheries are threatened by overfishing, as well as polluted run-off and changes in flood regimes due to the operation of water infrastructure and climate variability.

2.4 COASTAL AQUACULTURE

Overall aquaculture production levels stagnated since about 2014, at levels well below earlier plateaus (Figure 2). Based on Department of Fisheries statistics, one published analysis found that during 1995-2015 mean annual aquaculture production varied between 0.5 and 1.4 million tonnes, with 62% from coastal aquaculture and 38% from freshwater [21]. Peak aquaculture production was in 2009. Value of mean 1 million tonnes produced per year was estimated at around US$2.2 billion [21].

In the case of shrimp, aquaculture production has diverged from capture fisheries as the main source, but with a sharp decline in 2013 from which some recovery is suggested (Figure 4). One explanation for the 2013 decline was outbreaks of the early mortality syndrome (EMS) virus [22]. In 2017, export of processed shrimp and prawns was valued at about US$ 1.8 billion [7].

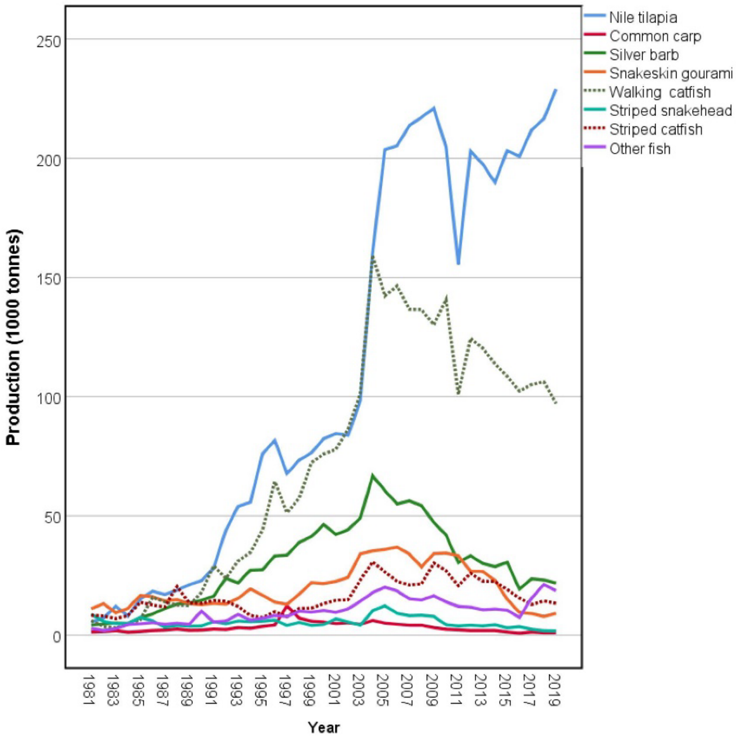
Figure 5 Shrimp capture and aquaculture production volumes for 1991-2019. Drawn by the authors based on data from the Department of Fisheries, Thailand.



2.5 INLAND AQUACULTURE

In terms of farmed freshwater fish culture, Nile tilapia has been by far the dominant species since 2004, when it matched walking catfish production at its peak (Figure 5). Technology played an important role in this growth. Scientists discovered that they could make all-male populations of fish by exposing young fish to hormones in their feed [23]. Selective breeding has led to faster growing, more standard shaped fish. Inter-species hybridization has created a new attractive strain of red (tuptim) Nile tilapia. The sharp declines of both species in 2011 coincide with the severe and prolonged flooding across large parts of Thailand, arising from high rainfall prior to the monsoon and other climatic factors [8]. One official estimated the aquaculture area affected by this extreme event was greater than 200,000 rai (or 32,000 hectares).[005]

Figure 6 Aquaculture production of top freshwater fish species in 1981-2019. Drawn by the authors based on data provided by the Department of Fisheries, Thailand.



3 CLIMATE-RELATED RISKS AND IMPACTS

CHAPTER SUMMARY Climate-related risks to production or profitability of fish and shrimp farms, include abrupt changes in temperature, heat waves, cold spells, intense rainfall events, floods, and droughts. The relative importance of such risks varies with site geography, water management, and rearing system. Sea level rise, ocean warming, storms, and changes in seasonality are important risks for coastal and marine capture fisheries. Climate variables important to capture fisheries and aquaculture differ among locations, vary with seasons, and among years. Temperatures in Southeast Asia have increased 0.14^{o}C-0.20^{o}C per decade. Average daily rainfall intensity across Thailand has increased by 0.24-0.73 mm day^{-1} per decade, whilst the number of rain days has decreased by 1.3-5.9 days per decade. Modelling projects changes in future climate, depending on emission scenarios and assumptions made by models. Mean annual temperatures across Thailand are projected to increase by 3.8^{o}C by 2080-2099, relative to 1986-2005 period under RCP8.5 emission scenario. Comparing fisheries and aquaculture, extreme events are of relatively greater concern to aquaculture, whereas slow-onset and long-term shifts are greater concerns for fisheries.

In this chapter, evidence about contemporary climate-related risks and impacts of extreme weather and climate events on fisheries and aquaculture activities in Thailand are reviewed. Apart from historical evidence, studies of potential future risks, and impacts under a changing climate are also examined.

3.1 CLIMATE VARIABILITY AND CHANGE

Climate differences between places, climate variability among years, and climate changes over decades can each have impacts on aquatic ecosystems, fish growth, survival or reproduction, and thus on yields, profits, and livelihoods in capture fisheries and aquaculture (Figure 1).

The climate of Thailand varies among the major regions. In the more northerly regions the southwest monsoon brings warm moist air from the Indian Ocean to drive wet season rainfall from May-October, and the northeast monsoon takes dry cool air (October-February) from China and the South China Sea to define the dry season [24]. In the southern region of Thailand, northeast monsoon brings abundant rain along the east coast [25].

3.1.1 Historical trends

Climate variables important to capture fisheries and aquaculture at different locations have varied over the decades, sometimes showing distinct long-term trends. Rising temperatures are the most consistent trend [1], while increases in rainfall intensities have also been documented [26, 27]. Across Thailand, the number of warm days increased by 3.4 days per decade, and of warm nights by 3.5 days per decade [1].

According to the Intergovernmental Panel on Climate Change (IPCC), mean annual temperatures across Southeast Asia have increased 0.14^{o}C-0.20^{o}C per decade since 1960 (Atlas-59) [28]. Analyses for meteorological stations in Thailand for 1970-2006 indicate increases in mean temperature of 0.1^{o}C-0.4^{o}C per decade [1]. Sea surface temperatures in the Andaman Sea increased between 1982-

2014, with warmest temperatures influenced by the El Niño-Southern Oscillation (ENSO) [29]. In April 2016, a strong El-Niño event resulted in record extreme high surface air temperatures over water and land across mainland Southeast Asia [30]. Historical highs in April also occurred in El-Niño years.

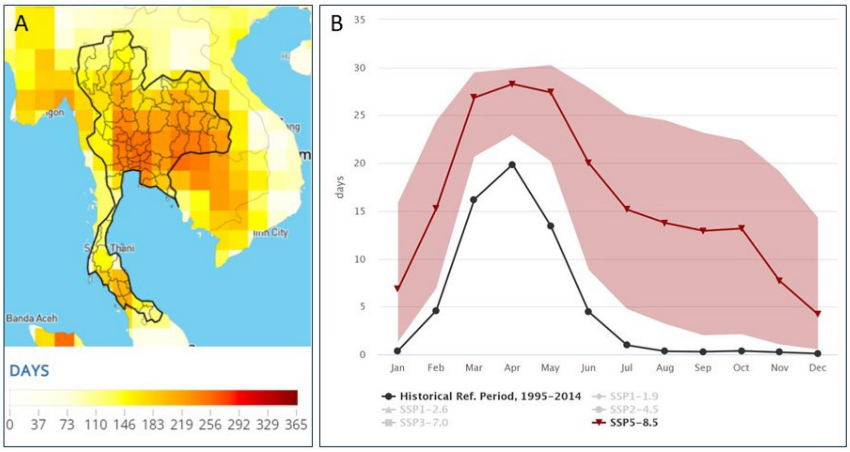
The IPCC special report on oceans concludes that the ocean is warming, with a rate of heat uptake more than doubling since 1993 (p9) [31]. Warming is also causing losses of oxygen from the ocean, while the increased absorption of CO_2 has driven surface acidification (p9 or A.2 SPM) [31].

Average daily rainfall intensity across Thailand has increased by 0.24-0.73 mm day^{-1} $decade^{-1}$, whilst the number of rain days has decreased by 1.3-5.9 days per decade [27]. The IPCC Sixth Assessment Report notes that rainfall intensity has increased in most countries in Southeast Asia, while the number of wet days has declined (11.4.2) [28].

3.1.2 Future projections

Average daily temperatures across Thailand are projected by a set of models to increase on average by 3.8°C by 2080-2099, relative to 1986-2005 period under the business as usual Representative Concentration Pathways (RCP) emission scenario RCP8.5, and by 1.9°C in the RCP4.5 scenario [28, 32]. Projections for mainland Southeast Asia suggest that record high extremes in April will continue as global warming progresses [30]. This is evident for Thailand in the latest findings in the sixth assessment report [28], where days with high maximum temperatures will be greatest in the Central and Northeast regions (Figure 7A), and most frequent in March-May (Figure 7B).

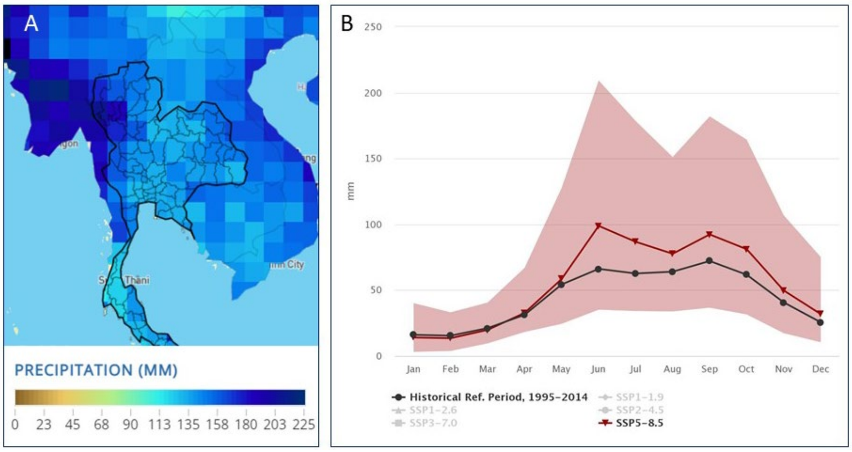
Figure 7 Days with maximum temperature > 35°C in Thailand projected for 2080-2099 under SSP5-8.5 using model ensemble. Source: https://climateknowledgeportal.worldbank



Projections of precipitation under possible future climates are more variable in space and uncertain than for temperatures. Some Global Climate Models (GCMs) struggle to simulate rainfall seasons and spatial patterns (Atlas 5.4.3) [28]. Annual mean precipitation trends for Thailand were not significant (Atlas 5.4.2) [28]. CORDEX set of regional model simulations project an increase of 20% mean rainfall in December-February (a very dry period) by 2100 over northern central Thailand under RCP8.5 assumptions, whereas during June-August drier conditions are projected (Atlas 5.4.4). Meteorological droughts are projected to increase in Southeast Asia at 4°C of global warming [28].

Many studies suggest that extreme events – droughts, floods, windstorms – will increase in severity or frequency [33]. Regional climate models (RCMs) covering Southeast Asia suggest fewer but more intense tropical cyclones (p11-96) [28]. Under most scenarios, projected rainfall for June-September increases in mid and long-term, as does runoff (Section 8.4.2.4.1) [28]. Thus, increased river floods are projected for Southeast Asia. Extreme precipitation is projected to intensify (11.4) [28]. The projected largest 1-day precipitation in Thailand in the IPCC Sixth Assessment Report [28] datasets is highest along western border with Myanmar (Figure 8A), but only marginally higher than historical reference period in the wettest months (Figure 8B).

Figure 8 Average largest 1-day precipitation in Thailand projected for 2080-2099 under SSP5-8.5 using model ensemble. Source: https://climateknowledgeportal.worldbank



Sea levels for 2081-2100 are projected to rise above those for 1995-2014 by 0.8-1.0m under SSP5-8.5 (TS93) [28]. Sea level rise at the mouth of the Chao Phraya River, after taking into account land subsidence due to groundwater extraction, is projected at 1.07-1.18 mm $year^{-1}$ out to 2100 under RCP8.5 [34]. Subsidence and sea level rises, not large dams or expansion of aquaculture, were main drivers of rapid retreat of the Chao Phraya Delta over the last couple of decades [35].

3.2 Fisheries

3.2.1 Marine capture fisheries

Climate-related risks of concern include storms, increasing sea water temperatures, and ocean acidification. The impacts on capture fisheries of these risks have rarely been studied in Thailand.

