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THE IMPACT OF OVERFISHING OF BIGEYE TUNA (THUNNUS OBESUS) POPULATIONS ON THE BALANCE OF THE INDONESIAN MARINE ECOSYSTEM: A LITERATURE STUDY IN THE BANDA SEA

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Abstract

Indonesia has a sea area of approximately 3.1 km2 including inland areas, archipelagic waters, territorial seas and the Exclusive Economic Zone. The length of Indonesia's coastline is estimated at around 54,716 km, making Indonesia the country with the second longest coastline after Canada. The length of this coastline reflects the diversity and richness of marine ecosystems in Indonesia and is rich in abundant fishery resources, one of which is bigeye tuna (Thunnus Obesus). The research method used in this article is a literature review which includes a comprehensive review of various scientific sources, research reports, and statistical data related to the impact of overfishing of bigeye tuna on the balance of the Indonesian marine ecosystem, especially in the Banda Sea. Overfishing practices have caused a decline in the population of this fish, with a significant impact on the balance of the marine ecosystem in the Banda Sea. Unsustainable fishing practices, the use of destructive fishing gear, and minimal supervision and law enforcement against illegal fishing practices have contributed to the decline in the population of bigeye tuna (Thunnus Obesus). The impacts of overfishing of bigeye tuna (Thunnus Obesus) are: Drastic Decrease in Tuna Population, Food Chain Imbalance, Impact on Other Species, Marine Habitat Damage, and Biodiversity Decline, thus becoming a national and global threat. To overcome the impacts of overfishing of bigeye tuna in the Banda Sea, it is necessary to set strict catch quotas, stricter supervision and law enforcement, use of environmentally friendly fishing gear, and restoration of damaged marine habitats

Keywords: *ecosystem, overfishing, tuna*

INTRODUCTION

Concern about overfishing of bigeye tuna (Thunnus obesus) in the eastern Pacific Ocean (EPO) has prompted a search for practical options for reducing fishing mortality. Bigeye tuna are caught mainly by longline and in purse-seines, approximately half the catch being taken in purse-seine sets made on floating objects (IATTC, 2006a). The most recent stock assessment for bigeye tuna indicates that fishing mortality remains too high to be sustainable (Maunder and Hoyle, 2007) in (Lennert-Cody et al., 2008). The latest stock assessment by the IATTC reveals that bigeye tuna in the EPO is currently experiencing increasing fishing mortality and reduced abundance because of increasing fishing pressure (Xu et al., 2018) in (Lin et al., 2023). Oceanic pelagics such as bigeye tuna (Thunnus obesus, Scrombridae) are managed by Regional Fisheries Management Organizations (RFMOs) that use conditional decision-making to develop stocking limits for international fishing fleets. Limits are negotiated between member and non-member RFMOs participating in two

geographically distinct segments of the Pacific Ocean: the Inter-American Tropical Tuna Commission (IATTC) Area in the Eastern Pacific Ocean and the Western and Central Pacific Fisheries Commission (WCPFC) Area (Ayers et al., 2018). However, major challenges remain. The latest industry estimates suggest 22% of tuna stocks are experiencing overfishing and 13% are overfished. ISSF data indicates Atlantic Ocean bigeye, Indian Ocean yellowfin and Pacific bluefin tuna stocks continue to be overfished and subject to overfishing; Indian Ocean albacore and bigeye continue to be subject to overfishing but all skipjack stocks remain healthy (Marine Stewardship Council, 2021).

