



# Advancing fishing technology education and research: a 65-year legacy at Nha Trang University, Vietnam

Khanh Quoc Nguyen<sup>1,2</sup> • Phu Duc Tran<sup>1</sup> • Phuong Viet Le<sup>1</sup> • Luong Trong Nguyen<sup>1</sup> • Phuong Van To<sup>1</sup>

<sup>1</sup> Nha Trang University, 2 Nguyen Dinh Chieu, Nha Trang City, Vietnam

<sup>2</sup> Fisheries and Oceans Canada, St. John's, NL, A1C 5X1, Canada

## Correspondence

Khanh Quoc Nguyen; Nha Trang University, 2 Nguyen Dinh Chieu, Nha Trang City, Vietnam

✉ [khanhnq@ntu.edu.vn](mailto:khanhnq@ntu.edu.vn)

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## Abstract

As a coastal country, Vietnam relies on marine exploitation for food security and livelihoods. Training human resources to research, exploit, and manage marine resources is an important strategy to maintain rapid and sustainable economic growth and development. Official training in fishing technology at Nha Trang University (NTU) started in 1959. With 65 years of teaching, the unique program only offered at NTU, has made significant contribution to social-economic development in general and sustainable marine fisheries in particular. In this paper, we review the major achievements in teaching and scientific research in fishing technology at NTU as well as highlight the challenges and progress. Over the years, thousands of students have been trained under the fishing technology program and they then have worked all over the country, working in fisheries management, science, and services. Hundreds of research projects and peer-reviewed papers have been conducted and published. Those have supported fishing efficiency, environmentally friendly fishing methods, and effective management. However, the number of fishing technology students has decreased during the past few years because of unfavorable study and working environments where students are often exposed to commercial fishing vessels that frequently operate under rough weather conditions. Despite challenges and difficulties, NTU is determined to maintain the program to support the ocean economic development of the nation.

**Keywords:** fisheries science; human resources; marine capture; training challenges; unique program

## 1 | INTRODUCTION

Aquatic foods have been recognized as having the important role in food and nutrition security and providing unique bioavailable micronutrients (Golden *et al.* 2021). Upon high demand, the global marine fisheries rapidly increased during 1980s, however, the marine landing volume has remained at approximately 80 – 84 million tons since 1990s (Figure 1). In 2022, marine capture produced 79.7 million tonnes and at a value of USD 157 billion (FAO 2024; Gephart *et al.* 2024). In addition to fish and invertebrate species, millions of tons of algae are harvested

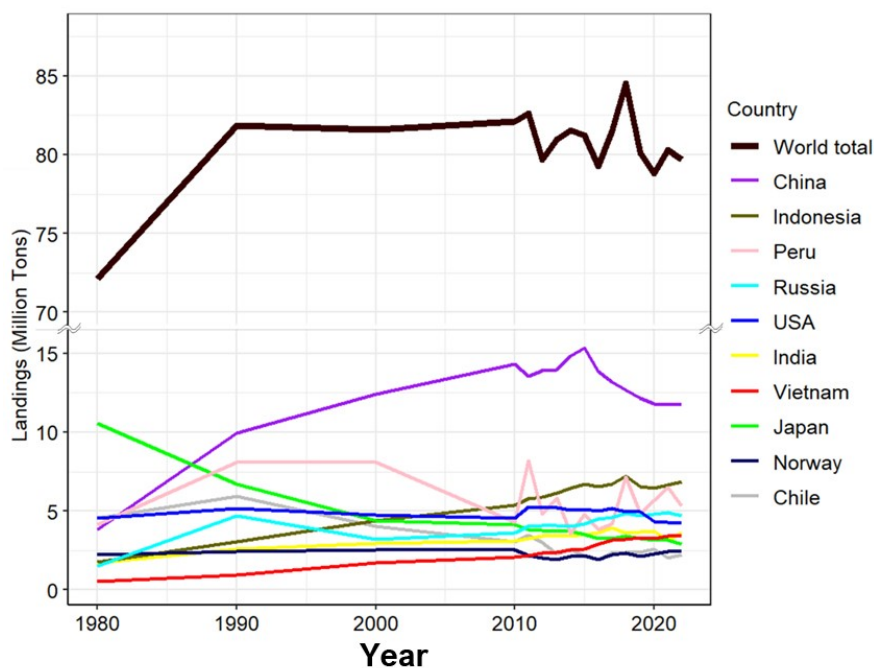
annually (FAO 2024). Aquatic foods continue to be the most commonly traded food commodities in the world, with more than 220 countries reporting some trading activity of fisheries products in 2020 (Gephart *et al.* 2024). An estimated approximately 33.4 million people were engaged directly or indirectly in capture fisheries (FAO 2024). Although marine fisheries have made a significant contribution to all aspects of social economics and critical dynamic forces for human survival and development of nations, challenges in sustainably using marine resources have grown (Bailey and Hopkins 2023; Elliott *et al.* 2023).