In 1997, tropical cyclone Linda, with wind speeds over 25 m s^{-1} and storm surge caused loss of life at sea, as well as damage to fishing gear, fishing boats, and coastal infrastructure in the Gulf of Thailand, making landfall in Nakhon Si Thammarat province [36]. In January 2019, Tropical Storm Pabuk also made landfall in Nakhon Si Thammarat, causing damage to the fishing industry, as well aquaculture farms along the coast in several provinces [37]. The storm also damaged coral reefs in Malaysia [38]. Sustained wind speeds of 20 m s^{-1} were recorded. It should be emphasized that tropical storms are rare in this southern region.

Squid fishers lose traps to strong waves and currents. Many traps continue to kill fish and crustaceans – what is known as ghost fishing [39]. In addition to damaging boats and fishing gear, storms also impact the homes of fishers in low-lying coastal areas. For island communities along the Andaman coast, Southern Thailand, climate stressors that rated highly included extreme weather events and changes in rainfall patterns or seasons [40]. Planning how, when, and where to fish depends on many things, especially the phase of the moon, tides, whether it is the rainy or dry season.[003] "*If the seasons change it would greatly affect plans for fishing*."[003] An academic argued that "*changes in seasons will have a significant impact on planning harvests of aquatic animals,*" for example horseshoe crabs, which in the hot season are buried under the sand.[003]

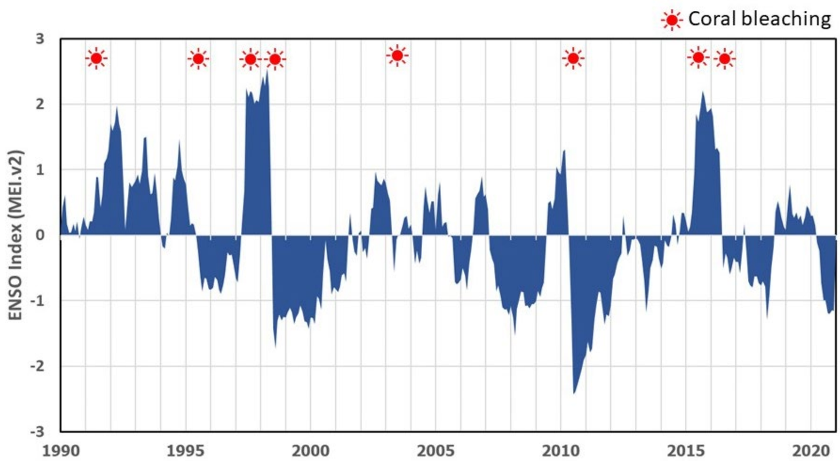
Fishers in Chumphon province perceived trends of increasing air and sea temperature, precipitation over land and offshore, and storms [41]. Perceptions of increased temperature and precipitation are consistent with 30-year trends in instrumental records. Based on shared experiences, fishers are sensitive to unusual changes in wind direction or timing of storms.[004] According to a researcher who worked with local fishers, "*In the case of heavy rain or a storm, the impacts are not so much on the resource; it's about getting out to fish and back in.*"[004]

The importance of climate variability to key habitat supporting fisheries is illustrated by the impacts of decadal fluctuations in the ENSO and Indian Ocean Dipole. Coral reefs in the Andaman Sea at Phuket contracted sharply in the El-Niño years of 1997, 2010, and 2019 – due to lowering of sea level in 1997 and extreme sea temperatures in the other two years [9]. The IPCC Fifth Assessment Report projects spatial shifts in distribution of marine species with local extinctions in the tropics, and a 40-60% decline in fisheries yields by 2055 relative to 2005 [2].

The IPCC special report on oceans concludes that ocean warming, through impacts on fish growth, reproduction and survival, already impacts fisheries catches (p451) [31]. Oceans are also acidifying and losing oxygen (p450) [31]. Ocean warming and acidifications will have more direct and greater impacts on fisheries than sea level rise (p381) [31]. Ocean acidification combined with warming poses serious threats to coral reef ecosystems and associated fisheries (p35) [2]. Sea level rise could exacerbate impacts of storms on fishery infrastructure like jetties and coastal processing or storage facilities (p381) [31].

Coral bleaching events in the Andaman Sea coastline [10], for example, are often associated with El Nino phase of ENSO (Figure 9) and warmer than usual sea surface temperatures above 30^{o}C. Low sea levels can also cause bleaching, while high sea levels may partly offset high temperature effects [9, 42].

Figure 9 Two-monthly ENSO Index scores for 1991-2019 and coral reef bleaching events in Andaman Sea, Thailand. Authors own analysis using Multivariate ENSO Index Version 2 (MEI.v2) from: https://psl.noaa.gov/enso/mei/ Coral bleaching events up to 2012 based on [10] and after this on [9, 42, 43].



A global review of published studies on marine fisheries found that climate changes often amplify the impacts of local stressors at the species level, whereas at trophic and ecosystem levels, climate changes both reduce and intensify local stressors [44]. A Thai researcher concluded that so far, "*there is less fish than compared to 40-50 years ago, but it is not because of global warming; it's probably from overfishing or destroying habitats.*"[053] More work is needed on modelling these interactions over time.

3.2.2 Inland capture fisheries

At the regional level, inland capture fisheries, like that in the Mekong River Basin, are likely to continue to be vulnerable to multiple threats, including dam construction, water abstraction and irrigation diversions, draining of wetlands, and pollution [45]. Climate changes will exacerbate these impacts (p1355) [2]. In the case of inland capture fisheries dependent on wetlands and floodplains, floods may be beneficial rather than a source of losses, and changes in flood regimes – such as loss of the flood pulse – a greater problem than floods [46, 47]. There has been very little research on climate-related risks and impacts on inland fisheries within Thailand beyond the mainstem of the Mekong River.

In the wet season (June-October) about half of the Lower Songkhram River Basin is wetlands or rice fields, supporting a large and diverse capture fisheries [48]. How land use and climate change individually and jointly impacts streamflow and quality were studied under RCP4.5 and RCP8.5 climate scenarios, and contrasting economic and conservation land use scenarios [49]. Together the factors decreased future streamflow by 16% and increased nitrate nitrogen loading by 24%. The consequences for fisheries were not directly addressed in this study but would be large. Water bodies and ecosystems that support inland fisheries are under multiple stresses, from water extraction or diversions, though habitat degradation, pollution, and introduction of non-native invasive species [50].

Fishers in Songkhla Lake basin perceive that fisheries are impacted by climate variability, with reduced number of fish, diversity of fish, loss of mangroves, change in salinity levels, and in flow of water pollution among the important adverse impacts [51]. The authors suggest that irregular rainfall, abnormal storms, with severe flooding is likely to be important types of variability. Fish and shrimp catches from Songkhla Lake for the period 2003-2016 are highly seasonal, with the peak in the wet season months (September-November) [52]. Interannual variability in fish and shrimp landings was also substantial and attributed to regional climate variability.

3.3 AQUACULTURE

Climate-related risks to production or profitability of fish and shrimp farms include discrete events such as abrupt changes in temperature or salinity, heat waves, cold spells, intense rainfall events, floods, low dissolved oxygen episodes, and windstorms [53]. Sea level rise, ocean warming, and ocean acidification are slower, on-going changes likely to become important to marine aquaculture [53]. The relative importance of such risks varies with location, water management, and rearing system.

3.3.1 Inland aquaculture

Understanding of risks by fish farmers comes mostly from personal experience of the impacts of extreme weather events or unusual seasons, and observations of water and climate conditions over multiple years. Thus, in 2011, 65% of fish cage farms in the Ping and Nan rivers in Northern Thailand suffered significant losses from floods (or high flows), with the economic losses from just fish deaths averaging 81,000 Baht per farm [54]. In 2012, 44% suffered from drought (or low flows), at an average loss of 63,000 Baht per farm due to fish deaths. Apart from deaths, damage to cages, slow growth, and disease were also attributed to extreme high and low flow conditions [54].

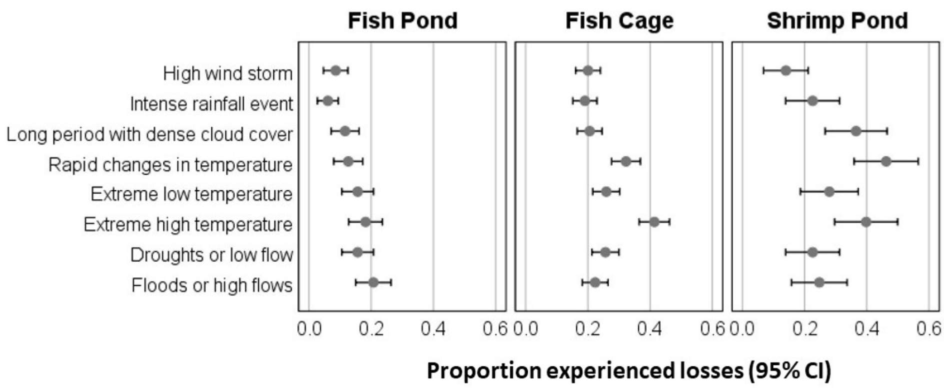
The operation of water infrastructure, for example, to support irrigated agriculture in otherwise dry months, modifies river flow regimes in Northern Thailand. Risks of low flows to river cage culture in the Upper Ping follows seasonality of rainfall, whereas in the Nan River it is strongly distorted by operation of infrastructure for hydropower and irrigation diversions [54]. Northern river cage farmers interviewed perceived that risk from droughts or low river flows has worsened over the previous two decades [55], consistent with peak and minimum discharges of the Ping River at the monitoring station in Chiang Mai city [54].

Northern reservoir cage farmers perceive that climate is changing [56]. Cage culture in reservoirs is impacted by drought (32%), heat waves (45%), cold spells (51%), and periods with dense cloud cover (50%) [56]. Median value of losses in last fish crop across all extreme weather events was 28,000 Baht per farm impacted, or 32% of household income [56]. Fish farmers were also concerned with risks from heavy rainfall, strong winds, and when deep waters (low in dissolved oxygen) rose to the surface.

Recurrent mass mortality events show that fish farmed in cages in rivers are vulnerable or at risk from water pollution [57], illegal wastewater disposal, boating accidents, and run-off from urban, industrial and agricultural land uses after first heavy rains for a period [58]. A study that monitored water quality over a decade in canals supplying shrimp farm areas in Bangkok and Trang suggests that shrimp farms are also at risk from polluted run-off from urban areas [59]. Although there were few significant correlations between water quality and climate variables, the authors conclude that "*farmers and stakeholders should be highly aware of climate change impacts on shrimp production and … monitoring to protect pond water from fecal and organic pollution*" [59].

The likelihood of having experienced significant losses from various climate-related disturbances varies with rearing system and between countries (Figure 9). Farming fish in ponds, in general, were less likely to have suffered losses than those rearing fish in cages in rivers or reservoirs or freshwater shrimp in ponds [60]. Rapid changes in temperature posed the biggest challenge in the latter systems.

Figure 10 Proportion (and 95% confidence intervals) of fish or shrimp farmers who have ever experienced significant impacts (losses) from climate-related disturbances. Farms in Northeast Thailand (n=686). Source: Survey by the authors in 2018 documented in [60].



Few studies in Thailand have explicitly assessed how projected changes in climate may impact capture fisheries or aquaculture. A study of the potential impacts of climate change on hatchery production of tilapia in Northern Thailand showed that projected warmer temperatures would result in gains in production at more northern and higher elevation situated government hatchery stations, and losses at more southern and lower elevation sites [61]. The study used empirically derived equations for the temperature effects on fecundity, hatching, and survival under the scenarios RCP8.5 and RCP4.5 for 2040-2059 and 2080-2099 [61].

3.3.2 Coastal and marine aquaculture

Coastal aquaculture is affected by heavy rain and floods. Shrimp farms in the Bang Pakong River Basin are vulnerable to damages and losses by floods when tropical storms result in 10-day cumulative rainfall above 250 mm and highly vulnerable above 300 mm [62, 63]. Impacts may extend offshore. The cultivation of blood cockles in Surat Thani province for the domestic market is sensitive to climate variability and water quality [64]. Monsoonal flooding in 1996 resulted in yields falling below 10% the next year and cultivated area to less than 4% of previous values. In several other years, heavy rains in the wet or dry seasons caused major losses (1988, 1993, 2008, 2011). Drought, strong winds, and waves also caused significant damage. The Department of Fisheries rules for disaster compensation, according to the authors of the study, were developed for shrimp farming and difficult to apply to bivalve mollusks cultivation [64].

Warming of oceans and inland waters is likely to be causing changes in the distribution of cultured species. This may also result in changes in the distribution of diseases and pathogens [53]. While warmer temperatures may result in faster growth rates (in cooler areas), they may also change feeding efficiency and effect maturation [53].

Disease is already a major constraint on aquaculture production. Climate is known to be important for the outbreak and spread of diseases in aquaculture. The incidence of white spot disease in shrimp in Chanthaburi province was associated with lower temperatures and increase variability in daily temperature [65]. The study carried out in 2009-2014 found most cases occurred between October and February. WSD is caused by the white spot syndrome virus (WSSV). Another study in Rayong province found that inclement (stormy) weather was associated with WSD [66].