Indonesia has a sea area of about 3.1 km2 including inland areas, archipelagic waters, territorial seas and the Exclusive Economic Zone. The length of Indonesia's coastline is estimated at around 54,716 km, making Indonesia the country with the second longest coastline after Canada. The length of this coastline reflects the diversity and richness of marine ecosystems in Indonesia and is rich in abundant fishery resources, one of which is tuna. According to (Anung Widodo et al., 2015), the Banda Sea waters as an ecosystem unit are a combination of three specialties, namely a narrow continental sea, oceanic (deep sea) and located in the tropics (Nurhakim et al., 2007). Oceanographically, the Banda Sea is an important part of the Indonesian through flow dynamics system (ARLINDO) or Indonesian through flow, which connects water masses from the Pacific Ocean to the Indian Ocean (Sulaiman, 2000) quoted from. According to (Tambunan, 2021) tuna species include skipjack, yellowfin tuna, bigeye tuna, southern bluefin, and skipjack. Tuna are a group of fish that migrate far (highly migratory fish stocks) or fish that migrate limitedly between the Exclusive Economic Zones (EEZ) of one or more countries and the high seas (straddling fish stocks). Tuna is a leading fishery commodity in Indonesia. This fish is spread in the western and southern waters of Sumatra, the southern waters of Java, Bali, Nusa Tenggara, the Flores Sea, the Banda Sea, the Sulawesi Sea, and the northern waters of Papua. According to (Essington et al., 2002) quoted from (Xie et al., 2023) "As apex predators in the marine ecosystem, tunas play critical roles in marine food webs and reflect significant changes in the marine ecosystem, particularly in terms of pollution".

Although tuna is a very rich natural resource, it is experiencing overfishing in the Banda Sea. Overfishing can cause an imbalance in the marine ecosystem and is a global problem that threatens marine biodiversity and has an impact on the loss of marine life. Uncontrolled and continuous fishing activities and the addition of fishing fleets, fishing gear and fishing aids can lead to excessive fishing in both small and large sizes. Irrational and uncontrolled fishing that continues will result in a decrease in stocks and even extinction (Mardhiyah, 2017) from (Bete et al., 2022). According to

Hanamoto, E. (1986) in (Fachruddin Syah et al., 2019) Bigeye tuna (Thunnus obesus) is one type of tuna that is widely caught in the eastern Indian Ocean (SDL). This type is a type of pelagic fish that has a high migration rate. This fish is spread in subtropical waters and all tropical waters in the world's oceans, but not in the southwest Atlantic waters. Bigeye tuna (Thunnus obesus) is one of the important species in the marine ecosystem, especially in the Banda Sea waters. As an apex predator, bigeye tuna plays a crucial role in maintaining the balance of the food chain and the dynamics of the marine ecosystem.

However, overfishing practices have caused a decline in the population of this fish, with a significant impact on the balance of the marine ecosystem in the Banda Sea. Unsustainable fishing practices, the use of destructive fishing gear, and minimal supervision and law enforcement against illegal fishing practices have contributed to the decline in the bigeye tuna population. Therefore, it is important to conduct this research and the purpose of this research is to determine the impact of overfishing of the bigeye tuna (Thunnus Obesus) population on the balance of the Indonesian marine ecosystem.The introductory section contains: (1) research problems; (2) insights and problem solving plans; (3) formulation of research objectives; (4) a summary of theoretical studies related to research problems.

METHOD

The research method used in this article is a literature review that includes a comprehensive review of various scientific sources, research reports, and statistical data related to the impact of bigeye tuna overfishing on the balance of the Indonesian marine ecosystem, especially in the Banda Sea. This study involves an in-depth analysis of journal publications, government and non-government agency reports, and data obtained from international organizations such as the Western and Central Pacific Fisheries Commission (WCPFC) and the Indian Ocean Tuna Commission (IOTC). The data are then evaluated and synthesized to identify patterns, trends, and ecological implications of bigeye tuna overfishing, as well as to develop effective policy recommendations and conservation strategies. This literature review approach allows researchers to collect and interpret comprehensive information and provides a framework for understanding the phenomenon of overfishing in the context of the broader marine ecosystem.