Over-exploitation, illegal, unreported, and unregulated (IUU) fishing, ecosystem loss, resource decline, marine pollution, and rising seawater temperature are among the threats to sustainable fisheries (Sumaila *et al.* 2016; Mediodia *et al.* 2024; Nguyen *et al.* 2024a). In recent decades, there have been significant advances in technology, management, education, and training in harvesting and using effective marine resources (Glass *et al.* 2007; Eigaard *et al.* 2014; Okwuosa *et al.* 2018). However, sustainable fisheries development goals for poverty eradication and food security have had challenges. More efforts are therefore required throughout the global scope to reach the goals of the Rio Conventions including the Convention on Biological Diversity (UN 1992). Training human resources is a key measure to effectively enforce at-sea monitoring, control, and surveillance (MCS), and stock management, which safeguards livelihoods and incomes for millions of fishworkers and maintains natural resources for future generations (MRAG 2019).

Fisheries science involves a wide knowledge across disciplinary boundaries, which is not easily addressed by a

single discipline, methodology, or set of stakeholders (FAO 2024). To date, universities in most coastal countries have offered the fisheries-related programs such as marine biology, ichthyology, ecology, natural resources, marine ecosystem, fisheries stock assessment and management, ocean science, and wildlife conservation. However, only a few universities in the world are training the fishing technology program (Kang and Park 2015; Turgeon *et al.* 2018), specially undergraduate level such as Pukyong National University, South Korea (PNU 2024), Shanghai Ocean University, China (SHOU 2024), Fisheries College and Research Institute, India (FCRI 2024), Technical University of Denmark (DTU 2024), and Nha Trang University (NTU), Vietnam (NTU 2024). Despite intensive aquaculture development during the past three decades, capturing wild species has remained the primary food supply around the globe (FAO 2024) and is in high demand (Nguyen and Winger 2019; Gephart *et al.* 2024). Training manpower in fishing technology therefore significantly contributes to the sustainable utilization of fishery resources nationally and internationally.

**FIGURE 1** Marine capture production of top 10 countries including Vietnam and the world total from 1980 to 2022 (retrieved from FAO 2024). The period of 1980 – 2010 showed five-year landings moving average, while from 2010 denoted yearly landings. The legend is ordered by landing volume in 2022.



Vietnam has 28 coastal provinces including >3,260 km coastline and an exclusive economic zone (EEZ) of more than one million km<sup>2</sup>, where marine fisheries exploitation is one of the most important contributions to the social-economic development, food safety, and livelihoods (Nguyen *et al.* 2017; Nguyen *et al.* 2022a). Developing an ocean economy where marine fisheries are second most important has a prominent place in the vision for future national economic growth (Nguyen and Hoang 2015). In 2022, the total marine landings were 3.45 million metric tons (Figure 1) accounting for more than \$5.6 billion in export value, remaining a top ten country for

seafood exports in the world (FAO 2024; VASEP 2024). There are 823,276 people directly working on 94,572 fishing vessels, along with another three million people working on seafood processing and fisheries services that rely on marine fisheries (MARD 2021). Marine-based foods account for approximately 40% of the animal protein and micronutrients in the Vietnamese diet (Van *et al.* 2022). As a typical of the tropical marine area, Vietnam has a high marine diversity and productive habitat. Among 2,038 marine living species reported, more than 130 species have been commercially harvested using various fishing methods such as trawl, purse seine, gillnet, longline,

stick-held falling net, and traps (Tran *et al.* 2020; Nguyen *et al.* 2021a, 2021b, 2022a, 2022b, 2022c, 2022d; Nguyen and Nguyen 2022; Nguyen *et al.* 2023). However, marine fisheries are still considered small-scale and open-access management regimes (Pomeroy *et al.* 2009; Pham *et al.* 2014). An estimated 88% of landings are from near-shore areas including the four main fishing grounds of the Gulf of Tonkin, the central coast, the southeastern coast, and the Gulf of Thailand (General Statistics Office 2023).