In the tropics, diseases are expected to accelerate, while extreme high temperatures are expected to weaken immune system responses [53]. According to a private sector expert in Thailand, warmer water temperatures would support faster growth of bacteria and phytoplankton, causing water quality to be more variable. This would have "*major impacts on the yield of shrimp and fish, both quantitatively and qualitatively*."[002] More work on risks and impacts in Thailand is needed.

Sea level rise may result in salinity intrusion in coastal areas, leading to shifts in types of aquaculture practiced (p381) [31]. Thus, just over half of the aquaculture farmers surveyed in Nakhon Nayok Province identified salinity increases, drought, and floods as key stresses [67]; just under half also do increasing and decreasing water temperatures as important stresses. In response, sometimes switched from monoculture white shrimp to various forms of polyculture. Others switched species to better match saline conditions [67]. A study of the vulnerability of a coastal fishing community in Chanthaburi province to sea level rise of 0.50 m estimated that it would result in inundation of 2,060 households and 88 km^2 of land, 65% of which is low-lying shrimp ponds [68]. Mangrove forests covering 13% of the studied areas would also be at risk of degradation, threatening local fishery stocks and fishing livelihoods [68].

3.4 LINKAGES

The impacts of climate and extreme events on other dimensions of food systems – including supply and value chains – have rarely been studied in Thailand. Extreme events such as floods can impact transport logistics. The major floods of 2011 provide some evidence [62, 69]. The effects of the recent COVID-19 outbreak on aquaculture activities provide further insights into the resilience of the sector to disrupted mobility and logistics [70].

Farmed fish production depends on the availability of low cost fishmeal and fish oil as key ingredients in fish feed [14]. Uncertainties persist in how climate change may impact key upwelling systems that typically supply the bulk of the catches used in making feeds (p1702) [71]. Comparing fisheries and aquaculture, extreme events are of relatively greater concern to aquaculture, whereas slow-onset and long-term shifts are greater concerns for fisheries.

4 CLIMATE RESILIENCE

CHAPTER SUMMARY Climate-related risks to the productivity and profitability of aquaculture are actively managed by fish farmers at the production unit level or collectively with other stakeholders at watershed or coastal zone scales. Adaptation is already underway. Resilience of fisheries is enhanced by diversification of species fished, gear used, times and places fished, and having multiple income sources. Fish conservation areas help maintain sources of renewal from which a disturbed site may recruit and recover.

Climate resilience is defined in this report as the capacity of a social-ecological system to handle climate-related risks and impacts to sustain livelihoods and food provision. Climate resilience has several dimensions. The capacity to manage climate-related risks and impacts is the first entry point into climate resilience, as it is highly relevant to today's climate, whether it is changing or not. Risks may be reduced by choice of sites or timing, and thus lowering exposure, or impacts might be reduced by protection measures that lower sensitivity or absorb impact. Irrespective of efforts to manage risks, significant impacts will sometimes occur. The capacity to re-organize and recover following climate-related disturbances is thus also a dimension of climate resilience. If over decades climate changes – for example, warmer night-time minimum temperatures – then the challenge of responding becomes greater, and the capacity to adapt to changing climate conditions becomes relevant. If changes are rapid or in unanticipated directions, then the capacity to innovate and transform becomes important for climate resilience [72]. Finally, as the impacts of climate change are likely to be larger on poorer, small-scale fishing and fish farming households, it is important that enhanced capacities for climate resilience are accessible to all.

Fish farmers and fishers respond to perceived climate-related risks and experienced impacts with practices that help reduce risks, enhance capacities to recover, support adaptation and innovation to climate changes (Figure 1). Apart from individual actions, collective actions and support from other stakeholders may also be important to enhancing climate resilience. In this chapter, we examine the evidence for how these actions have already, or might in the future, aid responses to climate changes in the fisheries and aquaculture sectors.

4.1 MARINE FISHERIES

The likely continuing decline of live coral cover under pressure from coastal pollution, overfishing, ocean warming, and acidification, the IPCC concludes, will further increase the vulnerability of small-scale fisheries (p702) [71]. Vulnerability of small-scale fishers households might be reduced by building social resilience and diversification of livelihoods (p88) [2]. Thus, fishers in Chumphon province adapted to changes in climate (e.g. more severe or frequent storms) that impacted their fishing by adjusting fishing time, fishing further away, and diversifying into rubber, oil palm or fruit trees or ecotourism [41]. Small-scale fishers in the Gulf of Thailand perceive themselves as more resilient to declining fisheries if they are able to find other work, learn new skills, compete effectively, and cope with change [73]. A higher education and living in urban areas were associated with greater resilience. Climate resilience is enhanced by diversification of species fished and having incomes from beyond fisheries sector [74].

A study of coastal communities along the Andaman Sea in which fishing livelihoods were prominent, concluded that adaptation "*needs to be planned for now not at some distant point in the future*"

[40], based on the importance given to climate-related stressors. Another study in a subdistrict of Krabi province took a participatory process to identifying impacts of sea level rise and prepared an adaptation plan for local government to consider including in their strategy [75]. To cope with sea level rise inundation effects on fishing, households responded that they would draw on local knowledge to adjust fishing times and gear [75].

The IPCC special report on extreme events [76] strongly underlines the many ways improving management of risks from extreme events contributes to adaptation to climate change. Ecosystem-based adaptation, for instance, mangrove conservation and restoration, may simultaneously reduce risks to coastal fishing communities from extreme events, conserve biodiversity, and contribute to sustainable fisheries and livelihoods (p355) [76]**.**

The IPCC Fifth Assessment Report argues that enhancing ecological resilience of the marine environment may reduce or delay the effects of climate change (p1710) [71]. Recent modelling studies of global fisheries biomass, catch, and profit suggest that reforms that enable climate-adaptive fisheries management could offset impacts of climate change under the two least severe scenarios examined (RCPs 4.5 and 6.0), but not the most severe (RCP8.5) [77].

The IPCC special report on oceans suggests "*reduction of pollution and other stressors*" will, at least initially, help cope with ocean acidification (p542) [31]. A review that finds needs for adaptation options for small-scale and industrial fishers argues that many "*impacts on tropical fisheries would be prevented if greenhouse gas-mitigation actions keep global atmospheric warming below 1.5°C relative to pre-industrial levels*" [78]. Another review concludes that putting an end to overfishing alongside reducing the adverse environmental impacts of fishing practices "*would make fish stocks and marine ecosystems more resilient to climate change*" [79].

For some fish species, climatic refugia may offer a way to conserve species within a region [44]. The Southeast Asian Fisheries Development Center (SEAFDEC) and Department of Fisheries in Thailand have collaborated on a project to establish a regional set of fisheries refugia, including sites in Trat and Surat Thani provinces in the Gulf of Thailand [80]. Various forms of fish conservation areas help maintain sources of renewal from which a disturbed site may recruit and recover. Following coral bleaching events, studies elsewhere in the world have shown that restricting the types of fishing gear used can improve recovery, while still allowing local fishers to catch fish that are not coral dependent [81].

4.2 INLAND FISHERIES

In the case of inland fisheries, another consideration is that men and women make use of wetland resources in different ways. Men fish in deeper parts, using gill nets or cast nets, whereas women fish closer to shore using scoop nets, barrage nets or lift nets [82]. Details of climate risk management and adaptation can be expected to differ as well. The authors of a study on the impacts of climate variability on fisheries in Songkhla Lake basin suggest several adaptation strategies, including enforcing laws and regulations, community learning about climate, and strengthening community networks [51].

Climate change is likely to cause changes in species composition in tropical inland water bodies [50]. Water bodies and ecosystems that support inland fisheries are under multiple stresses, from water extraction or diversions, though habitat degradation, pollution, and introduction of non-native invasive species [50]. Inland fisheries aimed at providing food may change function and serve recreational fisheries [83].

4.3 AQUACULTURE

In aquaculture, responses may take place on different time and space scales (Table 1). At the shortest time scale, immediate responses to conditions might range from minutes to hours. Intermediate tactics are responses over the course of a season, for example, decisions on when to stock fish and harvest them.

Table 1 **Time and space scales for management of climate-related risks relevant to adaptation in aquaculture.** Modified after: [84]

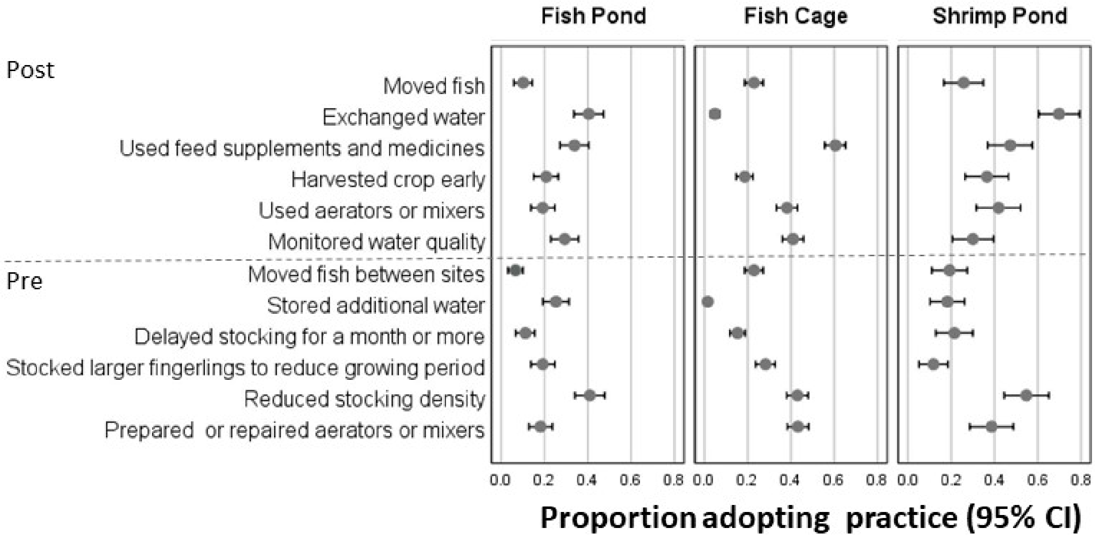
Risk management scales	Short Reactions (Hours)	Intermediate Tactics (Days-Weeks)	Longer Strategies (Months-Years)
Production unit – household	Early harvest Relocate cages to near banks Emergency aeration	Adjust stocking size, density, start date, harvest date Share rearing knowledge	Invest in aeration and automation Move production indoors Move or rent new site Livelihood diversification
Watershed – river section	Share warning information on rainfall, river flows, diversions Water pollution incidents	Management of water infrastructure Lobbying for releases or extra storage	Wetland restoration Operating rules of water infrastructure New zonation rules Former growers' groups
National – Sectoral	Emergency relief	Disaster compensation and assistance Water quality monitoring	New species trials Genetic improvement programs New insurance schemes
International – rivers or trade	Transborder flood or high flow warnings	Sharing information about disease outbreaks Negotiate on trade disputes	Collaboration on disease management Collaboration on invasive species and conservation Negotiate sustainability standards

4.3.1 Shorter-term measures

River cage farmers in Northern Thailand manage climate-related risks by adjusting stocking calendars, altering rearing practices, adopting information technologies, and taking financial or social measures [84]. Several practices and strategies may be combined to address a specific risk, while a particular practice may be relevant to managing several different climate-related risks [84]. Fish farmers manage risks they perceive to be manageable. Thus, many climate-related risks in reservoir cage culture are managed in the short-term by adjusting feed routines and applying aeration, and in the medium-term by adjusting stocking densities or seeking new information on how to reduce risks [56]. Fish farmers also seek to maintain good relations with other stakeholders like reservoir managers, as these are important for risk management [56].

Climate-related risks to fish pond and cage culture in Northeast Thailand are managed alongside market and disease risks [85]. Important decisions are made prior to stocking a pond or cage, and again once rearing has begun (Pre vs. Post, Figure 10). Moreover, effective climate risk management does not just depend on actions on individual farms, but also measures at greater spatial (watershed) or administrative levels (Table 1). Examples include lobbying for new water infrastructure or dry season water releases. Adaptation to water-related climate issues requires going beyond the aquaculture sector to the management of catchments and coastal zones [86].

Figure 11 Proportion (and 95% confidence intervals) of farms having adopted various practices to manage climate-related risks. Pre = pre-stocking. Post = post-stocking. Northeast Thailand (n=686). Source: Survey by the authors in 2018 documented in [60].