RESULTS AND DISCUSSION

Tuna fish have an important role in the marine ecosystem, namely as a top predator in the marine ecosystem, tuna play an important role in the marine food web and reflect significant changes in the marine ecosystem, especially in terms of pollution. Tuna fish have an important role in the marine ecosystem, namely as a top predator preying on various species of smaller fish, cephalopods, and crustaceans, thereby helping to control

prey populations and maintain the balance of the ecosystem. In addition, tuna by preying on small fish and other marine animals, tuna help regulate their prey populations. This is important to prevent population explosions that can disrupt the balance of the ecosystem and cause depletion of other food resources. Tuna fish are also a food source for other larger predators, such as sharks and large marine mammals. Tuna fish are extensive swimmers, often migrating long distances across the ocean. This migration helps in the transfer of nutrients between different marine ecosystems, which supports biological productivity and the balance of the wider ecosystem. Thus, tuna play an important role in the marine food web. Maintaining healthy and sustainable tuna populations is essential to maintaining the balance of the marine ecosystem. However, the tuna population, especially the bigeye tuna, has been overfished since 2012, so this can have an impact on the ecosystem in the Banda Sea, thus becoming a national and global threat because excessive tuna fishing activities can cause the tuna population to decline, even become extinct and can disrupt the food chain in the ecosystem, and can also create an imbalance and damage the marine ecosystem.

Tuna are fished worldwide in all the oceans between 50°N and 45°S, but mainly in the intertropical areas. All tuna species are classified as being "highly migratory" species. This typical status is often fully justified: this is for instance the case for southern bluefin tuna, a species showing large migrations between its feeding and spawning areas around the Antarctica in the Atlantic, Indian and Pacific oceans. Northern bluefin in the Atlantic and Pacific oceans are also showing such permanent wide scale migration.

According to FAO, the first important point to keep in mind in the comparison of overfishing risks faced by the various tuna stocks world wide is the between oceans similarities in the Pacific, Indian and Atlantic oceans:

- All these tuna species are the same in each ocean and show very similar biological and behavioural characteristics.

- They are fished by multigear fisheries (mainly purse seiners, longliners and pole and line vessels) that are nearly identical in all the oceans world wide; furthermore many of the industrial fleets are mobile from one ocean to the other.

- They live in offshore and coastal pelagic ecosystems that are typical of each ocean, but showing similar global characteristics in their structure and fauna (similar associated species: sharks, billfishes, turtles, etc) and similar rates of specific by-catches.

There is then a major potential field of investigation in the between oceans comparisons of tuna stocks and their increasing exploitation by multigear

tuna fisheries. Furthermore this potential for comparative analysis of tuna overfishing mechanism is widely facilitated by the histories of the fisheries in each ocean: while the Eastern Pacific has been showing 30 years of apparent growth overfishing, the Western Pacific stock is still experiencing a moderate exploitation rate. The same comparison will be also valid between the Atlantic (where tuna purse seine fisheries have been very active for 40 years) and the Indian Ocean (where active tuna fisheries have been developed only since the early eighties with the arrival of a large fleet of purse seiners).

Bigeye tuna is a tropical species that shows some similarities with temperate species, such as its wide habitat sometimes in temperate waters, and its affinity for inhabiting deep and cold waters. Bigeye tuna stocks and fisheries have shown similar patterns worldwide over the past few years. A large increase in small bigeye catches has been observed over the past few years for surface fisheries (in relation to the use of FADs), while a large increase in large fish catches has also been observed for longlines targeting large bigeyes sold at high prices to the sashimi market (mainly but not exclusively in Japan). This increase in catches is mainly due to the specific targeting of bigeye tuna using deep longlines. Atlantic bigeye, a stock well assessed by ICCAT since the early eighties, can be considered a typical bigeye scenario of bigeye overfishing. The recent increase in catches has resulted, during the mid-nineties, in catches well above previously estimated MSY. Since this overcatch is largely achieved in small fish, there is serious concern based on all projections made by stock assessment models, that the stock may soon face overfishing. After nearly 10 years of high catches, it appears that scientists' previous estimates of MSY were too low. In fact, the current status of Atlantic bigeye stocks is not fully understood by scientists (Fonteneau, 2003)