Vietnamese marine fisheries currently experience both short-term and long-term challenges as follows: (1) The European Commission has issued a “yellow card” for Vietnamese fisheries since 2017; (2) Illegal, unreported, and unregulated fishing is not well controlled (Nguyen *et al.* 2013; Phuong and Pomeroy 2023); (3) the low quality of fish captured due to fishing technology and handling process on-board (Nguyen and Tran 2014); (4) more recently, the fishery has been faced with a new challenge of changes in warming ocean water temperatures, resulting in the marine resources changing significantly, resulting in a reduction in the catch per unit effort in and total landings for substantial commercial species (Nguyen and Nguyen 2017); and (5) very little biological and demographic information of most marine species have been documented to conduct a stock assessment and deploy a Total Allowable Catch (TAC) and quota allocation management system (Nguyen 2024b). These challenges have shown that the importance of the high quality education in fisheries science in general and fishing technology in particular for sustainable use of fisheries marine resources. Given an important social economic contributor, the Vietnamese Government via the Ministry of Agriculture and Rural Development has adopted management plans and strategies, where training human resources and applying new technologies to sustainably develop and protect marine fisheries resources are the most important indicators (MARD 2021). NTU has a long history and strength in fisheries science training and research and is the only Vietnamese university offering a fishing technology program at undergraduate and graduate levels, which has been chosen by the Ministry of Agriculture and Rural Development to perform the project of training and developing human resources in fisheries (MARD 2022). In this paper, we highlight the path that education and research in fishing technology at NTU has taken in the past 65 years, including milestones, achievements, and contributions in relation to nation building and social-economic and sustainable fisheries development. This paper also indicates challenges, strategic response, and future outlook.

## 2 | HISTORICAL BACKGROUND AND FISHING TECHNOLOGY EDUCATION AT NTU

NTU was established on August 1, 1959 as the Fisheries Faculty of Hanoi Institute of Agriculture and Forestry (Ha Noi, Vietnam), offering three undergraduate programs:

fishing technology, seafood processing, and aquaculture (NTU 2024). The university’s name (e.g., Faculty of Fisheries, College of Fisheries, University of Marine Products, University of Fisheries, and Nha Trang University) and location (Ha Noi, Hai Phong, Nha Trang) changed several times. In 1976, NTU settled in Khanh Hoa province, south-central coast of Vietnam. Figure 2 provides the NTU’s history timeline and development. NTU currently offers 60 undergraduate and 28 graduate programs including more than 17,500 active students from all over the nation and numerous international countries (NTU 2024). Building on the demand of social economic development, training programs focus on fisheries, aquaculture, engineering, science, economics, computer, linguistics, and laws. However, fisheries science has remained the greatest strength of the university and has investigated efforts and resources among the programs. In addition to the advanced programs in fishing technology, NTU offers certificate and diploma programs, which serve several hundred trainees annually.

Fishing technology is one of the earliest programs of NTU and has encompassed a 65-year history, which is a unique program that is not found elsewhere in Vietnam. The program has significantly contributed to marine fisheries management and development in Vietnam including living resource exploitation and fisheries resource protection and conservation. Currently, the fishing technology program at all levels is managed by the Institute of Marine Science and Fishing Technology (IMSFT). The university has annually offered admissions for 30 – 100 undergraduate students since 1959 with a few gaps recently (see challenges section for details). In 1988, NTU was allowed to train the graduate program in fishing technology, but the first cohort started in 1994 with 8 master students and the first doctoral (Doctor of Philosophy – PhD) students enrolled in 2000 (NTU 2024).