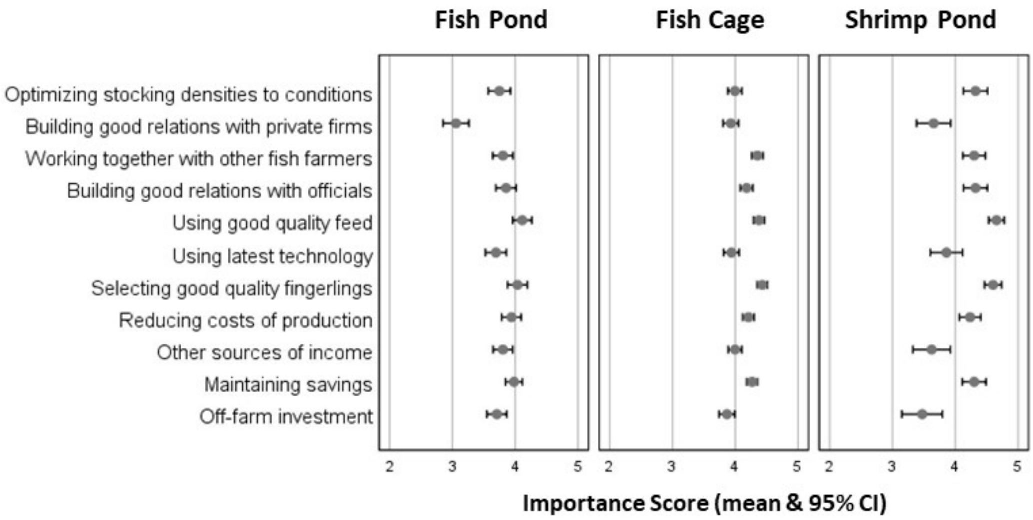


Shrimp pond farms in Chachoengsao province responded to the risks of damage from floods by increasing the height of dikes (67%), using nets to prevent escape of shrimp (57%), and harvesting shrimp early (31%) [62]. A few farms adjusted rearing calendar to avoid the high risk September-October period [62] – another important option, alongside netting, for farms with limited financial resources [63, 87].

4.3.2 Intermediate term

The importance of social relations – other farmers or officials – to maintain yields and profits suggests that they are sources of social resilience (Figure 11). Having other sources of income and savings were also important underlining the role of finance in climate resilience. Not surprisingly, choice of stock and feed were also very important to profits.

Figure 12 Mean importance score (and 95% confidence intervals) given by farmers for various tactics and strategies to manage climate-related risks. On scale of 1 (not at all important) thru 5 (very important). Northeast Thailand (n=686). Source: Survey by the authors in 2018 documented in [60].



4.3.3 Longer-term measures

Longer-term responses include construction of water infrastructure, genetic improvement programs, novel rearing systems, and major changes in the location of activities. Selective breeding may help adapt to some climate change stresses, but the rates and limits of adaptation are not well characterized [53]. Farmed fish production also depends on hatchery techniques being developed to rear a species in captivity, acclimatize juveniles to expected environmental rearing conditions, and genetic improvement of stock. Genetic improvement programs often target faster growth, but may also aim to improve disease resistance, salinity or thermal tolerance.

One way to approach adaptation is through domestication,[005] which can be a difficult and long process. Moreover, some practices such as domestication to standardize production may reduce genetic variability available to adapt to climate stresses. Another related one is acclimatization or epigenetic adaptation [88], for example, by early exposure of nursery stock to a stressor such as less (or more) saline conditions. Increasing the tolerance to environmental conditions increases climate resilience by reducing sensitivity, and thus risks of significant impacts.

Restoration of mangroves to create integrated mangrove-shrimp systems increases climate resilience by providing protection to aquaculture activities from cyclones, sea level rise, and storm surges [89]. Aquaculture may itself be an adaptation, for example, as certain areas become more prone to inundation.

Awareness and capacities to adopt risk management practices vary. Wealthy, more educated farmers who belong to growers' groups adopt more risk management practices, for example, aeration-circulation or information communication technologies [85]; they also recognize the value of climate change adaptation strategies. Large reservoir cage farms agreed with more proposed adaptation strategies to future changes in climate than small farms, for example, on the *need to adapt to current climate variability* and to *try new farming methods* but not to *diversify* [56]. Finally, several studies suggest significant gender differences in perceptions of risk and their management [90].

5 POLICY ENVIRONMENT

CHAPTER SUMMARY Existing laws, regulations, and policies already contain many of the elements needed for an effective policy response to climate change in fisheries and aquaculture in Thailand. The Climate Change Master Plan makes suggestions on zoning to protect nursery habitats, use of calendars to navigate seasonal risks, and adoption of innovations that would contribute to climate resilience. The Inland Fisheries Action plan includes awareness campaigns aimed at fishers, a response system for newly emerging diseases due to climate change, and studies of impacts on fish migration and reproduction.

This chapter examines how existing laws, regulations, policies, and plans respond to climate change risks and impacts in fisheries and aquaculture in Thailand. Three lines of evidence are considered. First, cross-references to key terms or concepts – such as climate change, natural disasters, or floods – in policy documents. Second, the absence of such cross-references when discussing policies or plans for fisheries or aquaculture development where success is likely to be highly sensitive to climate. Third, the views of interviewed experts on policy or plan formulation and implementation. The analysis begins with key national development strategies and climate plans before moving on to fisheries sector laws, policies, and plans (Table 2).

5.1 NATIONAL DEVELOPMENT

The 12th National Economic and Social Development Plan acknowledges climate change impacts food and agriculture exports, and income of poor farmers (p35) [91]. It also notes that climate change aggravates the deterioration of marine resources already impacted by various economic activities, including aquaculture (p57). Thus, one of the flagship projects of the 12th Plan is on "*Preventing Illegal Unreported and Unregulated (IUU) Fishing and Developing Sustainable Fisheries and Aquaculture Systems*" (p131) [91]. The 12th Plan also refers to "*The Environmentally-Friendly Coastal Aquaculture and Shrimp-Farming Industry Development Project*" (p234). Development guidelines to "*protect marine resources and prevent coastal erosion"* looks to zonation as a way to reduce conflicts between artisanal fisheries and tourism development, as well as conservation (p143). Strategy 3 of the 12th Plan aims to strengthen the economy and underpin sustainable competitiveness, for which a bioeconomy "*requires the development of a risk management system and resilience in the face of climate change*" (p103). Insurance for risks of crops losses due to climate change and adapting agricultural systems are encouraged, the latter through support for research and development, and knowledge transfer (p108-9).

The draft 13th National Economic and Social Development Plan (2023-2027), as in the 12th Plan, lists climate change as a threat to agricultural activities (section 2.1), which might apply to aquaculture. Climate change is considered a major threat to coastal and marine resources needed to maintain fisheries (p72) [92]. Coral reefs are recognized as important nursery grounds (p73). Milestone 1 refers to Thailand as a leading country in high-value agricultural and processed agricultural products, which depends on efficient use of natural resources (p105) [92]. Milestone 11 refers to Thailand reducing the risks of natural disasters and the impacts of climate change, through adaptation in the agricultural sector (p111).

The 20-Year National Strategy (2018-2037) says very little about fisheries or aquaculture; in one place promoting fishery resource assessment and need to accelerate marine aquaculture development (4.2.4) [93]. Climate is mentioned much more frequently, for instance, in relation to reducing losses and damages from disasters through weather forecasts and warning systems (4.3.2). It also calls for "*enhancing people's capacity to cope with and adjust*" (4.3.2). The Strategy also notes the importance of developing response systems to emerging infectious diseases arising from climate change (4.3.4).

Table 2 National policies, laws, and plans examined in this study.

Policy or Plans	Year	Responsible agency	Main Goal
National development			
12th National Economic and Social Development Plan	2017-2021	Office of the National Economic and Social Development Council [91]	Comprehensive 5-year National Development plan
13th National Economic and Social Development Plan (Draft)	2023-2027	Office of the National Economic and Social Development Council [92]	Comprehensive 5-year National Development plan
20-Year National Strategy	2018-2037	Office of the National Economic and Social Development Council [93]	A developed country with security, prosperity, and sustainability in accordance with the Sufficiency Economy Philosophy
Climate			
Climate Change Master Plan (Revised 2020)	2015-2050	Office of Natural Resources and Environmental Policy and Planning [94, 95]	(Vision) Thailand is immune to climate change with low-carbon growth according to sustainable development guidelines
National Adaptation Plan	2018	Office of Natural Resources and Environmental Policy and Planning [96]	mission refers to developing a research and technology database, raising awareness and mainstreaming climate resilience into development.
Thailand's 3rd National Communication	2018	Office of Natural Resources and Environmental Policy and Planning [25]	Presents Thailand's efforts in implementing climate actions to reduce greenhouse gas emissions and enhance climate resilience
Natural resources			
Strategic Plan for Research and Development in Agriculture and Agro-Industry	2023-2027	Agricultural Research Development Agency [97]	Agricultural and agro-industry sectors grow sustainably through research, technology and innovation with the aim to become a leading country in value-adding agricultural product processing
Water Resources Act	2018	Office of the Council of State [98]	The allocation, use, development, management, maintenance, rehabilitation and conservation of water resources and rights in water
20-Year Strategic Plan for	2018-2037	Ministry of Natural	Strategies for the Ministry

the Ministry of Natural Resources and Environment		Resources and Environment [99]	consistent with the world situation and the National strategy
20-Year Water Resources Management Master Plan	2018-2037	Office of the National Water Resources [100]	A framework to guide the development and optimization of the country's water resource management.
Fisheries and aquaculture			
Royal Ordinance on Fisheries & Amendment (Fisheries Act & Law)	2015, 2017	Office of the Council of State [101, 102]	Protection and control comprehensive framework for fisheries and aquaculture
Marine Fisheries Master Plan	2020-2022	Department of Fisheries [6]	For the development of fisheries in Thai waters and the resolution of problems pertaining to fisheries outside of Thai waters
Aquaculture Master Plan	2017- 2021	Department of Fisheries [103]	Sustainable aquaculture that produces safe and quality food to meet domestic consumer demand and for export
Inland Fisheries Action Plan	2020	Department of Fisheries [104]	Develop participatory management of freshwater fisheries resources to maintain the diversity of aquatic life and support sustainable use

5.2 CLIMATE CHANGE

The revised draft of the Climate Change Master Plan promotes zoning coastal areas for aquaculture and conservation of nursery habitats, and genetic diversity for high productivity and resistance to changes in climatic factors (p70) [94]. Alongside recommendations for livestock and crop cultivation, the Master Plan suggests adjusting cultivation calendars, attention to emerging diseases associated with changes in climate, and measures to address flood, drought, and windstorm disasters (p68). The Plan also calls for promotion and support for fish farmers to adopt modern technologies and innovations, from Internet of Things through to sensor technology and automation. At the same time, it acknowledges the importance of bringing these together with local wisdom (p68) [94]. Fish farmer networks should be built to monitor changes in climate and impacts (p69) [94], and assessments made of the impacts of climate change factors (2.1.11 p69) [94].

The Climate Change Master Plan acknowledges impacts on freshwater and marine fisheries production (p43) [94], and notes that impacts on coral reefs may also impact tourism (p44). In response, it promotes fisheries operations that consider aquatic resources and ecosystems by using fisheries stock assessment in planning (p70) [94]. The Master Plan also supports the establishment of local community groups for management and adaptation of fisheries in their area (p70) [94]. Assessment of ocean acidification and other climate change factors is encouraged (p69) [94]. In the agriculture sector, the Master Plan promotes the development and use of insurance to manage risks from storms, floods and droughts (p69) [94]. The importance of integrated water management to managing climate-related risks is also underlined (p65) [94]. Overall, the Climate Change Master Plan is comprehensive and has sufficient specific and illustrative cross-references to aquaculture and fisheries that it can be acknowledged as a significant part of the enabling environment for strengthening climate resilience in these sectors.

As a follow-up the 2015 Climate Change Master Plan Thailand prepared its National Adaptation Plan (NAP) with a focus on six sectors, three of which are of direct importance to fisheries and aquaculture, namely: water management, natural resources management, agriculture and food security. Under an objective to increasing capacity to cope with and manage climate change risks in agriculture, the National Adaptation Plan (NAP) calls explicitly for *"breeding programs to increase tolerance of fish to higher water temperatures*" and to *"develop fisheries management in line with climate change trends" [96].* Aquaculture is not explicitly mentioned in the document but the reference to breeding programs would seem to fit. The NAP mission refers to developing a research and technology database, raising awareness and mainstreaming climate resilience into development.

Thailand's Third National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) reports on actions taken to reduce greenhouse gas emissions and to enhance climate resilience [25]. Neither fisheries or aquaculture are mentioned.

5.3 NATURAL RESOURCES

In coastal and marine areas, the 20-Year Strategic Plan for the Ministry of Natural Resources and Environment aims to continue to generate income from coastal tourism that is environmentally friendly, as well as export earnings from the fisheries and aquaculture sectors [99]. The plan urges stakeholders to be "*ready to cope with the effects of climate change on the marine and coastal resources and the marine economy*." Working groups will use spatial planning and protection zones to deal with conflicts among different resource users. The inner Gulf of Thailand being an example of success of various maritime provinces collaborating. Aquaculture is not discussed in the Plan. The Plan supports early warning systems to reduce risks of disasters, but does not specifically mention fisheries or aquaculture.

