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# Taboos/Norms and Modern Science, and Possible Integration for Sustainable Management of the Flyingfish Resource of Orchid Island, Taiwan

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**Abstract:** Coastal management without scientific data or modern techniques has been implemented successfully by many coastal communities, and traditional ecological knowledge (TEK), which is regarded as a culturally framed belief system, has played an important role in the successful cases. TEK of flyingfish culture in the Orchid Island was proved to have a theoretical basis and advantages in managing the flyingfish resource. However, modernization, introduction of modern techniques (motorized boats), development of tourism, and numerous other factors have caused TEK to change or disappear, and integration of TEK with the modern science of environmental management may be a solution to sustain the marine resource. TEK constitutes numerous taboos and norms (T&N). This study, for the first time, itemized the T&N of the flyingfish culture by category, with plausible motives explained by the respondents through in-depth interviews of tribespeople in 2014 and 2015, and identified the T&N with ecological conservation implications. The study also implemented a sampling scheme to provide the first records of fishery composition, flyingfish catch amount (about 260,000–280,000 fish per year), and the catch rate for the island. Finally, this study discussed three interrelated approaches for sustainable management of the flyingfish resource, including integration of TEK with science-based monitoring, control and surveillance (MCS), and research.

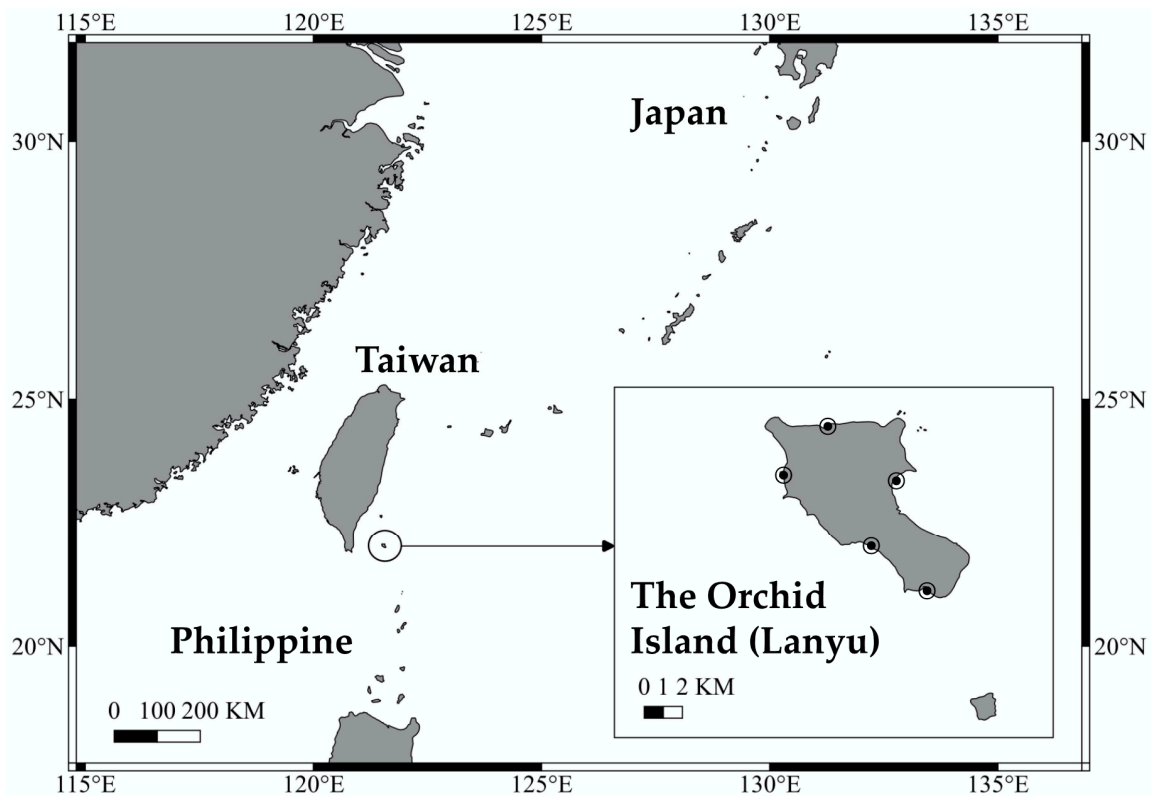
**Keywords:** traditional ecological knowledge; indigenous & community conserved area; Orchid Island; Tao; flyingfish culture; taboos and norms; MCS

## 1. Introduction

Coastal management without scientific data or modern techniques has been implemented successfully by many coastal communities globally for centuries [1–3]. This management utilized traditional ecological knowledge (TEK) or local ecological knowledge (LEK), which local or indigenous people developed through their direct contact with the environment over hundreds or thousands of years [4]. Numerous definitions of TEK exist, and the concept may “mean different things to different people” [5]. Among a large number of studies [3], Berkes et al. (2000) define TEK as “a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings with one another and with their environment” [6]. By contrast, Davis and Ruddle (2010), after reviewing many definitions, interpret TEK from a theoretical perspective as a “concept” that “TEK might be regarded as that aspect of a culturally framed belief system most directly arising from and concerned with food production and other material needs” [5].