The undergraduate program has a number of compulsory and elective courses for all students including theory of fishing gear, fishing gear design, fish capture methods, stock assessment, fish detecting methods, sustainable fisheries, fisheries laws and regulations, fisheries management, fisheries biology and ecology, navigation in fisheries, and fisheries oceanography. Students can take from three to four years to complete their studies (commonly four years). The master program includes 15 courses with a concentration on advanced fishing gear and selectivity, advanced statistical stock assessment, cooperations and responsibility fisheries, fisheries planning and development, fisheries profiles, fisheries management, international cooperations and responsibility fisheries, and application of advanced technology and equipment in fishing. In addition to the course work, masters students have to complete the thesis and pass the defense before graduating. The students can finish their master’s program within two years. Finally, the PhD stu-

dents can perform the thesis and defend it in a minimum of three years along with completing a few additional courses. PhD mandatory courses include information of fisheries science, experimental design and data analysis for fisheries science, applying advanced technology in capture fisheries, advanced theory of fishing, stock assessment, and advanced fisheries management. Moreover, PhD students can be required to take additional courses if they have not experienced the master programs in fishing technology or fisheries management. These courses consist of bio-technical basis of fishing, application of advanced technology and equipment in fishing, selective fishing, theory of fishing, fisheries survey and statistics.

Global fisheries including Vietnam have experienced complex challenges such as resources continuing to decline because of overfishing, IUU fishing, pollution, poor management, shifting habitat and environment, and others (FAO 2024). Education in fishing technology is there-

fore not only focused on a narrow range of knowledge of technological issues, it must involve ecological and environmental knowledge, social science, and management. The current undergraduate curriculum is designed to satisfy these industrial requirements and environmental changes, which includes four disciplines consisting of orientation and support, weak, moderate, and strong links to fishing technology based on the assessment of experts, labour users, and alumni (Table 1). Generally, the orientation and support subjects of the fishing technology curriculum at NTU are large, compared to other universities (DTU 2024; FCRI 2024; PNU 2024; SHOU 2024). However, this is necessary for the Vietnamese students and common for most training programs in Vietnam (Hoang 2021). While non-fisheries-related subjects offer students better adaptation to their working environment, specialized knowledge allows them to work independently and confidently.

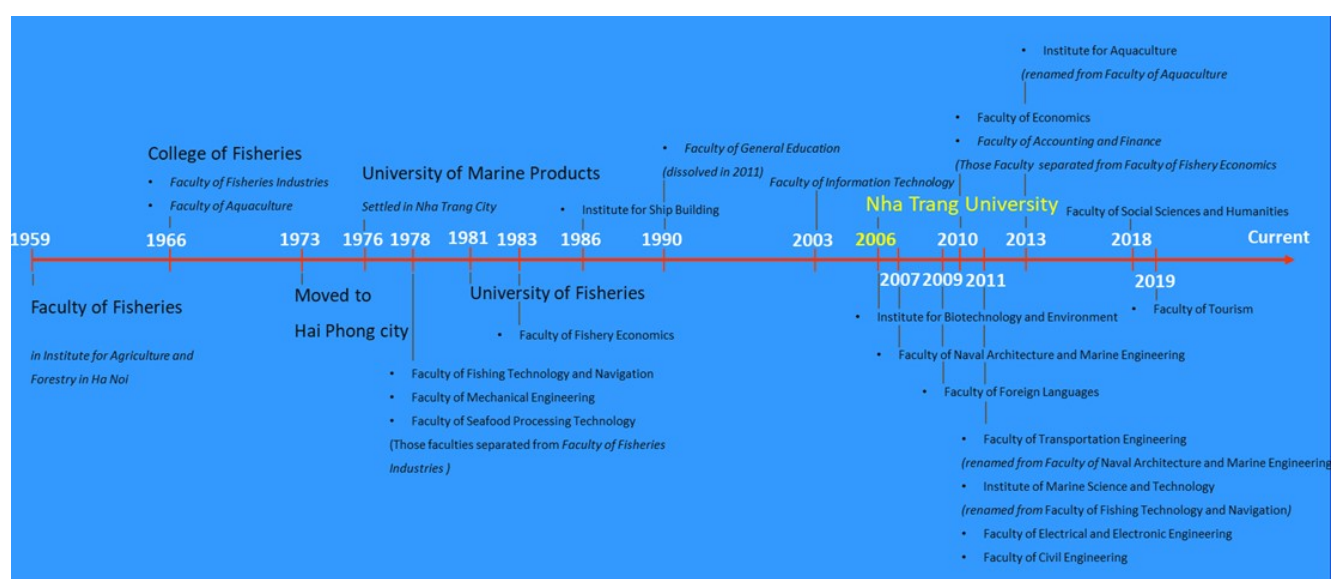


FIGURE 2 History of Nha Trang University, Vietnam (NTU 2024).