The 2018 Water Resources Act does not mention fisheries or aquaculture directly, but does recognize "*agriculture or livestock farming for subsistence*" as type 1 class of users of public water resources (section 41) [98], which does not have to have a license or pay fees (section 42). Disaster mitigation and ecosystem conservation are also type 1. Three departments are given powers to issue licenses: Royal Irrigation Department (Ministry of Agriculture and Cooperatives); Department of Groundwater Resources, and the Department of Water Resources (Ministry of Natural Resources and Environment) (section 43) [98]. The Ministry of Interior is also given significant powers over land uses, which might impact water resources (section 74) [98]. Climate change is not mentioned.

The Office of the National Water Resources was established in 2017, drawing initially on staff from the Department of Water Resources and the Royal Irrigation Department. The 20-Year Water Resources Management Master Plan (2018-2037) mentions fisheries twice and aquaculture three times as sources of water pollution [100]. Climate change is not mentioned.

The Strategic Plan for Research and Development in Agriculture and Agro-Industry makes numerous references to climate change and fisheries, and occasionally links them [97]. Under strategy 3 on natural resources and the environment, it suggests a program on "*Risk management for the Future*" that includes calls for research to develop insurance and better understanding of climate risks to agriculture, livestock, and fisheries (p237) [97].

5.4 FISHERIES

Fisheries management procedures changed substantially after the 2015 Royal Ordinance on Fisheries [101] was enacted and then amended in 2017 [102], providing a new legal framework (the Fisheries Law) for issuing licenses, catch management, and deterrents for breaking laws. Historically, key regulations to restrict the number of fishing vessels in operation and fishing effort were not implemented or enforced [5]. The Ordinance indicated that fishing should be managed scientifically to maintain a sustainable fishery [5]. The pragmatic decision was made to focus on controlling the number and size of fishing vessels, and the amount of time a vessel was allowed to fish, in turn based on a total allowable catch and total allowable effort and estimates for maximum sustainable yield [5]. Preliminary indications are that total allowable effort seems to work better for demersal fish caught by trawlers than for pelagic fish caught in seine nets [5].

Thailand's Marine Fisheries Management Plan (2020-2022) [6] following on from the 2015 reforms and the previous Marine Fisheries Management Plan (2015-2019), aims to restore fisheries resource to a level that supports maximum sustainable yield, eliminate IUU, and improve livelihoods of artisanal fisheries [80]. The current Plan reports good progress since previous plan (2015-19) on reducing overfishing and IUU fishing [6]; the former has been achieved in part by reducing fishing capacity and fishing effort, and partly by "*rebuilding fish resources through artificial reefs and restocking*" [6]. The maximum sustainable yield model is based on the assumption of equilibrium, and does not take into account environmental changes like climate change (p19) [6]. The model assumes reduction of fish stock is directly related to fishing effort. These limitations are acknowledged by the plan. The Marine Fisheries Management Plan considers climate change one possible contributing cause of resource decline in coral reefs, but it is not included in the primary list of five major challenges to managing marine fisheries resources sustainably [6]. This list is: degraded fishery resources; Illegal, unreported and unregulated (IUU) fishing; habitat degradation and declining biodiversity; poor socio-economic condition of artisanal fishers and communities; and inadequate fisheries management capacity.

The Inland Fisheries Action Plan identifies climate as one of four strategic issues to be addressed by adaptation to reduce loss and damages from disasters and the impacts of climate change (p6) [104]. Stock enhancement programs, for example, are threatened by changes in climate, which impact reproduction and recruitment (p55) [104]. Climate change is also seen as an opportunity to get support (p55) [104]. The Inland Fisheries Action Plan also calls for establishing an adaptive response system for new disease threats caused by climate change. Public relations campaigns are planned to educate communities and fishers affected by climate change impacts on aquatic animals in the Mekong River (p54, p82) [104]. Climate is noted as a risk to carrying out restoration and conservation projects (p64) [104]. A project is also proposed to study climate change impacts upon migration behavior, reproduction, growth, and spawning of economically important fish species (p89) [104].

Fishery Improvement Projects are multi-stakeholder processes often driven by non-state actors. Thus, the Andaman Trawl Fishery Improvement Project developed by the Thai Sustainable Fisheries Roundtable and the World Wildlife Fund brought together various stakeholders, including artisanal fishers, to focus on the management of blue swimming crab, trash fish, and other small fish used in fishmeal [105]. The Gulf of Thailand mixed-trawl Fishery Improvement Project was driven by the Thai Sustainable Fisheries Roundtable with support from the Agricultural Research Development Agency

[106]. Ultimately, these efforts should lead to certification. Fishery Improvement Projects in Thailand do not yet refer to climate change.

5.5 AQUACULTURE

Strategy 3 of the Aquaculture Master Plan (2017-2021) calls for support for research and innovation in aquaculture production to improve economic competitiveness – as part of the "Thailand 4.0" innovative, value-based industrial development model (p35) [103]. Guideline 3.2 under strategy 3 calls for support for research and development of environmentally friendly aquaculture, with specific reference to mitigation and adaptation to global climate change (3.2.1) and zero waste, closed systems (3.2.2) [103]. Elsewhere, the Aquaculture Master Plan calls for all agencies and sectors to work together to restore declining fishery resources affected by climate change (p13) [103].

The Strategic Plan for Research and Development in Agriculture and Agro-Industry also calls for research on high-productivity, climate resistant aquaculture (p239) [97].

The analysis of governance above focuses on rules, regulations, institutions, and policies of governments. Some of the actions by the private sector are also important to the practices adopted by fish farmers and fishers, for example, the introduction of voluntary private standards driven by retailers [107].

6 POLICY FRAMEWORK FOR CLIMATE RESILIENCE

CHAPTER SUMMARY This chapter proposes a policy framework for enhancing climate resilience in fisheries and aquaculture in Thailand. It draws on the foundations provided by the previous chapters, as well as the views of officials, experts, and other stakeholders interviewed. The box below summarizes key elements of the framework.

POLICY FRAMEWORK FOR CLIMATE RESILIENCE IN FISHERIES AND AQUACULTURE

VISION

Fisheries and aquaculture in Thailand become more climate resilient through enhancing capacities to manage climate-related risks, recover from disturbances, adapt to climate, and innovate to transform to changed climates, while making access to enhanced capacities more inclusive and sustainable.

OBJECTIVES AND STRATEGIES

Objective 1: Enhance capacities to manage and reduce climate-related risks and impacts

- Strategy 1. Raise awareness of the importance of climate to fisheries and aquaculture
- Strategy 2. Support development of early warning and risk information systems
- Strategy 3. Share effective climate-related risk management practices

Objective 2: Enhance capacities to recover from the impacts of extreme events

- Strategy 4. Protect and nurture social-ecological sources of renewal
- Strategy 5. Learn from extreme events about how to cope and recover
- Strategy 6. Enable risk sharing and other financial instruments to support recovery

Objective 3: Enhance capacities to adapt to on-going changes in climate

- Strategy 7. Monitor changes in climate and impacts on fisheries and aquaculture
- Strategy 8. Improve fit between institutions and aquatic resources

Objective 4: Enhance capacities to innovate and transform to handle unanticipated changes in climate

- Strategy 9. Support research and innovation on climate resilience
- Strategy 10. Combine different kinds of knowledge for better solutions

Objective 5: Make access to enhanced capacities for climate resilience more inclusive and sustainable

- Strategy 11. Reduce social and gender inequalities in access and allocation of resources
- Strategy 12. Mainstream efforts to enhance climate resilience into sector development

The rest of this chapter elaborates on each of the objectives and strategies. In listing specific topics or activities, the aim is not prescriptive, but rather to provide options and illustrative examples. Some of the activities may already be underway or planned, whereas others fill key gaps.

6.1 MANAGE CLIMATE RISKS

Enhanced capacities to manage climate-related risks are useful under current climate, while also helping to develop the technology and skills needed to prepare for and handle future changes in climate. Capacities needed to respond may differ at the individual fish farm or fishing boat level, as well as collective levels such as the watershed or fishing ground. Three strategies are suggested (Table 4).

6.1.1 Strategy 1: Raise awareness of the importance of climate to fisheries and aquaculture

Our interviews and readings suggest that awareness of the importance of climate to the fisheries and aquaculture sectors is uneven among officials and other stakeholders, making it difficult to start a dialogue to design and support efforts to enhance climate resilience. An official we interviewed, for example, pointed out that understanding of adaptation to climate change among fish farmers may be incomplete, and identifying and filling key gaps in knowledge was "*something that we must hurry to deal with*."[057]

Raising awareness amongst government officials might be done through a training course tailored specifically to the risks and impacts to the fisheries and aquaculture sectors. In terms of content, we suggest starting with recent climate variability and extreme events before tackling future climate change and climate resilience more broadly. An expert working group on climate resilience could be established to help design such trainings and revise them every 3-5 years. A possible second stage of the program could involve trained officials sharing their understanding with provincial offices, fisher and fish farmer organizations, and firms. The latter might be done through a series of online seminars.

Table 3 Strategies to enhance climate resilience in fisheries and aquaculture. Notes on projects ideas, key elements of the enabling policy environment, and potential stakeholders. Ministry abbreviations expanded in table footnote.

Strategy	Fisheries project ideas	Aquaculture project ideas	Policy environment	Potential stakeholders
Objective 1: Manage and reduce climate-related risks and impacts				
Strategy 1 Raise awareness of the importance of climate to fisheries and aquaculture	Training program to raise awareness of ocean warming, acidification and sea-level rise impacts on marine fisheries Establish an expert working group on climate resilience	Training program to raise awareness of recent and future climate impacts on different forms of aquaculture Establish an expert working group on climate resilience	Inland fisheries action plan calls for public education program	Fisheries (MOAC) ONEP (MONRE) Research organizations, CSOs, firms
Strategy 2 Support development of early warning and risk information systems	Conduct a review of experiences with early warning systems and weather services intended for, or used by, fishers Follow seasonal forecasting research to anticipate ocean high temperature anomalies (eg ENSO)	Develop smart phone apps drawing on existing weather services and river monitoring systems Follow seasonal forecasting research to anticipate severe dry seasons for aquaculture	Aquaculture Master Plan calls for early warning system for disease that could include seasonal and other climate variables	Fisheries, Irrigation (MOAC) Disaster Prevention and Management (MOI). Water Resources (MONRE) Marine (MOT) Meteorology (MDES) Fish farmers, fishers
Strategy 3 Share effective climate-related risk management practices	Establish new or use existing online platforms for documenting, evaluating, and sharing climate risk management practices	Establish new or use existing online platforms for documenting, evaluating, and sharing climate risk management practices	12th National Plan calls for development of risk management systems	Fisheries (MOAC) ONEP (MONRE) Fish farmers associations, research organizations, technology firms
Objective 2: Recover from the impacts of extreme events				
Strategy 4 Protect and nurture social-ecological sources of renewal	Establish and protect refugia and nursery habitats Zonation to reduce conflict among resource users Form groups for fishers to enhance sharing and retention of knowledge	Conserve natural stock sources Maintain hatcheries in multiple locations Encourage diversity in rearing systems Stock enhancement programs for inland water bodies Form growers' groups or clubs	12th National Plan offers guidelines to protect marine resources 13th National plan calls for protection of coral reefs as nurseries	Department of National Park, Wildlife and Plant Conservation (MONRE) Fisheries (MOAC) Fisheries associations, biodiversity conservation organizations Local communities

Strategy	Fisheries project ideas	Aquaculture project ideas	Policy environment	Potential stakeholders
Strategy 5 Learn from extreme events about how to cope and recover	Document impacts of storm surges to anticipate implications of sea level rise Contrast ENSO phases to anticipate impacts of ocean warming	Inundation or loss history risk mapping for assessing sites		Fisheries, Agricultural Economics (MOAC) Disaster prevention and management, local government (MOI) Meteorology (MDES)
Strategy 6 Enable risk sharing and other financial instruments to support recovery	Support weather-indexed insurance for losses and damages Review experiences with risk-sharing schemes including different forms of insurance Study the merits and limitations of household livelihood portfolios for recovery when fishing is impacted by extreme events	Support weather-indexed insurance for losses and damages Review experiences with risk-sharing schemes including different forms of insurance Study the merits and limitations of household livelihood portfolios for recovery when fish farming is impacted by extreme events	12th National Plan and Climate Change Master Plan promote use of crop insurance	Fisheries (MOAC) Bank of Agriculture and Agricultural Cooperatives Insurance companies Research institutes
Objective 3: Adapt to on-going changes in climate				
Strategy 7 Monitor changes in climate and impacts on fisheries and aquaculture	Expand network for monitoring sea surface temperatures and other conditions offshore Enhance stock monitoring to enable detection of shifts in distribution related to changes in ocean temperatures	Establish a national monitoring network of automated water temperature observations in representative water bodies in which aquaculture is practiced	Climate Change Master Plan calls for farmers and fishers to monitor changes in climate and impacts National Adaptation Plan calls for fisheries management to be responsive to changes in climate	Fisheries (MOAC) Pollution Control, Marine and Coastal Resources (MONRE) Meteorology (MDES)