Orchid Island, or Lanyu in Chinese and “Island of the People” according to its ethnic name, is a traditional habitat of the Tao ethnic group located off the southeast coast of Taiwan (Figure 1) [7]. The Tao’s marine TEK is known by the flyingfish (the Exocoetidae) culture [7,8]. It consists of a calendar

of various festivals and ceremonies centered on the irruption season of flyingfish (called the flyingfish season). In addition to taro, the large shoal of migratory flyingfish that arrives at Orchid Island regularly each year [9] is an important dietary food for the Tao people. To secure the food supply, related taboos, norms, and festivals were thus developed, transmitted through myths, and demonstrated by a number of ceremonies during the flyingfish season that were the most important cultural and socioeconomic activities of the year. Together, these taboos and norms (T&N), which were supported by both the knowledge of the local environment and the deep-rooted social values, culturally framed a belief system and constituted the flyingfish culture [5,10,11].



**Figure 1.** Location of the Orchid Island (also called “Lanyu”). The five dots on the map of the island are the fishing ports visited by researchers for catch statistics estimation.

Liu and Chang (2019) [10] applied the five conditions for achieving effective ecological and environmental resource management (EERM) established by Dietz et al. (2003) [12] to analyze the effectiveness of Tao TEK, and concluded that Tao TEK complies with the conditions proposed. Moreover, the authors proved that application of the flyingfish culture to the management of Orchid Island’s marine and fishery resources has its theoretical basis and advantages. However, as seen in many other examples [13–16], inappropriate government policies, modern science and technology, education, and the market economy have caused this unique marine TEK to change [7,10]. Specifically, in the belief system, some of the T&N have ecological conversation implications (such as effort control) and some might simply be superstitions. Modernization through introduction of modern technology and education has caused young generations to gradually disrespect the T&N as a whole (not only those considered as superstitions). The attraction of the market economy further induced the abandonment of the T&N. These effects negatively impacted the sustainable use of the marine resources in the Orchid Island, particularly the flyingfish resource [10].

The value of TEK to the success of EERM has been well recognized and was advocated to be integrated into modern marine environmental management, whereas the traditional command-and-control system was demonstrated to be inefficient for many reasons [17–20]. Integrating the Tao TEK with ecological benefits into the modern science of environmental management may be a solution

to sustain the marine resources. Before integration, however, the types of T&N need to be identified and the ecological benefits of the T&N need to be further explained to regain the respect and appreciation of younger generations. The design of a modern investigation of the resource and the introduction of scientific knowledge associated with the EERM of the region are also necessary for integration.

To fulfill the above needs, this study serves three purposes: (1) identifying and providing the first itemized list of the major T&N relating to the flyingfish culture and plausible explanations for the T&N based on a literature review and in-depth interviews; and identifying the T&N from the list that have ecological conservation implications; (2) investigating the catches of flyingfish from the fishery aspect (fishing methods, total amount, and catch rate) and from the biological aspect (species composition and biological features), to provide the first record of flyingfish catch estimates of the region and scientific knowledge about the resource; and (3) proposing an integrated resource management scheme and advice for sustaining the flyingfish resource of the island.

## 2. Materials and Methods

### 2.1. Flyingfish Culture Related T&N and Their Ecological Conservation Implications

This study attempted to understand the views of Tao people on the various T&N of flyingfish culture and how these arise to achieve the first purpose of the study mentioned above. The methods used were the same as those described in Reference [10], and can be briefly described as follows: this study involved cultural T&N and other sensitive issues, so the triangulation method (using multiple approaches to collect and analyze data to enhance the credibility of a research study) was used to enhance its credibility [21–23]. A literature search was firstly conducted in which flyingfish related T&N were collected from magazines, electronic media, master theses, and books ([24–32] are some of the major references). A selection of the important practices in flyingfish culture are summarized in Sections 3 and 4 of Reference [10] with specific quotations from two of the most important books on Tao culture written by a Tao researcher/elder [24,25]. In-depth interviews were then carried out during fieldwork (described later) to ask Orchid Island residences about their understanding of the culture. Two phases of in-depth interviews were conducted in two flyingfish seasons by two researchers staying on the island for two months during each season. Overt observations [33] were also made by the researchers during their stay.