TABLE 1 Distribution of fishing technology-related knowledge for the undergraduate program (IMSFT 2015).

Criteria	Courses		Credits	
	No.	%	No.	%
Orientation, General Subject, and Support	31	50,82	65	39,39
Weak	8	13,11	23	13,94
Moderate	6	9,84	19	11,52
Strong	16	26,23	58	35,15
Total	61	100	165	100

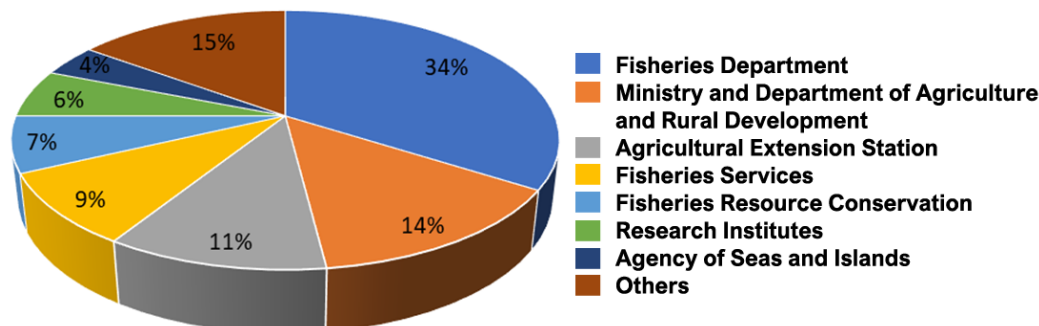
### 3 | ACHIEVEMENT AND CONTRIBUTION

As the unique program carried out by NTU during the past 65 years, the contribution of the fishing technology program to fisheries science and management is uncountable. With more than 30,000 alumni and certificate trainees active throughout the country, where there were approximately 1,500, 122, and 17 undergraduate, master,

and PhD students, respectively, who have directly worked on the fishing vessels, institutes, and management agencies (IMSFT 2015). In addition to generating wealth and prosperity throughout the Vietnamese communities, they have contributed to sustainable marine fisheries development. Fishing technology undergraduate and graduate students have worked in all 28 coastal provinces and the

Ministry of Agriculture and Rural Development at Ha Noi on a wide scale (Figure 3). The recent report shows that more than 350 fisheries officers, managers, and scientists are actively working throughout regions of Vietnam along with several people working for the national and international non-governmental organizations (MARD 2022). Most undergraduate students work in the Fisheries Department, Ministry/Department of Agriculture and Rural Development, and Agricultural Extension Station, accounting for 59%. They are also working on Fisheries Ser-

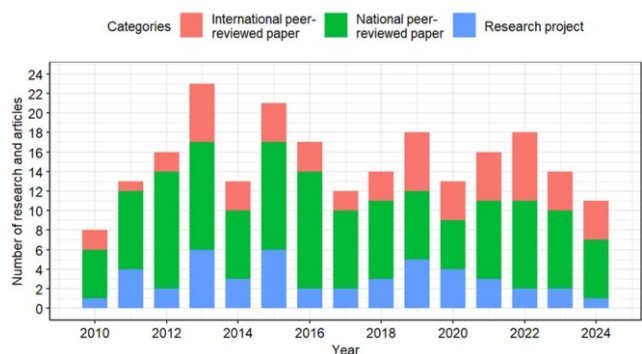
vices (e.g., fishing harbours, fishing gear companies, fisheries associations and unions), Fisheries Resource Conservation (e.g., marine protected areas, fisheries surveillance, and coast guard vessels), and Fisheries Research Institutes. Some of them have had high positions in their workplaces such as Minister, Premier, General Director, and Managers, along with some top experts and scientists who have been named locally and internationally (Xung *et al.* 2019).