Strategy	Fisheries project ideas	Aquaculture project ideas	Policy environment	Potential stakeholders
Strategy 8 Improve fit between institutions and aquatic resources	Expand regional cooperation on the management of cross-border fish stocks in marine and freshwater river systems Include seasonality and inter-annual climate variability in design of fisheries improvement programs Facilitate adaptive co-management of aquatic resources including migratory species	Strengthen coordination across departments and ministries to improve aquaculture water management Include spatial differences and inter-annual variability in climate in resource planning for hatcheries and stock enhancement program Zonation to reduce conflict among users	Climate Change Master Plan calls for stock assessment to guide planning 12th National Plan calls for zonation to reduce conflicts with tourism 20-Year Plan for Ministry of Environment and Natural Resources calls for cooperation among provinces on resource management	Irrigation (MOAC), Water Resources (MONRE) Fishing companies Private hatcheries Thai Sustainable Fisheries Roundtable Local communities
Objective 4: Innovate and transform to handle unanticipated changes in climate				
Strategy 9 Support research and innovation on climate resilience	Provide incentives for private investment in research and development Develop models to assess ocean warming and acidification impacts on distribution of commercially important fish species	Support genetic improvement programs targeting thermal, disease and salinity tolerance Encourage domestication and acclimatization of alternative species Support innovations aimed at increasing control of environmental conditions for rearing	Climate Change Master Plan encourages assessment of ocean acidification Aquaculture Master plan calls for research and innovation to improve competitiveness	Agriculture Economics (MOAC) Fisheries (MOAC) National Innovation Agency National Science and Technology Development Agency (Ministry of Higher Education, Science, Research and Innovation)Private hatcheries, government hatcheries Research organizations
Strategy 10 Combine different kinds of knowledge for better solutions	Involve fishers in technology development and management planning Build capacity for local processing to add-value to production	Involve fish farmers in technology development and management planning Build capacity for local processing to add-value to production	Climate Change Master Plan support use of modern technologies together with local wisdom	Fisheries (MOAC) Technology firms, entrepreneurs Fishing companies, fisheries organizations Research organizations

Strategy	Fisheries project ideas	Aquaculture project ideas	Policy environment	Potential stakeholders
Objective 5: Make access to enhanced capacities for climate resilience more inclusive and sustainable				
Strategy 11 Reduce social and gender inequalities in access and allocation of resources	Include gender and labor rights in licenses, codes of conduct, and regulatory standards Assess gender and social inequality measures of other projects and programs in this framework	Include gender and labor rights in licenses, codes of conduct, and regulatory standards Assess gender and social inequality measures of other projects and programs in this framework	20 Year Plan promotes gender equality and women's role in social development	Fisheries (MOAC) Women in fisheries organization Fishing companies, industry associations
Strategy 12 Mainstream efforts to enhance climate resilience into sector development	Assess contributions to SDGs of other projects and programs in this framework Identify entry points in sector development policies and plans or other opportunities to mainstream	Assess contributions to SDGs of other projects and programs in this framework Identify entry points in sector development policies and plans or other opportunities to mainstream	Aquaculture Master Plan calls for work on environmentally friendly systems	ONEP (MONRE)

[1] MDES = Ministry of Digital Economy and Society; MOAC = Ministry of Agriculture and Cooperatives; MOI = Ministry of Interior; MONRE = Ministry of Natural Resources and Environment; MOT = Ministry of Transport.

6.1.2 Strategy 2: Support development of early warning and risk information systems

Reliable climate-related risk information systems tailored directly at the decision needs of fishers or fish farmers are uncommon, and if developed then rarely maintained beyond pilot projects. At the same time there is highly centralized system of warnings for severe weather conditions and natural hazards that is relied upon by most layers of government. A limitation with the current system of announcements, from the official's perspective, is that "*fish farmers and fishers ignore the advice, as they think the economic benefits outweigh the risks.*"[060]

We suggest beginning with an evaluation and review of these experiences before supporting efforts to tailor services to fisheries and aquaculture. For some areas and activities, commercial climate/weather services may also have potential for expansion or refinement. Thus, for marine capture fisheries, fishers have been using the Windguru product-service for a long time to get reliable information about winds, waves, and rain in the next few hours.[003] Fish farmers with cages in the Mekong receive information about "*whether the Mekong River will rise, or a warning to be careful of heavy rain*" [001] from the Department of Fisheries, which receives the information from the Meteorological Department. Early warnings are really the function of the Department of Disaster Mitigation and the Office of the National Water Resources, but they are unable to reach directly to the fish farmers. The Department of Fisheries can use their farm registration information to contact.[001] An expert interviewed underlined that "*smallholder farmers may have access to less information about, for instance, drought or heavy rain,*"[005] making it important to have services, but also other means to share warnings.[005]

In the mid-term, this strategy includes extending the time frame from hours to days and weeks, with the development of seasonal forecasting skills. Modelling studies suggest, for example, that it will be possible to forecast heat waves in April, a few months in advance, by monitoring sea surface temperature anomalies from ENSO events [30]. Finally, risk information systems may also be developed in the forms of maps or seasonal calendars, and thus say more about climate than imminent severe weather.

6.1.3 Strategy 3: Share effective climate-related risk management practices

Local wisdom and scientific knowledge are both potential sources of practices which help reduce climate-related risks. Local experience-based knowledge, validated by other farmers, is an important source of effective risk management practices, especially at the level of the individual aquaculture farm and crop.

Evaluating and sharing this knowledge should build on existing information sharing activities of grower associations and clubs. In many places, the establishment of online groups using social media platforms offers opportunities. Experts noted that demonstrations of technological or practice innovations on farms to other fish farmers are a powerful tool for increasing adoption, but when based on short-term projects, don't give enough time for others to visit or observe long-term benefits[018]. Less is known about management of climate-related risks in capture fisheries in Thailand. For this reason, the proposed emphasis in this case is on documentation and assessment.

An interviewee pointed out that the "*Ministry of Agriculture has a policy strategy related to climate change and agriculture. There are strategies that involves many areas working together. The key* *strategy is to create a database of technology, knowledge, and innovations*."[005] Something similar is needed for fisheries and aquaculture.

6.2 RECOVER FROM IMPACTS

Not all risks can be reduced to zero through managing exposure and sensitivity (Figure 1). Significant impacts may still be experienced. The notion of being able to reorganize and recover from disturbances is a core element of the climate resilience approach to handling climate change (Table 4).

6.2.1 Strategy 4: Protect and nurture social-ecological sources of renewal

Recovery of fisheries or aquaculture activities following an extreme event can be difficult and slow on the ecological side if there is no juvenile fish available to naturally recruit, or cultured fish to stock, to rebuild devasted populations. On the social side, renewal often requires money to build boats and replace damaged fishing gear or to repair ponds and cages; and maybe more if critical road, water or other infrastructure is also damaged.

An important strategy for enhancing resilience is to protect and nurture social-ecological sources of renewal [108]. For fisheries, and ponds stocked with wild juvenile fish or shrimp, this means conserving some locations as refugia from which recruitment into depleted area is possible.[051] "*Marine aquaculture and fisheries in conservation areas are important to monitor*,"[051] to ensure they remain viable recruitment sources following disturbances. In the Marine Fisheries Management Plan, the Department of Marine and Coastal Resources and the Department of Fisheries commit to collaborating "*to improve the status of critical habitats and rebuild biodiversity*" [6].

For intensive aquaculture, this may be pursued by having hatcheries in different locations than pond or cage rearing areas. In longer-time frames, it is important not to over-specialize or over-standardize. Allowing some diversity in rearing systems and strain diversity protects social (practices) and ecological sources of renewal.

6.2.2 Strategy 5: Learn from extreme events about how to cope and recover

There is widespread recognition of the importance of extreme events to aquaculture and coastal lives, but not the need to learn from impacts of past events and recovery processes. More broadly, natural disasters are seen as exceptional situations rather than a part of normal development.

Extreme events, from impact through to recovery, should be seen as opportunities to learn [108]. Thus, we suggest that different types of natural disasters or major climate-related disturbances be documented and analyzed to gain insights on potential impacts and recovery strategies in the future. For example, mapping impacts and efforts to storm surges on coastal fisheries and aquaculture infrastructure may help improve responses to sea level rise. Comparisons among years with different ENSO phases may help improve understanding of ocean warming impacts and recovery processes.

In situations where uncertainties are large, there may be a need for contingency planning, robust decision-making [109] or other tools for preparing for the unexpected. Coordination between departments in different ministries, for example, those that work on routine programs to develop the fisheries sectors, with other agencies that provide assistance to recover from disasters such as rebuild boats or fishpond embankments, is essential for enhancing climate resilience.

6.2.3 Strategy 6: Enable risk sharing and other financial instruments to support recovery

The conventional response to extreme events is to look for humanitarian aid or donations. The problem is emergency relief is of limited duration and amount, compared to losses and damages that must be addressed for recovery of livelihoods. Thus, compensation is available for damage or loss of produce due to natural disasters.[060] Compensation is partial and only for items indicated in the regulations, and requires the provincial administration to declare an area as disaster-affected. Moreover, "c*ompensation will only occur if registered with the Department of Fisheries. Not fully covered, so many people don't pay attention. More than 30-40% don't register.*"[061]

Introduce weather-indexed insurance and assistance schemes. Insurance schemes should be designed to reward good risk management practices in aquaculture. The legal framework might need some adjustment in order to enable such schemes. Risk sharing might also be done through agreements between buyers or suppliers of stock and producers, or at the community level through a mutual fund. Contract farming can also be thought of as a form of risk sharing, although one in which the risk burden lies more heavily with the farmers than the firm providing inputs and intending to buy the harvest.[006]

National plans encourage development of agricultural insurance, but it is not clear that weather-indexed schemes are understood properly. Experts interviewed felt aquaculture insurance was still a dream[060] and difficult to do[052], but that it could be done by a third party like the Bank for Agriculture and Agricultural Cooperatives (BAAC).[060] The BAAC is in a relatively good position to provide insurance, and already does so for different aspects of rice production.[060] When it comes to aquaculture, "*no one dares to insure it because the damages can be quite high,*"[060] making insurance costs high as well.

6.3 ADAPT TO CHANGES

Capacities to adapt to changing conditions can be enhanced by maintaining flexibility, keeping options open, and monitoring changes (Table 4). The key challenge is deciding what level of change is needed to trigger a response.

6.3.1 Strategy 7: Monitor changes in climate and impacts on fisheries and aquaculture

To adapt it is important to understand how climate is changing and its impacts on fish, fisheries, and aquaculture. Monitoring provides a foundation for adaptive management. Monitoring systems that generate information that fish farmers or fishers can use to manage risks is still relatively undeveloped [110]. In many cases, monitoring is only just beginning. For resource managers, the information needs are even greater, but the key timeseries of ideal data is non-existent.[051]

In the case of marine capture fisheries, expanding the network for monitoring sea surface temperatures is important, as it would allow more detailed modeling of seasonal and ENSO events, as well as exploration of projection of impacts on fisheries due to ocean warming. Improved stock assessment information is needed to evaluate management interventions and improve the sustainability of marine capture fisheries

Most officials interviewed wanted to see clear impacts that could be attributed to climate change before proceeding further. "*For aquaculture it is not yet clear. Because climate change is so fast,* *data collection is incomplete.*"[051] Attribution of single events to climate change is often difficult and is not essential to justify enhancing climate resilience.

6.3.2 Strategy 8: Improve fit between institutions and aquatic resources

Another strategy is to adjust watershed and fishery zone management to better reflect the spatial and temporal scales of aquatic resources and their users. On land, this is about watershed management or storage to meet the needs of aquaculture stakeholders. At sea, this is about adaptive management of fishery resources, for example, the declaration of no-take zones or closed seasons. In both locations, the increasing attention given to ecosystem-based approaches creates opportunities to enhance climate resilience.

Experiences with zoning of cage culture as a governance instrument, based on notion of carrying capacities of particular water bodies, is relevant to responding flexibly to spatially varying climate-related risks. In the past, "*the fish farmer could rear in public waters as they wanted. But at present, the Department of Fisheries has determined, for the public water sources, how much can be farmed there, how far apart should the cages be placed in order to avoid problems in some seasons when there is not enough water to circulate that lead to fish mortality.*"[060] In terms of *"where to place the cage, determining the area, there is a provincial committee consisting of representatives of various departments. They will determine whether can farm or not, how much to farm, whether farmers must register, for instance.*"[060] "*There is now more supervision and monitoring. This has been done for many years.*"[060] More broadly, zoning is a key planning tool to reduce conflict between different inland water and coastal water uses.