During the first phase (1 March 2014–5 June 2014), contact was established with each of the six tribes on the island, and the contents of this study were communicated and discussed with them. With the tribes' consent, the initial list of respondents was drawn up with the assistance and consultation of the respected tribal elders. After the initial respondents were determined, with their assistance, the snowballing method was used for the random selection of the other respondents. Efforts were made to balance the selection of respondents by tribe and age as much as possible. Preliminary interviews were also performed during this phase. The complete interviews were held during the second phase (1 April 2015–25 May 2015). A total of 58 Orchid Island residents from the six tribes, ranging in age from 30 to 60, with eight types of occupation (including retired at home), were interviewed with their consent (refer to Table 1 of Reference [10]). The appendix of Reference [10] provides important translated quotations from the two Chinese books and from the respondents. For this study, the interviews had two purposes: first, to confirm the T&N collected from the literature and enquire about the inputs of new T&N (to make the list as complete as possible); and second, to seek explanations for the meaning of the taboos. Based on these results, significant T&N were itemized, and plausible explanations were provided. The T&N with implications for, or effects on, ecological conservation and management were also identified.

**Table 1.** Selected taboos and norms of flyingfish culture that have ecological management implications. Refer to Appendix A for the code.

Code	Taboo/Norm (in Brief)	Ecological Implication
O02	Flyingfish caught by a fishing group must be shared among members and cannot be sold.	Catch control: control the catch enough for their own needs.
E05	Flyingfish caught by a fishing group must be consumed in a day or a week in the early period of the season.	Catch control: control not to fish over their needs for consumption.
R06	The harvests must be cooked by boiling method before daytime feasting festival (about May).	Catch control: reduce the consumption for restaurants that sell fire roasting fish.
O06	Any preserved or stored fish in the home should be finished first before flyingfish are eaten.	Catch control: reduce consumption and avoid waste.
R09	Boil and consume unfinished flyingfish with taro as staple diet.	Catch control: reduce consumption and avoid waste.
O07	Discard all stored flyingfish after the festival marking the end of flyingfish consumption (approximately in October).	Catch control: encourage not to fish flyingfish over their needs.
L15	Women cannot participate in fishing activities.	Effort control: reduce fishing manpower.
E07	Family having a funeral cannot go fishing for some time.	Effort control: reduce fishing efforts in the sea.
O03	Only one fishing trip per day is allowed during flyingfish season.	Effort control: reduce fishing efforts and avoid overexploitation.
O08	Categorization of fishes into three groups: men's fish, women's fish, and elders' fish.	Effort control: reduce fishing efforts for a single fish or a few fish resources.
R04	Harvests of flyingfish must be blessed with sea water and undergo scale-removing process.	Effort control: time-consuming scale-removing process can reduce fishing time at sea.
E06	Process of flyingfish harvests must be finished by sunset.	Effort control: reduce fishing time at sea.
L06	Fishers of a tribe cannot fish in the waters of other tribes.	Effort control: reduce excessive fishing efforts in other fishing grounds.
R02	Fishing with nets, spear gun, or fishing poles for other fish species (mainly the coral reef fishes) is strictly prohibited during the flyingfish season.	Closed fishing season: no fishing efforts in the spawning season of coral reef fishes (overlapping with flyingfish season).

## 2.2. Flyingfish Catches with Respect to Fishery and Biological Aspects

Tao people do not maintain a system of specific catch statistics; therefore, they have no information on the total amount and species composition for monitoring the resource dynamics. For the second purpose, the two researchers visited five fishing ports daily (the two major ports on the western side of the island) or once per two days (the remaining three ports) during their stay to record fishing activities, estimate the landing and species composition, and, with the agreement of the fishers, randomly sample fish for size measurement and maturity examination. The species was identified based on Reference [34,35]. Fishing methods were recorded and catch rate was calculated as fish per day. Tao people respect the flyingfish and dislike anyone touching the catch; thus, for most cases the number of fish caught could only be counted in tens or even hundreds of fish, and the estimation made in the second year (2015) contained more detailed information than that of the first trial in 2014.

## 3. Flyingfish Culture Related T&N and Their Ecological Conservation Implications

### 3.1. The T&N Related to the Flyingfish Culture

Historically, food and medical resources on Orchid Island were highly deficient; thus, the flyingfish that seasonally migrate to the island each year became a major food source for the Tao and were also used as “currency” for the exchange of goods [36]. However, going to sea to fish was dangerous at that time and the catch was not necessarily sufficient to satisfy the needs of the Tao. According to respondents, the Tao ancestors regarded flyingfish as a gift from the gods, or even an “elf” that could communicate with the ancestors, while at-sea accidents or unfavorable catches were considered to be due to offenses to the gods, or due to evil spirits and bad luck. These beliefs may be the basis for the development of the beautiful and sophisticated flyingfish culture, which contains many T&N, myths, and stories [24,25]. Descriptions of the culture can be found in Section 3 of Reference [10], including the important flyingfish calendar that defines and divides Tao's yearly activities into three periods.