Indonesia has a significant role in tropical tuna catch in the Western Pacific Ocean (Williams and Reid 2018). From eleven designated Indonesia's Fisheries Management Areas (FMAs), FMAs 713, 714, 715, 716 and 717 are related to the Western and Central Pacific Fisheries Commission (WCPFC). FMAs 713, 714 and 715 are Indonesia archipelagic waters (IAW), whereas FMAs 716 and 716 are in the Indonesian Exclusive Economic Zone (IEEZ). The IAW, FMAs 713, 714 and 715 have been considered to have a higher contribution to the Indonesian tuna catch relative to the IEEZ, with proportion of around 60% came from the IAW (Satria et al 2014; Satria et al 2015; Satria et al 2016; Satria et al 2017). Fisheries operating in the IAW are mainly small scale commercial vessels using pole and line, purse seine, handline, troll line and gillnet, which highly influencing the livelihood for the small scale fishers. These vessels are mostly associated with fish aggregating devices (FADs) and targeting tropical tuna, which

comprised of approximately 65% skipjack (Katsuwonus pelamis - SKJ), followed by 28% yellowfin (Thunnus albacares - YFT) and 6% bigeye tuna (T. obesus - BET) in 2006 (Satria et al 2017). These vessels also catch bycatch species, however, to date very limited studies and data collection on bycatch of tuna fisheries in the IAW. Within the IAW, risk assessments using PSA have been conducted for live bait fishery for Indonesian pole and line tuna fishery (International Pole and Line Foundation Indonesia (IPNLF) and Centre for Environment, Fisheries and Aquaculture Science (CEFAS) in consultation with Center for Fisheries Research, Ministry for Marine Affairs and Fisheries of Indonesia (CFR), and preliminary PSA for handline tuna fishery in the IAW by Masyarakat dan Perikanan Indonesia (MDPI). Since comprehensive stock assessments for tuna in the Western and Central Pacific Ocean (WCPO), have been done by the WCPFC, PSA for the tuna stock (SKJ, YFT, and BET) might be redundant, as the tuna species are believed to be one stock in the whole WCPO. Therefore, within this study PSA was conducted to investigate which gear/fishery that has the highest impact on the tuna stock (instead of investigating the potential risk of stock being a subject to overfishing) and identify which bycatch (sharks) species are in high risk by the identified fishery (gear) (Sadiyah et al., 2019)

Currently, most tuna are caught by purse seine, and longline is the second most common gear. Indonesia and Japan are consistently the top two fishing nations. The tuna fishing industry has long been plagued by overfishing, corruption, human rights abuses, fraud, and illegal, unreported and unregulated fishing, all of which endanger the well-being of the environment and communities. Pacific island fisheries are particularly threatened by corruption and a lack of strong governance (Hanich and Tsamleyi 2009). In addition, illegal, unreported and unregulated tuna fishing is a major problem, particularly in the Pacific Ocean, where estimates suggest the annual loss of value to coastal countries is around $333.5 million (MRAG Asia Pacific 2021). Globally, tuna abundance has declined by more than 50% over the past century, with the largest, longest-lived, and most valuable tuna declining most sharply (Juan-Jordá et al. 2011). Tuna stocks are either overfished or fished at levels close to the maximum sustainable yield, preventing further increases in catch. Overfished tuna fisheries must be rebuilt with more stringent measures to reduce excess capacity in the face of increasing demand (Orth, 2023)

The 2021 WCPFC-CA bigeye tuna catch was 149,693 tonnes, well below the peak (195,052 tonnes) recorded in 2004. The increase in purse seine catches of 3,396 tonnes, was accompanied by a decrease in longline catches of 7,618 tonnes, and a decrease in other gear types of almost 700 tonnes, resulting in an overall decrease of 5,000 tonnes in the total bigeye tuna catch compared to 2020. Of the total bigeye tuna catch in 2021, 34% was