**FIGURE 3** Working places of fishing technology students (IMSFT 2015).

In addition to the education, it has been recognized as a Vietnamese center of expertise in fish capture. The fishing technology staff has core strengths in fishing gear design and testing, conservation engineering, fisheries biology, fish capture behaviour, and mechanical engineering. Since 2010, the fishing technology team has conducted 46 research projects, published 125 national and 56 international peer-reviewed papers in fisheries science (Figure 4) (IMSFT 2024; Scopus 2024). Research projects have had a wide range, but focused on fishing gear design (Khanh *et al.* 2013; Nguyen and Nguyen 2022), selectivity (Nguyen and Larsen 2013; Nguyen *et al.* 2021a), improving catch efficiency (Tran *et al.* 2020; Nguyen *et al.* 2023), bycatch reduction (Nguyen *et al.* 2022a), low fuel consumption (Nguyen and Tran 2015; Nguyen *et al.* 2021b; Nguyen *et al.* 2022c), resource conservation (Nguyen *et al.* 2022c; 2022d), and fisheries management (Nguyen *et al.* 2013; Phuong *et al.* 2023). These have significantly contributed to improving sustainable fishing practices, profitability of commercial fishing enterprises, and fisheries management plans and strategies. Our research direction falls within the global general trend, but is conducted with significantly less effort and resources compared to other countries (Aksnes and Browman 2016). Moreover, bycatch reduction (Kennelly and Broadhurst 2021), ghost fishing (Richardson *et al.* 2021), and using biodegradable materials (Standal *et al.* 2020) are among the top priority of research topics for many fisheries but receive very little attention in Vietnam. Annual stock assessment has been conducted in all commercial species by many countries (FAO 2024), and this is a big gap for Vietnamese fisheries. A total allowable catch and quota allocation management

system have been implemented for decades in Europe, North America, and Australia (FAO 2024). All of those suggest that there is available room for further research in fishing technology and fisheries management and that needs a lot of effort to maintain healthy marine resources.



**FIGURE 4** The research projects and peer-reviewed papers were conducted and published by fishing technology staff from 2010 to 2024 (IMSFT 2024).

In addition to substantial research projects, many of those have been effectively applied and used in policy making, regulations, and commercial practice. For example, national standards for fishing gear materials and technical requirements (TCVN 8393:2021) were based on the research of the IMSFT (Le 2021). The application of light emitting diode (LED) in commercial fisheries to reduce fuel consumption during the fishing process was first conducted by IMSFT in 2013 (Nguyen and Tran 2015) and is the most attractive technology for several fisheries such

as purse seine, tuna handline, and stick-held falling nets (Nguyen *et al.* 2021b; Nguyen *et al.* 2022a, 2022b). Building artificial coral reefs is one of the most effective technical measures to recover marine resources, which has been deployed in five coastal provinces (Nguyen *et al.* 2015; Nguyen *et al.* 2022a). The multiple year project on transferring environmentally friendly fishing methods has brought benefits for swimming crab (*Charybdis feriata*) harvesters and contributed to the conservation of marine resources (Tran *et al.* 2020).

The international cooperation has brought successes and achievements in fishing technology training and research, which is effective beyond Vietnam. For example, multiple years of collaborating with the Royal Norwegian Government, known as NORAD project, has significantly improved the fishing technology training and research capacity of NTU, resulting in substantially international peer-reviewed papers published by the staff who studied in Norway. NTU has received internship students from Canada through cooperation with Memorial University of Newfoundland and Labrador, Canada (Fisheries and Marine Institute). This also includes the number of students and staff of NTU who have been trained in fishery technology in Canada. The active project on request for expression of interest in relation to the delivery of the MCS training course and officer exchange program components of Australia's combating IUU fishing and promoting sustainable fisheries in Southeast Asia program has improved fisheries management, innovating fisheries value chains, and maintaining health of fish stocks in Vietnam and across Southeast Asia countries.

With those contributions to social-economic development and training human resources of the nation, NTU and its faculties have been recognized with numerous awards and honours for their meaningful contributions to society from the Government such as Labor Medals, Independence Medals, as well as the most prestigious award – the Labor Hero Medal (NTU 2024).