Flyingfish culture comprises hundreds of detailed T&N; furthermore, different tribes may interpret the T&N differently. Based on the references cited in Section 2 and interviews with 58 tribespeople of different tribes, ages, and occupations, this study, for the first time, attempted to compile 41 T&N

associated with flyingfish culture. Nonetheless, this list is preliminary and not complete (complex details were not included) and does not include those T&N that relate to flyingfish festivals which are too detailed (some of these are found in Reference [10]). The plausible motives behind the T&N were explained, mostly by respondents. They were not necessarily agreed to by all respondents; however, they provided plausible views on the background of T&N, in addition to clues for further studies. Details of the T&N and plausible motives are listed in Appendix A for the sake of clarity. Based on the motives explained by the respondents, the T&N were loosely categorized into four groups: respect, luck (good catch), exorcism (safety), and others.

### 3.1.1. Respect

Flyingfish are regarded as a sacred gift from gods and must be “welcomed” by tribespeople as honorable guests. Consequently, any disrespectful actions, either overt or implicit, are prohibited during the flyingfish season. Such disrespectful actions include fishing by any methods for other fish species along the coast, playing in or throwing stones toward the sea, pointing at flyingfish, and saying unlucky words. Admiration is also shown towards the harvest, in which flyingfish must be splashed with seawater following prayers of appreciation and blessings, after which scales are removed and washed back into the ocean, implying their return to nature. The preparation of fish is another aspect representing respect towards the catch, in which fish are only allowed to be boiled in seawater (symbolizing “blessing”) before the daytime feast (approximately in May, Table 2 of Reference [10]); specific cutlery are reserved for eating flyingfish; flyingfish can only be eaten with taro, a local staple; and, fish are never mixed with other animal food forms such as pork or shellfish. To mark the start of the flyingfish season all diners must be well dressed in traditional clothing during the first flyingfish service. At the end of the flyingfish season (October) all remaining flyingfish are returned to the ocean signifying a revival of the resource.

**Table 2.** Catch estimate (in fish numbers) and catch proportion of flyingfish by fishing methods for Orchid Island in 2014 and 2015. Composition of 2014 estimate was adjusted slightly based on the proportion of fishing methods used in 2015.

Fishing Methods	2015		2014
	Catch Estimates	Catch Proportion	Catch Estimates
Motorized netting	225,430	93.05%	263,800
Flyingfish net—night	204,275		
Flyingfish net—day <sup>1</sup>	4620		
Drive-in net	16,535		
Tatala small boat	3025	1.25%	4000
Tourism net <sup>2</sup>	1200	0.50%	2400
Coastal net <sup>3</sup>	3600	1.49%	4800
Unrecorded catch <sup>4</sup>	9000	3.72%	10,000
<b>Total</b>	<b>242,255</b>	<b>100.0%</b>	<b>285,000</b>

<sup>1</sup> Based on interviews with fishers in the ports; <sup>2</sup> Based on the observation of 6 weeks with good weather, 10 trips per week, and about 20 fish each trip; <sup>3</sup> Mainly in one port and starting from March. Excluding the days affected by typhoon, there were about 3 weeks with good weather, and each week fishers were deployed 6 times with about 200 fish caught per deployment; <sup>4</sup> Some boats fished after the end of the flyingfish season, after which the researchers had left the island. The catch estimate was based on the number of boats and average catches gathered from telephone interviews.

### 3.1.2. Luck

There are many T&N in this category, most of which relate to the luck needed for a good catch. Among these, many are associated with ensuring good luck is not diminished; for example, prohibiting people from other tribes fishing in the tribe’s waters; prohibiting people of other families trespassing on ceremonies or entering specific lots for drying fish; and refraining from passing other people’s houses with a harvest to avoid taking away the luck of those who do not yet have a catch. Many of the

other T&N are associated with bad luck related to women. Flyingfish are considered a sacred species, and women are forbidden to participate in fishing activities, touching fishing equipment, being close to the shore, or even engaging in intimate behavior with their husbands (for a certain period). The spirit of these T&N is also reflected in the fact that only male livestock are slaughtered during the flyingfish season. Furthermore, due to the high rate of early dystocia during that time, pregnant women were easily associated with death; therefore, pregnant women, their husbands, and midwives, are excluded from the activities of the flyingfish season.

### 3.1.3. Exorcism

The T&N of this category relate to evil spirits. During the period of waiting for the flyingfish to come and the early months of the irruption season (approximately in February and March), the harvest caught at night must be kept in the boat until the following morning to avoid evil. The harvests must be processed before sunset (before 3 pm); an evil spirit is believed to haunt and consume the flyingfish harvests after sunset. Harvests of a fishing group during the early period of the flyingfish season must be finished within a day or a week (depending on the tribe; eaten by themselves or shared with others). For the same reason, unfinished large fish (e.g., dolphinfish), which have ominous implications, that are prepared in the morning must be discarded at noon; similarly, unfinished flyingfish prepared during the afternoon must be discarded before sunset.