caught by longline, 51% by purse seine, and the remainder by trolling, pole-and-line, and other gear types. The majority of the WCPFC-CA catch was in the equatorial region, by both purse seine and longline fisheries, but there were some longline catches in the subtropics (e.g. east of Japan and off the east coast of Australia). In the equatorial region, the bulk of the longline catch is in the central Pacific, which borders the important traditional bigeye longline areas of the eastern Pacific. As with skipjack tuna and yellowfin tuna, domestic surface fisheries in the Philippines and Indonesia catch large numbers of small bigeye in the 20-50 cm range. In addition, large numbers of small bigeye in the 25-75 cm range are caught by the purse seine fishery on the tassels, which together with the Philippine and Indonesian fisheries account for the majority of catches by number. The longline fishery, which catches mostly bigeye over 100 cm, accounts for the majority of catches by weight in the WCPFC-CA. This is in contrast to large yellowfin tuna, which (apart from longline gear) is also caught in significant numbers from unrelated groups in the Philippine purse seine and handline fisheries. Large bigeye are very rarely caught in the WCPO purse seine fishery, and only relatively small numbers are caught by the Philippine handline fishery. Bigeye fish sampled in the longline fishery were predominantly mature, with an average size of around 130 cm, with most measuring between 80 and 160 cm (Hare et al., 2022)

Results

The Banda Sea is an area of Eastern Indonesian waters that is included in the waters of the West Pacific Ocean and borders the Indian Ocean. Topographically, the waters of Eastern Indonesia have a depth of more than 2,000 m, even in some places reaching 5,000 - 6,000 m. Based on the report of PT. Perikanan Samodra Besar Benoa, the Banda Sea is one of the quite potential fishing areas. (Uktolseja et al., 1991) in (Chodrijah & Nugraha, 2013)

In the Banda Sea, the case of overfishing of bigeye tuna according to the Indian Ocean Tuna Commission (IOTC), the bigeye tuna stock in the Banda Sea continues to experience overfishing with a fishing mortality rate (F) higher than the maximum supportable fishing mortality rate (FMSY). In 2020 it reached around 83,498 tons, which is higher than the average catch in previous years. In the past 10 years, the case of overfishing of bigeye tuna in the Banda Sea has continued to be a major concern. Based on a report by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, the bigeye tuna stock in the Banda Sea has experienced overfishing and overfished. The Center for Research on Fisheries Management and Conservation of Fish Resources (P4KSI) in the same year showed that yellowfin and bigeye tuna were caught by purse seines, huhate, and a combination of surface handlines and trolling at the juvenile stage. In 2021, the Banda Sea bigeye tuna population is still under severe pressure from overfishing. Despite management

efforts, the bigeye tuna population is still below the level that can support maximum sustainable production (MSY).

Discussion

Overfishing refers to the removal of certain types of fish from water bodies at a rate that the species cannot replenish, resulting in a sparse population of these species in the area (Prasetya, et al, 2025). Compared to climate change, air pollution, or water pollution, the issue of overfishing is frequently overlooked. Even if this happens or it is a warning for the depletion of more marine resources in the future, Human beings are still overfishing many species because they desire more wealth, which is overwhelmed and greedy for the ocean (Du et al., 2021)

Overfishing is when tuna are caught in numbers far greater than their ability to reproduce, which threatens tuna populations and the marine ecosystem as a whole. Here are some of the main impacts of overfishing on tuna:

1. Drastic Decline in Tuna Population

   The population of bigeye tuna has experienced a drastic decline, which has an impact on the food chain and ecosystem balance. Bigeye tuna (Thunnus obesus) are one of the top predators in the marine ecosystem, meaning they are at the top of the food chain. As top predators, bigeye tuna play an important role in controlling the populations of prey species below them, such as small fish, squid, and crustaceans. With the drastic decline in the bigeye tuna population, the ecosystem is experiencing a severe imbalance.
2. Food Chain Imbalance

   The food chain is a complex network of interactions between species that prey on and are preyed upon. When the population of top predators such as bigeye tuna declines, their prey species tend to experience uncontrolled population increases. For example, small fish that bigeye tuna normally prey on may reproduce more rapidly, increasing pressure on other food sources, such as the plankton and other small organisms they consume.
3. Impacts on Other Species

   The decline in bigeye tuna populations also impacts other species that depend on them, both directly and indirectly. For example, other predators that feed on bigeye tuna, such as sharks and large marine mammals, may have a harder time finding food, which could ultimately affect their survival. In addition, species that are preyed upon by bigeye tuna may experience behavioral and

lifestyle changes that adapt to reduced predation.