#### 4 | CHALLENGES AND STRATEGIC RESPONSES

Substantial millions of people in most coastal countries highly rely on capturing wild living resources for food and livelihoods, and the number of fishermen increased from 29.58 million in 1995 to ~39 million in 2018 globally (FAO 2024; Gephart *et al.* 2024). Most ocean science, technology and engineering students work on land the majority of the time and are required to work at sea only rarely after graduation (IMSFT 2015). However, land-based study programs usually attract more students than ocean related studies (DTU 2024; Herath and Radampola 2017; SHOU 2024; Turgeon *et al.* 2018). Although working and living conditions onboard the commercial and research vessels have been significantly improved based on the requirements of the International Labour Organization (e.g., Maritime Labour Convention 2006), marine-related

studies are not a favorite for young people (Herath and Radampola 2017; Turgeon *et al.* 2018).

In Vietnam, despite high demand and job availability, the number of registrations for the fishing technology program has decreased during the past few years resulting in fewer students. For example, there were no undergraduate students in 2010 – 2014 and 2016 – 2017, while graduate students have remained from few to none annually. Several reasons have been recognized by NTU and fishing technology lecturers as follows:

- 1) Study environment. The curriculum requires students to practise some time (one month × three times = three months total) on commercial fishing vessels (e.g., trawl, purse seine, gillnet, and longline). This is really unattractive and unfavorable to most young students who have never been onboard the fishing vessels which operate more frequently under rough weather conditions for financial reasons.
- 2) Working environment. Similar to the study environment, working on the vessels (coast guard, research, surveillance, or commercial fishing vessels) is not the top choice of most people.
- 3) Less comparable income. Most fishing technology students work in the public services or government resulting in less comparable income compared to other jobs such as tourism, finance, banking, and software development.
- 4) Short of funding and budget for graduate students. Graduate students often study in self-finance including stipends, accommodation, school fees, and research funding which require tens of thousands USD which is a huge saving for most people. Although NTU has supported graduate students through offering research projects, it is still less favorable.

The NTU's research vessels are old and not available for fishing technology students to practise, thus they usually carry out their practice courses onboard the commercial fishing vessels with a lack of direct guidance from the scientists and lectures resulting in some limitations. This also increases the training costs along with other expenses such as lab equipment and thesis data collection, which are substantially higher training costs compared to other programs such as economics, laws, and computer science.

Given the importance of the program, NTU and the Ministry of Agriculture and Rural Development have policies and measures to support for fishing technology students such as providing free accommodations, scholarships, and student loan programs. The flexible learning curriculum and the labour user-based training program have been conducted. This is expected to attract students to fill the gap of human resources in fishing technology and management of fisheries resources for now and beyond.

In addition to the funding program, increasing fisheries research capacity in Vietnam through interdisciplinary and inclusive training and research collaborations between the universities, labour users, agencies, and stakeholders including training according to industrial and business needs is expected to provide open working places with comparable incomes. Increasing international collaboration and exchange study programs could offer more jobs and higher education opportunities for students.

## 5 | MISSION PLAN AND FUTURE DIRECTIONS

The NTU's vision is to "become a high-ranking university in Vietnam and one of the leading universities in Asia in some disciplines in marine and fisheries science and technology by 2045" (NTU 2024). NTU targets to be one of the most distinguished public universities in Vietnam and beyond, and will fulfill its special obligation to the people of the nation to perform the mission: "carry out research, train highly qualified manpower, and transfer knowledge in multidiscipline, focusing on promoting strengths in marine and fisheries science and technology" (NTU 2024).