### 3.1.4. Others

Many T&N of this category are associated with sanitation considerations; for example, all flyingfish harvested or stored must be discarded after the ceremony that marks the end of flyingfish consumption (approximately in October). Keeping these products is believed to result in doom. Harvests caught together have to be shared equally among the participants, representing a “virtue of sharing” of the Tao people. Fish species are categorized into three groups: “women’s fish” (best “quality” but difficult to catch; both women and men can eat); “men’s fish” (inferior “quality” and easy to catch; only adult men can eat); and “elders’ fish” (lowest “quality” or rare, ferocious species; mainly for experienced elders to process and eat). However, some respondents disagreed with having a category of elders’ fish. Flyingfish are edible by all people.

## 3.2. *The T&N with Ecological Conservation Implications*

Among the T&N listed in Appendix A, 14 were identified that may have ecological conservation implications or effects: six of these are associated with catch control, seven with effort control, and one with the close of the fishing season (Table 1). The harvests caught by a fishing group shall be shared among the members of the group, cannot be sold, and must be consumed within a day or a week during the early period of the season; the harvests can only be boiled before daytime feasting (flyingfish sold in restaurants are fire roasted) and consumed before the stores of other fish species are used. These T&N have the effect of reducing catch consumption and avoiding wastage of food. More specifically, the norm that all flyingfish stores must be discarded or given to pigs to eat following the festival that marks the end of flyingfish consumption encourages tribespeople to only catch sufficient flyingfish for their needs.

Many T&N have the effect of reducing the effort required for fishing; for example, women cannot participate in fishing activities; families must wait a certain period after a funeral before fishing; and fishing more than once per day is forbidden. In addition, categorizing types of fish has the implication that men must spend more time for “women’s fish” that are not easy to catch. Under the conditions that women cannot participate in fishing activities and cannot eat “men’s fish,” such a norm reduces the fishing effort required for certain fish resources to avoid the possibility of over-exploitation. Prayers of appreciation and scale-removing must be performed before harvests are taken home. These processes are time consuming and must take place before sunset, and both have the effect of limiting fishing time (and effort) at sea. Another specific T&N is that fishers of a tribe cannot fish in the waters of other tribes, indicating the existence of a fishing territory institution of the

common property resources of flyingfish. This institution cannot control the distribution of fish resources; nevertheless, it can control who is eligible to fish and the means of fishing. As a result, the potential for over-exploitation of resources and the uncertainties in fishing management are expected to be reduced [26,37].

Finally, in flyingfish season, fishing nets, spearguns, and fishing rods are forbidden to be used for catching other species, mainly the coral reef fishes. Incidental catches must be released back into the sea. The flyingfish season generally spans from March to May, which is also the spawning season of the coral reef fishes. Therefore, this T&N has the effect of ensuring a closed fishing season for the spawning coral reef fishes.

#### 4. Flyingfish Catches with Respect to Fishery and Biological Aspects

##### 4.1. Fishery Information

Understanding fishery composition and catch amount are basic tasks for resource management. Traditionally, tribespeople used labor-intensive big boats (and formed fishing groups) and hand-made colorful wooden small boats (locally known as “tatala”) for catching flyingfish. For the big boats, the catch per day was usually only 20–30 fish, and 60 fish was considered a huge catch [38]. However, the situation was substantially changed by the introduction of highly efficient motorized boats, which almost destroyed the traditional fishery composition (i.e., fishing methods), in addition to the compliance with many of the T&N described above. The average catch per day of a motorized boat is approximately 200–300 fish, with the peak catch exceeding 1000 fish. Therefore, the investigation of the current fishery composition is crucial for further considerations of flyingfish resource management.

Three types of fishing methods were found from the investigation to use motorized boats: flyingfish net (a type of gillnet) fishing during both nighttime and daytime, and drive-in net (locally known as purse seine) fishing during daytime. In addition, tatala small boat nets, tourism nets (fishing for tourism purposes), and coastal nets were also found to be used. Table 2 shows the estimated flyingfish catch by fishing method for 2014 and 2015. This is the first recorded flyingfish estimate for Orchid Island. The lower catch in 2015 may have been due to the strong typhoon that hit the island during the flyingfish season, which reduced the available fishing days. In addition, tribespeople noted that the fish migrated farther from the coast in 2015 compared to normal, which may have been an effect of a strong El Nino in 2015 [39]. The table suggests that the Tao people caught about 260,000–280,000 flyingfish per year (about 80% were caught on the western side of the island) using the modern motorized fishing technology.