The large increase in the catch of oceanic apex predators (such as tuna, sharks, and marlin) by tuna fisheries around the world has, over the past few years, resulted in a serious decline at the top of the oceanic food chain. The potential impacts of this decline are unclear (given the fact that this pelagic biomass pyramid is virtually unfished and is still pristine in all its lower components). The potential top-down impacts of predator removal on these food chains, especially the removal of some predators that may play a role as "keystone species" in ecosystems (Paine 1966), are still largely or completely unknown. Similarly, the risks of altered interactions between populations of the various species of declining apex predators (including between tuna species) are still largely unknown to scientists. Overall, there is little doubt that these risks have been permanently increased by the worldwide increase in tuna, marlin, and shark catches, and the likely large decline in their biomass. Careful tuna fisheries management must take these risks into account.

4. Destruction of Marine Habitat
   Overfishing is also often accompanied by fishing practices that damage marine habitats, such as the use of non-selective fishing gear and the destruction of coral reefs. Coral reefs are important habitats for many marine species, including bigeye tuna. When these habitats are destroyed, the regeneration of bigeye tuna populations is hampered, further deteriorating the ecosystem.
5. Declining Biodiversity
   Biodiversity is key to a healthy and balanced ecosystem. With the decline in the bigeye tuna population, the biodiversity in the Banda Sea is also threatened. Other species that depend on bigeye tuna, either as predators or prey, will experience pressure that can cause their numbers to decline. As a result, the ecosystem becomes less stable and more vulnerable to environmental changes and other disturbances.

Solutions and Conservation Efforts

To address this problem, conservation efforts and sustainable fisheries management are needed. This includes setting catch quotas, prohibiting the use of destructive fishing gear, strict supervision of fishing activities, and efforts to restore marine habitats.

CONCLUSION

Overfishing of bigeye tuna in the Banda Sea has had a significant and widespread impact on the balance of the marine ecosystem in the region. This overfishing has caused a drastic decline in the population of bigeye tuna, which has triggered a series of negative impacts on various components of the marine ecosystem. The decline in the population of bigeye tuna, which functions as a top predator, has resulted in an imbalance in the food chain and disruption to various species that depend on them. The increase in the population of prey species due to the loss of natural predators has put excessive pressure on other food resources. The destruction of marine habitats, such as coral reefs, due to destructive fishing practices, has exacerbated the situation, reduced biodiversity, and threatened the stability of the ecosystem. Conservation and sustainable management efforts are needed to mitigate these negative impacts and maintain the sustainability of marine resources for future generations. With appropriate actions and international cooperation, it is hoped that the marine ecosystem in the Banda Sea can recover and remain sustainable.

REFERENCES

Anung Widodo, A., Thomas Mahulette, R., & Fayakun Satria. (2015). *Status Stok, Eksploitasi Dan Opsi Pengelolaan Sumberdaya Ikan Tuna Di Laut Banda Stock Status, Exploitation And The Management Option Of Tuna Resources In Banda Sea*.

Ayers, A. L., Hospital, J., & Boggs, C. (2018). Bigeye tuna catch limits lead to differential impacts for Hawai`i longliners. *Marine Policy*, *94*, 93–105. https://doi.org/https://doi.org/10.1016/j.marpol.2018.04.032

Bete, S., Tallo, I., Paulus, C. A., Program Studi Manajemen Sumberdaya Perairan, M., dan Perikanan, K., Nusa Cendana, U., Program Studi Manajemen Sumberdaya Perairan, D., & Peternakan, F. (2022). Pengelolaan Perikanan Tangkap pada pendekatan Ekosistem melalui Domain Teknik Penangkapan Ikan di Kecamatan Kakuluk Mesak Kabupaten Belu. *Jurnal Bahari Papadak*, *2022*, 127–136. https://ejurnal.undana.ac.id/index.php/JBP/index

Chodrijah, U., & Nugraha, D. B. (2013). *Distribusi Ukuran Tuna Hasil Tangkapan Pancing Longline Dan Daerah Penangkapannya Di Perairan Laut Banda Size Distribution Of Tuna Caught By Longline And Its Fishing Ground In The Banda Sea Waters*.