Another strategy is to facilitate adaptive co-management of fisheries and water resources [111]. Thus, should include aquaculture stakeholders in water management [112], for example, in river basin committees. The combination of state and non-state stakeholders is expected to lead to more resilient institutions, that is, with capacity to adapt management rules to changes in climate and their impacts on aquatic resources, because the participatory process builds trust among stakeholders. It is important that the government understands climate change, as it is important to fish farmers.[012] Governance of fisheries "*in some places it's just the state, it's not enough, it is also about community*."[003] Cooperation is essential as the "*state has the budget, the villagers are the thinkers*."[003] Implementation of this strategy is challenging, as it depends on attitudes of governments and communities towards governance more broadly. One way to begin would be to review past projects led by non-state actors, as well as those with a more collaborative structure with government.

6.4 INNOVATE AND TRANSFORM

6.4.1 Strategy 9: Support research and innovation on climate resilience

Experienced-based knowledge and practices may become less useful as climate changes go beyond boundaries of experience or anticipation [74]. Existing options for adaptation may be insufficient, enhancing climate resilience may therefore depend on finding novel solutions [113].

The IPCC 5th Assessment Report argues that climate resilience will often depend on innovation [114]. Novel solutions to difficult adaptation problems are more likely if there is adequate financial support and space for research and innovation [113, 115]. Funding for research ideally comes from a combination of public and private sources, with public funds steered towards smallholders and local innovation [113] or emerging issues not yet addressed by local research community, such as ocean warming and acidification [116].

In the case of inland aquaculture, genetic improvement programs, for instance, could be directed towards changing thermal tolerance or disease resistance, but this can be a long and costly process [86]. An alternative would be to encourage domestication, hybridization, and acclimatization techniques for novel stock for culture using promising native species. Another approach is to increase control of the rearing environment, for example, by bringing production indoors where temperature and light conditions can be tightly controlled. Recirculating aquaculture systems may be used to reduce water exchange, making it easier to maintain water quality and reduce disease risks. This might be done for rearing juveniles, for part of the year or for the full production cycle. Moving activities indoors into more controlled environments reduces exposure to many climate variables [89], but creates new vulnerabilities – for instance, dependence on reliable electricity source to support continuous aeration.

Support for these and other research topics may be in the form of research funds or innovation awards. A climate resilience and fisheries working group could help set the agenda and themes for calls for the research proposals, which might be run by one of the national innovation agencies.

6.4.2 Strategy 10: Combine different kinds of knowledge for better solutions

Fish farmers, fishers, firms, and government agencies all hold knowledge important for enhancing climate resilience, but do not always recognize the validity or importance of understanding of other stakeholders. Reviews suggest that when combine different kinds of knowledge, better solutions are often generated [117].

At a minimum, this means recognizing the value of experience-based knowledge of fish farmers and fishers for technology development, option assessment, and resource management. It is also important to combine social, technical, and ecological knowledge. The costs and benefits of alternative strategies need to be evaluated and re-evaluated as conditions change and innovation leads to new options becoming available. Some solutions may lie in the value chain, where knowledge of markets, consumer behaviour, and technical aspects of food preparation and storage need to be combined [118].

This strategy is part of the broader objective of increasing inclusiveness. Educational institutions, "*which may be seen as more impartial and informative*" can convene forums that go beyond the immediate policy agenda.[057] "*But don't just leave education institute to do it alone. Because sometimes there is an aspect of information or a way of thinking about the policy that must be considered. The best way is to try and find a mechanism, a committee with many people coming together to come up with ideas.*"[057]

6.5 ACCESS ENHANCED CAPACITIES

The 5th objective recognizes inequalities in access to resources, and the benefits arising from use of those resources, is an obstacle to climate resilient fisheries and aquaculture development (Table 4).

6.5.1 *Strategy 11: Reduce social and gender inequalities in access and allocation of resources*

Social and gender inequalities are not on most policy agendas in the fisheries sector [119]. The specific concern addressed by this strategy is that women, migrants, and small-scale fishers or fish farmers may not fully benefit from efforts to enhance climate resilience. This might arise from greater obstacles to access natural or social resources, for instance, because of reduced mobility.

In aquaculture, women and men do not perceive the same levels of risk, and are not impacted to the same amount by climate changes, nor do women follow identical risk management practices as men [120]. Gender differences in roles along fish value chains are often large, with women often in selling and processing roles. Marine fishing is a male-dominated activity, while inland and coastal land-based fishing may be more mixed, but still differentiated by gear type. There can also be large differences in capacities and risks faced by small-scale fishers as compared to large commercial fishing fleets.

In response to these potential inequalities, interested stakeholders could assess the designs and implementation of projects and programs in this policy framework from a social and gender inequality perspective. The results would then be fed back to projects for action. Some training by a gender specialist may also be warranted to help both evaluators and project leaders. SEAFDEC adopted a strategy on gender perspectives in 2017 long-term plan [121]. Another more formal and sector wide program would be to make certain gender and labor conditions mandatory criteria in standards that must be met to sell produce.

A pro-active agenda on inequalities is also needed that questions basic assumptions of the purpose of fishing – the resilience of what? For example, could small-scale fishers, rather than being zoned out from tourism areas, instead be the foundation for experienced-based tourism, where visitors learn how to trap, collect, prepare, and eat seafood? Whereby fishing becomes a cultural exchange.

6.5.2 *Strategy 12: Mainstream efforts to enhance climate resilience into sector development*

One of the ways to ensure that efforts to enhance climate resilience in the fisheries and aquaculture sectors are inclusive and sustainable is to integrate them with existing policies on sector development. The process of doing so is sometimes called *mainstreaming*. Analysis conducted a few years ago suggested developing a standalone climate change response policy may be a better approach [122]. This is no longer the case, with a strongly supporting master plan on climate change now available, and master plans for the sectors ready to be elaborated. Furthermore, there is renewed interest in the sustainable development goals in Thailand. Together these provide a lot of guidance for how mainstreaming might be done efficiently. The focus of this strategy therefore, is to ensure that the other 11 strategies lead to policy integration wherever this is feasible. Finally, one of the advantages of looking for mainstreaming opportunities is that there may be some synergies between adaptation and mitigation.

7 IMPLICATIONS FOR LAO PDR

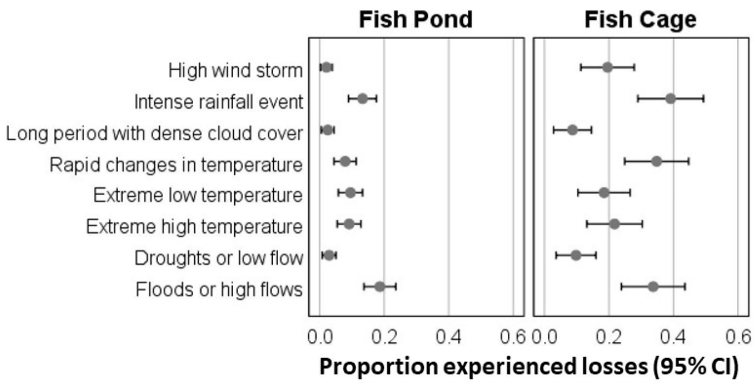
CHAPTER SUMMARY This chapter briefly summarizes the implications of the findings from Thailand for Lao PDR. Some new analyses of survey results for aquaculture in Laos provide some points of comparison with similar work done in Northeastern Thailand.

This study was primarily focused on Thailand. A few of the findings from this study, as expected in the Terms of Reference, help identify issues likely to also become important in Laos.

7.1 CLIMATE-RELATED RISKS

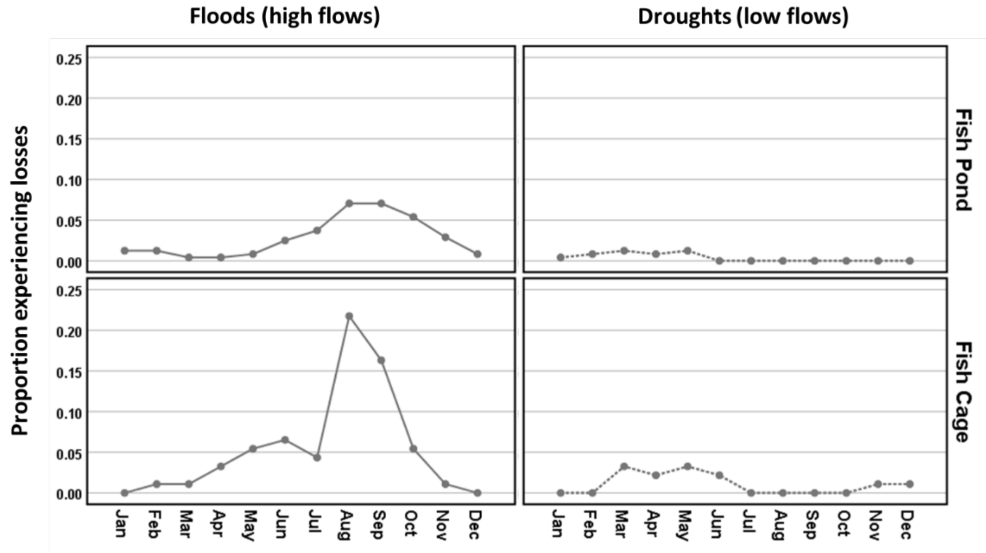
Reflecting similarities in climate (see 3.1), the portfolio of risks faced by fishpond farmers in Laos (Figure 12) is similar to that in Northeast Thailand (Figure 9). The climate of Laos, like that of Northern and Northeast Thailand, is driven by the monsoon with distinct wet (May to mid-October) and dry (mid-October to April) seasons [123].

Figure 13 Proportion (and 95% confidence intervals) of fish farmers who have ever experienced significant impacts (losses) from climate-related disturbances to their aquaculture farm. Laos (n=341). Source: Survey by the authors in 2018 documented in [60].



In the wet season, high flows impact upon cage culture in rivers, while flooding impacts pond culture. Month with greatest likelihood of experienced losses were August-September (Figure 13). In the dry season, access to water resources was a greater challenge in Northeast Thailand (Figure 9) than in Laos (Figure 12). Low flows for cage culture were most important in March-June period (Figure 13). Where drought or low flows are a risk, the stocking calendar needs to be planned so fish are harvested before water shortages impact production (see 4.2.1). In comparison to Thailand, fish farmers in Laos perceived conditions as more benign, and consequently have fewer technical and social strategies to manage climate-related risks (see 4.2.2). In the future, these strategies may become more important in Laos, as the aquaculture sector expands and production systems intensify.

Figure 14 **Proportion of fish farmers who have ever experienced significant impacts (losses) from floods or droughts to their aquaculture farm in each month of the year.** Laos (n=341). Source: Survey by the authors in 2018 documented in [60].

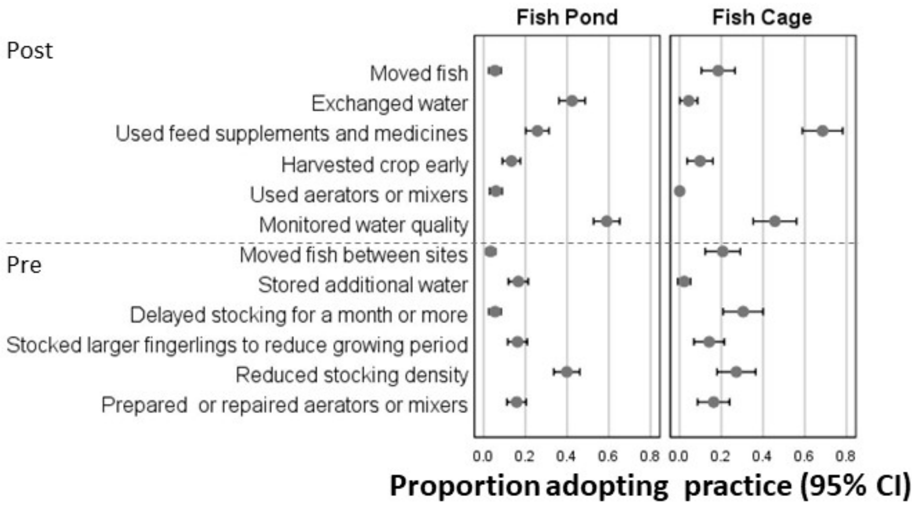


Projections for future climate in Laos are similar to those for Thailand (see 3.1.2). For Laos, projected increase for higher emission scenario is 3.9^{o}C [123]. The intensity and frequency of hot extremes has increased, and is projected to increase further (11.7) [28]. Thus, the probability of a heat wave for Laos increases to over 0.5 at RCP8.5 [123]. Intensity of rainfall is expected to increase, whereas annual rainfall remains unchanged. Warming trends are clearer and expected to continue in the future. Changes to river flow regulation due to operation of water infrastructure for hydropower generation or irrigation diversions, has strong interactions with climate in both countries, with impacts on timing and severity of climate-related risks for cage culture substantial. The impacts on inland fisheries due to water infrastructure are well studied, but more work is needed on interactions with climate in both countries.