The catch rates in 2015 for flyingfish nets (nighttime) was estimated to be 1767 fish/day. The catch rate was as high as 3395 fish/day during April of 2015 at the southwestern port and 3733 fish/day during May at the central eastern port; these values were considerably higher than in the past. For drive-in nets, the catch rate in 2015 was estimated to be 1838 fish/day, and was up to 2975 fish/day at the northwestern port and 1739 fish/day at the northern port. Flyingfish migrates from south to north, and fewer fish typically arrive at the northern ports after intensive exploitation by boats from the southern or central ports. Therefore, drive-in nets, used by 3–4 motorized boats to “drive” and circle the fish for netting, was intensively used by fishers from the northern ports. The high catch rate from utilizing motorized boats resulted in tribespeople returning to the use of traditional fishing methods and following all of the traditional T&N associated with fishing.

##### 4.2. Biological Information

Based on port sampling during 2014–2015 and two additional at-sea surveys in 2014, at least eight flyingfish species existed in the waters off Orchid Island (due to the restriction of using small mesh-sized nets, other small flyingfishes were observed at sea but could not be sampled). Flyingfishes in the catch are listed in Table 3, including major species of greater spotted flyingfish (GSP) and limpidwing flyingfish (LPW). Among these, GSP is unique to Orchid Island, occurring only in the

island's waters and not found elsewhere in Taiwan [9]. The mesh size of the flyingfish net is larger than that of the drive-in net, so only large flyingfish were caught; these comprised 69% and 24% of the catch in April and May of 2015, respectively, for GSP, and 31% and 76%, respectively, for LPW. Drive-in nets were mainly used in May; GSP comprised about 65% of the catch, and the remainder were mainly LPW and sailfin flyingfish.

**Table 3.** Flyingfish species occurring in the waters off Orchid Island. The first two species marked with an asterisk were the major species caught during the flyingfish season.

Species Name	Scientific Name	Local Name
Greater spotted flyingfish *	<i>Cheilopogon atrisignis</i>	papatawon
Limpidwing flyingfish *	<i>Cheilopogon unicolor</i>	sosowowon
Sutton's flyingfish	<i>Cypselurus suttoni</i>	matezetezem so panid
Spotwing flyingfish	<i>Cypselurus poecilopterus</i>	kalalow
Narrowhead flyingfish	<i>Cypselurus angusticeps</i>	loklok
Blackwing flyingfish	<i>Cheilopogon cyanopterus</i>	mavaeng so panid
Bony flyingfish	<i>Hirundichthys oxycephalus</i>	kararakpen no arayo
Sailfin flyingfish	<i>Parexocoetus brachypterus</i>	sanisi

The GSP and LPW in the catch were all large fish based on a visual survey by the researchers in each of the two years. In total, 470 fish were randomly sampled, and their sizes ranged from 24 to 31 cm for GSP, and 27 to 33 for LPW. The average gonadosomatic index (GSI, equal to gonad weight/gutted body weight) of females was 9.1 (2.6–18.9) for GSP and 8.7 (3.2–15.1) for LPW, suggesting that these large fish were in spawning or post-spawning stages. Two studies (supervised by the author of this study) on reproductive cycles based on the analyses of gonad histology and GSI support the view that the GSP and LPW collected from the region during flyingfish season were in spawning capable phase with the presence of tertiary vitellogenic oocytes, hydrated oocytes, and postovulatory follicles [40,41]. Researchers observed spawned eggs on fish during sampling; respondents also indicated occurrences of spawned eggs on nearshore floating objects. Therefore, it is highly likely that the spawning grounds of the two major species exist in the waters off Orchid Island.

## 5. Suggestions for Integrated Resource Management Scheme

“TEK might be conceptualized as a people's shared system of knowledge or other expression about the environment and ecosystem relationships that is developed through direct experience within a specific physical setting and transmitted intergenerationally” [5]. TEK in flyingfish culture of Tao could be regarded as “a culturally framed belief system” that is “mostly arising from and concerned with food production” [5] to secure the sustainable use of the seasonal flyingfish resource. However, nowadays, many tribespeople received modern knowledge from education in Taiwan, or locally from tourists or a Taiwanese spouse. Many experienced the convenience and efficiency of using motorized boats, and many enjoyed the commercial benefits from tourism and trading. As a result, numerous T&N in TEK have gradually been disregarded (more than two-thirds of the respondents of this study mentioned they did not comply, or observed non-compliance, with some of the T&N, and many considered they could secure a good catch without participating in any rituals), leading to the consequent weakening of flyingfish culture and its effect on EERM [7,10].

As indicated in Section 4, the fishing methods and conditions, in addition to fishing efficiency, are now significantly different from those used historically. Therefore, the management approaches implied in TEK must also be adjusted. To ensure sustainable management of the natural flyingfish resource under the current situations, this study notes three potential and interrelated approaches as follows, including integrating the T&N with modern science.