Du, Y., Sun, J., & Zhang, G. (2021). *The Impact of Overfishing on Environmental Resources and the Evaluation of Current Policies and Future Guideline*.

Fachruddin Syah, A., Lumban Gaol, J., Zainuddin, M., Apriliya, N. R., Berlianty, D., & Mahabror, D. (2019). Habitat Model Development of Bigeye tuna (Thunnus obesus) during Southeast Monsoon in the Eastern Indian Ocean using Satellite Remotely Sensed Data. *IOP Conference Series: Earth and Environmental Science*, *276*(1). https://doi.org/10.1088/1755-1315/276/1/012011

Fonteneau, A. (2003). *Biological Review Of Tuna Stocks And Overfishing*.

Hare, S. R. ., Williams, P. G. ., Castillo Jordán, C. Antonio., Hamer, P. A. ., Hampton, John., Lehodey, Patrick., Macdonald, Jed., Scott, R. D. ., Scutt Phillips, Joe., Senina, Inna., & Pilling, G. M. . (2022). *The Western and Central Pacific tuna fishery : 2021 Overview and Status of Stocks*. Pacific Community, Communauté du Pacifique.

Lennert-Cody, C. E., Roberts, J. J., & Stephenson Lennert-Cody, R. J. (2008). *Effects of gear characteristics on the presence of bigeye tuna (Thunnus obesus) in the catches of the purse-seine fishery of the eastern Pacific Ocean*. https://academic.oup.com/icesjms/article/65/6/970/603434

Lin, H., Wang, J., Zhu, J., & Chen, X. (2023). Evaluating the impacts of environmental and fishery v ar iability on the distribution of big e y e tuna in the Pacific Ocean. *ICES Journal of Marine Science*, *80*(10), 2642–2656. https://doi.org/10.1093/icesjms/fsad163

Marine Stewardship Council. (2021, May 2). *Tuna Fishing Rapidly Shifting Toward Sustainability*. 2021. https://www.msc.org/media-centre/news-opinion/news/2021/05/02/world-tuna-day-tuna-fishing-shifting-toward-sustainability

Orth, D. J. (2023). *Conserving Tuna: The Most Commercially Valuable Fish on Earth*. 2023.

Prasetya, S. P., Prasetyo, K., Warsono, W., Sarmini, S., Yani, M. T., Suprijono, A., ... & Ibrahim, M. H. (2025). Comparison of climate change awareness among coastal communities in northern and southern East Java, Indonesia. Jurnal Pendidikan Geografi: Kajian, Teori, dan Praktek dalam Bidang Pendidikan dan Ilmu Geografi, 30(1), 9.

Sadiyah, L., Satria, F., Hargiyatno, I. T., & Widodo, A. A. (2019). Potential risks of tuna fishing conducted in Indonesia's waters and its impact on tuna and shark. *IOP Conference Series: Earth and Environmental Science*, *404*(1). https://doi.org/10.1088/1755-1315/404/1/012081

Tambunan, N. Y. (2021). Peran Lembaga Pengelola Perikanan (LPP) Dalam Perikanan Tuna Di Indonesia. *Jurnal Ilmu Sosial dan Pendidikan*, *5*. http://ejournal.mandalanursa.org/index.php/JISIP/index

Xie, J., Bian, Z., Wu, Q., Tao, L., Wu, F., & Lin, T. (2023). Global knowledge domain and prospects in tuna research: A bibliometric analysis. *Aquaculture and Fisheries*, *8*(2), 202–210. https://doi.org/https://doi.org/10.1016/j.aaf.2021.09.005