7.2 CLIMATE RESILIENCE

The use of technology is one way in which fish culture in Laos (Figure 14) differs from commercial fish farming in Northeast Thailand (Figure 10). Thus, there are still opportunities to increase use of aeration and mixers to help deal with climate-related risks of low dissolved oxygen episodes in ponds, and maybe also in cage culture in reservoirs. This need will likely increase as farmers intensify production once quality stock and feed become more easily available. While the expectation is that production in Laos will intensify, there may be some opportunities for organic farming for niche markets. Experiences in Thailand with organic certification may be useful for Laos.

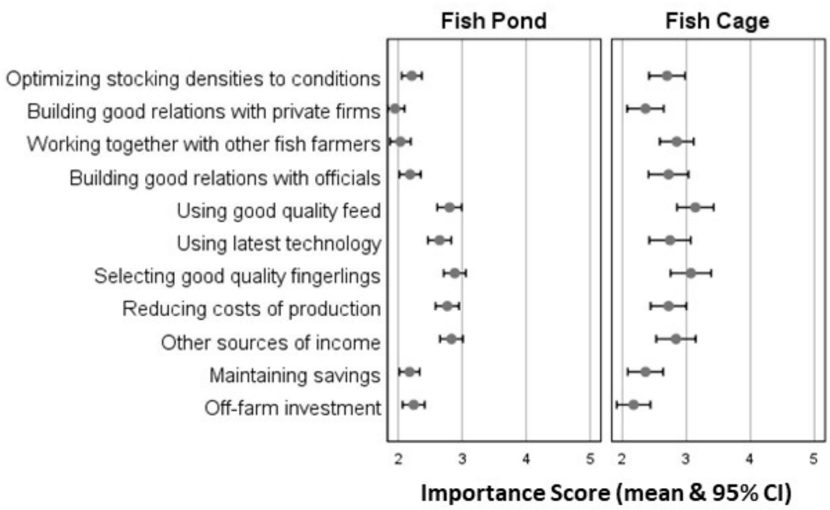
Figure 15 Proportion (and 95% confidence intervals) of farms having adopted various practices to manage climate-related risks. Pre = pre-stocking. Post = post-stocking. Laos (n=341). Source: Survey by the authors in 2018 documented in [60].



One way to support impacted inland fisheries in Laos is to release cultured fish to water bodies. Benefits however, may be short-term, in the case where these were non-native species and the receiving water body natural. In artificial water bodies the risks are lower. In the wetlands in Laos, fisheries were managed by declaring some areas as fish conservation zones and closing fishing altogether during spawning season.

Social relations and financial strategies were less important to managing risks in Laos (Figure 15) than in Thailand (Figure 11). Having other sources of income, on average, was among the more important tactics. Earlier studies in Laos have underlined that fishing is an important part of livelihood portfolio of individuals, but is often secondary to agricultural activities such as planting rice. One study in Savannakhet province found that households in locations regularly flooded were more likely to engage in fishing than those which were not [124] – underlining how the adoption of fishing (or fish farming), in some circumstances, might be in itself an adaptation.

Figure 16 Mean importance score (and 95% confidence intervals) given by farmers for various tactics and strategies to manage climate-related risks. On scale of 1 (not at all important) thru 5 (very important). Laos (n=341). Source: Survey by the authors in 2018 documented in [60].



Strategies to enhance climate resilience in Laos can be informed by those derived for Thailand if the differences in size, maturity, and relative importance of the aquaculture sectors in the two countries are acknowledged. At the policy level, the largest difference between Laos and Thailand is the level of resources available for fisheries management and aquaculture development. Opportunities for external development assistance, however, is greater for Laos than Thailand.

7.3 POLICY ENVIRONMENT

In Laos, the policy environment is paying increasingly more attention to aquaculture. In 2009, the first Fisheries Law was enacted [125]. The law encourages investment in aquaculture, and was followed-up in 2016 with the Law on Investment Promotion, which gave aquaculture the highest level of tax and duty incentives [126]. The Agricultural Development Strategy (2025) issued in 2015 also encouraged the adoption of aquaculture technologies, but alongside diversity of rearing systems [126]. The 8th National Socio-economic Development Plan (2016-2020) for Laos promotes fish farming and breeding centers in particular locations in the central and southern regions [127].

7.4 NEXT STEPS

In terms of immediate next steps we have three suggestions.

First, review state-of-the-knowledge on climate resilience in fisheries and aquaculture in Lao PDR. Starting with the those about management of climate-related risks. Existing data sets with information about the risks or impacts of climate-related phenomenon should be analyzed.

Second, a climate change working group at the level of the Ministry of Agriculture and Forestry could be established to facilitate sharing of knowledge and good practices within and among departments. Researchers working in Laos could be invited to a roundtable with the working group and explore how to start incorporating climate change concerns into fisheries and aquaculture development, and management policies.

Third, the policy framework proposed in this report could be used as a starting point for policy development initiative on climate resilience in fisheries and aquaculture in Laos. Sections about marine and coastal aquaculture and fisheries can be dropped and the focus on culture-based fisheries expanded to fit the different context in Laos compared to Thailand.

8 CONCLUSIONS AND RECOMMENDATIONS

CHAPTER SUMMARY The climate is changing, and extreme events will continue to have adverse impacts on fisheries and aquaculture. Long-term warming trends will result in warmer oceans, rising sea levels, and more acidic waters in the future. Enhancing the climate resilience of fisheries and aquaculture is possible.

The climate of Thailand is changing. It is getting warmer; rainfall is becoming more intense. Extreme events already have significant impacts on fisheries and aquaculture, and are projected to become more frequent or severe in the coming decades.

Climate-related risks important to inland and coastal aquaculture, as well as inland fisheries, include floods, droughts, heavy rainfall, and heat waves. Storms are already important risks for coastal and ocean fishers; ocean warming, acidification, and deoxygenation are on-going changes important for marine fisheries. Coastal aquaculture and fisheries must also adapt to sea level rise.

Fish and shrimp farmers already actively manage many farm-level, climate-related risks. They also collaborate with other farmers to respond to some shared, catchment-level risks with collective action. Small-scale fishers in both inland and coastal fisheries organize to manage shared risks, as well as to deal with conflicts over fishing grounds with large-scale fishing operations. In ocean fisheries, climate-related risks are important, but it is unclear how to respond to some growing threats from ocean warming and acidification, suggesting there are limits to enhancing climate resilience.

Efforts to respond to climate-related risks and enhance climate resilience take place in a context in which other stressors often dominate concerns of fisheries and aquaculture stakeholders. Unsustainable practices, such as overfishing and polluting, worry resource managers. Inequalities in access to resources, and the benefits arising from the use of those resources, worry civil society organizations. Market prices, trade competitiveness, and regulatory changes worry fishers and fish farmers.

Thus, enhancing resilience to climate is not the only policy objective important to the development of fisheries and aquaculture. Food security, employment, foreign exchange earnings from exports, international competitiveness, profitable returns on investment, sustainable livelihoods, conservation and so on, are examples of other objectives. Trade-offs and other interactions between objectives and the pursuit of climate resilience are likely, which is why the quality of governance is important.

Government policy and planning documents increasingly acknowledge climate change and the need for adaptation. In a few places there are even specific suggestions regarding fisheries and aquaculture, but for the most part such details await elaboration. A policy framework for enhancing capacities important for climate resilience is proposed around managing climate risks, recovering from disturbances, adapting to change, innovating to transform, and inclusiveness.

8.1 RECOMMENDATIONS

8.1.1 Form a climate resilience working group

The Department of Fisheries could convene a climate resilience working group to provide analysis, advice and guidance on fisheries and aquaculture development in Thailand. In the initial stages, the working group could focus on designing a program for raising awareness of climate change risks and impacts (Strategy 1). Once established, the working group could then focus on developing a program for documenting risks and impacts (Strategy 2) and adaptation measures (Strategy 3), as proposed as a database in various policy documents. The working group could meet online every 2-3 months or so to discuss new scientific findings and emerging policy development issues. Ideally, the working group would include stakeholders from various organizations and areas of expertise. Apart from experts in government agencies, individuals from academia, private sector, and fisher or fish farming organizations could be invited to participate. As the importance of specific climate-related risks varies with geographical location, rearing or fishing practices, and biology of the species harvested, it may be worthwhile to form working groups at the provincial level to develop and implement climate resilience programs.

8.1.2 Reduce critical knowledge gaps with investment in research

There are many knowledge gaps with respect to understanding of climate risks and impacts, as well as enhancing climate resilience in different systems. Investment in research is recommended in at least the following areas.

First, to improve management of marine fisheries, a better understanding is needed of how ocean warming trends are likely to effect life histories, age and size structure, and geographical distributions of key commercial species fished in the Gulf of Thailand and the Andaman Sea fisheries. To respond with better management implies that there is also a need to consider how fishers, regulators, and traders may react to potential changes, for instance, through models of international trade in seafood.

Second, to maintain aquaculture productivity, a better understanding is needed of the costs, benefits, and limitations of acclimatization, genetic improvement programs, and moving production into controlled environments indoors. This should initially focus on most important commercial species, but then expand the investigation into promising alternative culture species. Life cycle analysis tools could be used to explore trade-off among different environmental impacts.

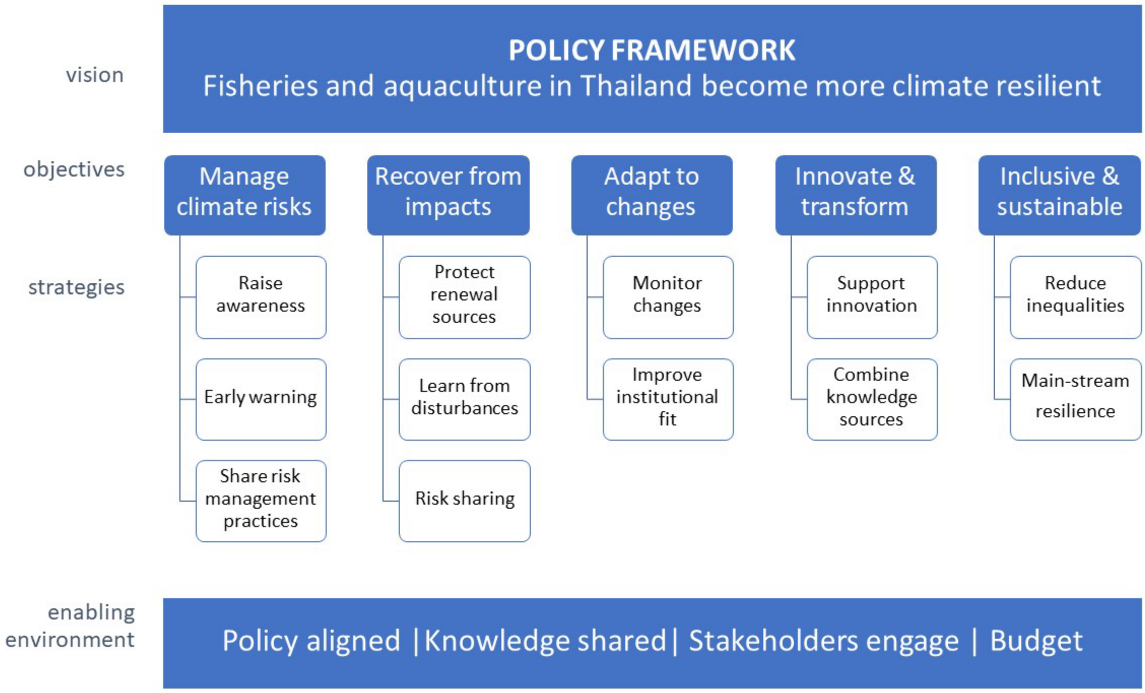
Third, an important part of the climate resilience approach is that an effort is put into understanding recovery and re-organization following disturbances. Ecosystems which act as nurseries or refugia are a source of recruitment to other areas degraded, following disturbances to inland and marine capture fisheries. Further research is needed to determine whether current conservation efforts are sufficient, and how they may need to be expanded or shift as ocean warming intensifies.

Fourth, the social dimensions of climate resilience have so far not received as much attention as the technical aspects of fishing and fish farming. A better understanding is needed of how governance of fisheries and aquaculture influences risks, impacts, and adaptation by vulnerable fishers and fish farmers. Studies are also needed on the generation and adoption of innovations.

8.1.3 Use the proposed policy framework to strengthen responses to climate change

The policy framework proposed in Chapter 6 of this report (Figure 17) could be used in a couple of different ways. First, the set of five objectives can be used to screen proposals claiming to address adaptation to climate; for instance, if they do not fit at least one objective, could be deemed to fail against the adaptation criteria. Second, the set of 12 strategies can be used to strengthen program and project proposals by including activities (plans, programs) that enhance climate resilience as one of the outcomes. Third, the set of 12 strategies may be applied to an organization to help clarify its strategic role in a broader policy initiative. Finally, in some systems we know enough about when, where, and how to respond to contemporary climate-related risks or potential future impacts of climate change in fisheries and aquaculture in Thailand. The policy framework can help respond more strategically.

Figure 17. Summary of the policy framework for enhancing climate resilience in fisheries and aquaculture in Thailand.



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