### 5.1. Enhancing Cultural Self-Recognition and Highlighting the T&N with Ecological Conservation Benefits

Cultural myths are traditional stories that have meanings attached and are powerful drivers of individual and national behavior [42,43]. As demonstrated in Liu and Chang [10], application of flyingfish cultural myths to the management of Orchid Island marine fishery resources has theoretical bases and advantages. The culture has established a sound scheme for conserving the resource, surveilling peoples' behaviors, and enforcing the T&N through admonition or boycott, in addition to the inherited virtue of respecting nature. Each of these factors could substantially benefit the conservation of marine resources.

From in-depth interviews and overt observations, five levels of recognition or compliance of T&N were found in Tao society following the impact on the culture of modernization processes. (1) Full compliance: most highly respected elders over 80 years old still live in a traditional manner, strictly comply with the norms, and believe in the existence of evil spirits. (2) Partial compliance: the majority of tribespeople only believe part of the T&N (especially those with a scientific basis); however, they still fear evil spirits, believe in curses, and respect their elders. Furthermore, when they offend the T&N, they tend to find excuses to justify their offences, or use pigs or chickens as a scapegoat, indicating their behaviors are still affected by the culture. (3) No care: a small proportion of tribespeople consider T&N as superstitions and do not care. They mostly engage in the tourism industry, are young, and have a language barrier with the elders. (4) Back to learning: Most middle-aged people returning from Taiwan are willing to learn and promote the culture. (5) Independent from culture: Some small number of tribespeople are not concerned with the culture and engage in a business that does not relate to the culture.

These results suggest that opportunities remain to enhance the recognition of, and consequently the respect of, the culture for Tao people. The government should take measures before it is too late. At least three measures could be considered: (1) to encourage young generations to learn the ethnic language to diminish language barriers between generations, and to appreciate and pass down TEK; (2) to promote cultural tourism, in addition to eco-tourism, related to the myths and T&N to induce tribespeople's understanding and recognition of tribal cultures; and (3) to highlight the T&N with ecological management benefits or effects based on scientific interpretations to demonstrate the wisdom behind the T&N, thus demonstrating that they are not just relics of the past but are also needed today, and even into the future, for natural resource conservation [44,45].

### 5.2. Integrating TEK with Science-based Monitoring, Control, and Surveillance (MCS) and Research

As indicated above, a large part of TEK is challenged by modern mainstream systems and began to lose its effectiveness in limiting the use of marine resources [7,10,46]. However, integrating TEK with modern science-based technology may revive the functions of TEK [17–19]. The following ideas relate to the integration of TEK with the modern management mechanism of MCS [47] and scientific research.

#### 5.2.1. Monitoring

Monitoring catch statistics is a basic task needed to manage a resource. Many of the T&N in Table 1 could prevent the catch from exceeding the needs of local consumption. However, the development of tourism (which increased the need for fish), weakening of compliance, and expansion of the use of motorized boats (which increased fishing efficiency) have substantially increased the catch size, as indicated in Section 4. These factors highlight the importance of understanding the composition and catch quantity of current fisheries. Section 4, for the first time, provided an estimate of the current catch level based on port sampling. Tribespeople could establish a similar reporting system to estimate catches by fishing method and port. This could be reported to the tribe's development association, and then to the township office to derive an aggregated catch amount. Data on the effort made in terms of fishing days and boats should be collected at the same time to allow the catch rate to be calculated. Species composition is also important information relating to the catches, and the catch rate by species

should be monitored to avoid a collapse of the resource. Because the major species are highly likely to spawn in the island's waters, if possible, size and gonad weight of major species should also be collected per month using a suitable sampling design.

### 5.2.2. Control

The flyingfish T&N in Table 1 provide internal regulations to control the utilization of the resource via effort control, catch control, and a closed fishing season. Under the current situation, it is a challenge to require compliance with all of the T&N by people benefiting from the tourism industry. However, for sustainable management of the flyingfish resource, the following measures could be considered. Regarding catch controls: (1) Investigate the needs of local people and tourists, and, if feasible, set a moderate limit on tourism consumption; the loss due to the limitation might be able to be offset by the price premium. (2) Consider a halt on the sale of flyingfish to Taiwan, which was observed in 2015, to reduce the uncertainty in catch control. (3) If feasible, negotiate a total allowable catch (TAC) and allocate this to the six tribes. When doing so, it would be good to implement the virtue of sharing exhibited in the T&N to give special consideration to the tribe with a low catch rate (i.e., to the north of the island). (4) Investigate the number and size of motorized boats by fishing method and implement a scheme to restrict the increase in these boats, particularly drive-in net boats with high catch rates. Due to the remarkable benefits obtained from fishing and tourism, operators tend to build larger and more efficient boats, as seen in the development of Taiwanese distant-water fisheries [48]. The restriction should be implemented before this takes place. (5) The ban on fishing for other species during the flyingfish season in the T&N will substantially benefit the conservation of the resources of coral reef species that spawn during this period. This should be emphasized and maintained, especially because the development of tourism has increased the need for coral reef fishing and fish consumption. (6) As described in Section 4.2, spawning grounds may exist for the two major flyingfish species (GSP and LPW). In-depth interviews of residents revealed several clues regarding the location of these spawning grounds. Further studies should be encouraged to find and protect the spawning grounds.