In order to develop high qualitative education, carry out research and technology transfer, and provide services in fishing technology to meet the demand of socio-economic development, NTU has investigated significant resources to construct infrastructures (e.g., labs) and purchase modern technologies and equipment (e.g., fishing and navigation simulation, fishing gear design software, fisheries management software, full and scale model of fishing gear, and navigation systems). These help students to learn and practise at regional and international standards (NTU 2024), and also help staff to conduct qualitative research to publish international peer-reviewed articles (IMSFT 2024). NTU continues to be an inclusive community dedicated to innovation and excellence in teaching and learning, research, scholarship, creative activity, service and public engagement to contribute knowledge and expertise regionally and nationally. NTU encourages and supports collaboration with the alumni community and industrial partners to build and develop projects in training and using human resources in fishing technology. Because of suitable and effective policies and transparent activities, fisheries companies, associations, and firms have remained a significant support to the fishing technology program (IMSFT 2024). Typical supporters during the past decade include Vietnam Tuna Association, Siam Brothers Vietnam, Marine Electronics Hai Dang, and the Fishing Technology and Navigation Alumni Association. Support, funding, and the public engagement framework are provided directly through the Institute of Marine Science and Fishing Technology offering programming to help facilitate engagement. Those corporations and engagements have helped to improve fishing technology education curriculums and have contributed to enhancing

training qualifications.

For the research, in order to solve the current and future fisheries challenges of Vietnam and contribute the international concerns, NTU investigates resources to maintain annual research activities and conduct a wide variety of applied research, including both short-term industrial response projects and long term several-year strategic initiatives, including:

- Fishing gear design and testing
- Biological resource assessments
- Management and conservation of fisheries resources
- Fisheries development
- Fish behaviour
- Fish handling and conserving
- Ghost fishing and marine plastic pollution from fishing gear
- Combating the impact of climate change and marine heatwave on fish stock and fisheries
- Applying new technology in fishing and fisheries management
- Building new models of recreational fishing connecting with marine tourism

NTU welcomes the support and collaborations from government and non-government organizations, agencies, companies, and others for creating and strengthening fishing technology education and research (NTU 2024). These activities have been successful (Xung *et al.* 2019), but are still available for a new journey.

## 6 | CONCLUSIONS

Education is the top national policy, and investments in high-quality education result in more rapid and sustainable economic growth and development (Nguyen 2019). The Vietnamese Government has supported great effort and resources for education, averaging 18% of gross domestic product annually. However, difficulties and challenges have inhibited Vietnamese education to reach Asian and international levels. By continuing to promote and diversify the contents as well as the format of training programs, NTU is recognized as a unique, interesting and rewarding education destination for national and international students. With a 65-year history of training and research in fishing technology, NTU, the only Vietnamese university and one of a few places in the world that is training this program, has trained thousands of students who have worked all over the country in different areas (IMSFT 2015). This helps to improve social-economic development, and also contributes to sustainable marine fisheries development. In addition, tens of thousands of fishermen have been trained by NTU during the past decades. This helps to meet the standards and requirements of national and international organizations in commercial fishing operations such as the International Labour Organization, the Western and Central Pacific

Fisheries Commission, the European Union, and the Southeast Asian Fisheries Development Center. Although there are challenges, NTU is determined to maintain the fishing technology and invest more resources to improve the training quality to reach the regional standards.

The capture of wild aquatic species has been an important source of income, livelihoods, and food security and continues to contribute to the social-economic development of coastal countries in the world. Fisheries resources have decreased and are overexploited in many parts of the oceans along with new challenges such as global warming, ecosystem changing and destruction due to invasive species, and marine pollution, which require international collaborations to mitigate its negative impacts to maintain sustainability and healthy oceans. Education including awareness among fishermen and post-secondary education has been recognized as a key role to utilize the globe and nation's economic growth.

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#### CONFLICT OF INTEREST

The authors declare no conflict of interest.

#### AUTHORS' CONTRIBUTION

KQ Nguyen: conceptualization, investigation, methodology, data curation, formal analysis, writing - review & editing; PD Tran: funding acquisition, resources, investigation, writing - original draft; PV Le: conceptualization, funding acquisition, investigation, visualization, formal analysis, writing - original draft; LT Nguyen: conceptualization, investigation, data curation, writing - original draft; PV To: conceptualization, investigation, writing - original draft.

#### DATA AVAILABILITY STATEMENT

The data that support the findings of the study will be made available on a reasonable request from the corresponding author.

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**KQ Nguyen**  <http://orcid.org/0000-0002-6133-3437>

**PD Tran**  <http://orcid.org/0009-0009-3775-5339>

**PV Le**  <http://orcid.org/0009-0007-5444-1353>

**LT Nguyen**  <http://orcid.org/0000-0003-3806-5275>

**PV To**  <http://orcid.org/0000-0001-7409-137X>