### 5.2.3. Surveillance

The culture already contains a spontaneous and mutual monitoring and management scheme. To enforce the control regulations, this component should be strengthened (Section 5.1 provides an option for this purpose.) Taking advantage of this feature and respecting the autonomy of each tribe, one recommended mechanism is to organize a motorcycle patrol team for each tribe. In addition, the functions of negotiation and decision making of each tribe's development association should be strengthened to deal with rule setting and reporting of offences. The township office should take the responsibility of negotiating general control regulations and cross-tribe issues.

### 5.2.4. Research

Scientific research could help clarify the concerns of the younger generation regarding the T&N. Many of the T&N gathered from the interviews (not shown here) provided important knowledge about the resource. Through participation in scientific research programs, the knowledge could be verified and more widely distributed; for example, the tribespeople have knowledge of the locations of small-scaled fish aggregation and the occasional change of fish migration routes, but are unclear about the causes and the large-scaled effects of climate change and variations of ocean currents on the migration routes; they found LPW outside of the flyingfish season (winter) in the waters of the island but are unclear about the large-scale distribution of flyingfish in the northwestern Pacific [9]; and they found juvenile flyingfish in their waters but have no information about the species and possible spawning ground to be protected. Scientific research could help address these issues, and joint research programs on these subjects, amongst others, could reinforce and enrich the T&N.

### 5.3. Highlighting and Strengthening Autonomous Decision-Making Function Necessary to Become an ICCA

Orchid Island contains a natural ecosystem with significant ecological benefits and cultural values. This ecosystem is voluntarily conserved by indigenous peoples and local communities through customary laws or other effective means (e.g., T&N). As such, it meets the definition of an Indigenous and Community Conservation Area (ICCA) [49,50], which is promoted by the International Union for Conservation of Nature (IUCN) for effective governance and resource management of natural ecosystems. An ICCA has three important features [49,50]: (1) an indigenous people or local community possesses a close and profound relationship with a site; (2) the people or community are the major player in decision making related to the site and has de facto and/or de jure capacity to develop and enforce regulations; and (3) the peoples' or communities' decisions and efforts lead to the conservation of biodiversity, ecological functions, and associated cultural values, regardless of original or primary motivations. Orchid Island and the Tao people's efforts are consistent with the first and third features. Implementing the approaches described in Sections 5.1 and 5.2 could strengthen the function of Tao people to fulfill the second feature. The government, or non-governmental organizations, are recommended to invest and contribute to make Orchid Island a world-recognized ICCA for effective governance of the flyingfish resource. The resulting sense of honor could in turn improve the self-recognition of Tao culture and enhance the functions of the T&N.

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## Appendix A

**Table A1.** Taboos and norms of the flyingfish culture on Orchid Island, and their possible motives, are summarized from literature reviews and in-depth interviews with indigenous residents. This list is considered incomplete and more information can be found in Liu and Chang (2019) [10] (on Tao's traditional calendar and myths of the culture) and Tang and Tang (2010) [7].

Code	Taboos and Norms	Plausible Motives or Interpretation
R01	Playing in or throwing stones toward the sea are prohibited during flyingfish season, and women must not get close to the shore.	To show respect to the coming of flyingfish.
R02	Fishing with nets, spear guns, or fishing poles for other fish species is strictly prohibited during the flyingfish season.	To show respect to flyingfish and focus on celebrations of the flyingfish festivals. Catching other fish is prohibited before the "ceremony to mark the end of catching flyingfish" (around July); it is believed to be necessary to maintain the resources of other fish species.
R03	Do not say any ominous words, do not point at the flyingfish in the sea, and do not wash food in the river.	According to tradition, if any ominous word is spoken when the fishing groups are living together, all of the fish must be discarded. If any child speaks ominous words during the flyingfish season, they are punished (Tao people normally do not punish their children because it is considered as a bad omen). During the flyingfish season, tribespeople will cook food with seawater' thus, if a tribesperson were to wash their food in the upper river, the sea will be contaminated.

Table A1. Cont.

Code	Taboos and Norms	Plausible Motives or Interpretation
R04	The harvested flyingfish need to be blessed with sea water first before the scale-removing process, and the removed scales need to be returned to the sea.	Returning fish scales to the sea shows gratitude to nature for providing food. The scales also draw big fish closer to the shore. Returning scales to the sea can also prevent the breeding of maggots on the shore.
R05	Everyone must be wearing traditional clothing with gold and agate as accessories on their first flyingfish feast for celebrations.	The first flyingfish caught is a symbol of good luck, and is shared and celebrated with the fisherman's family. The first fish shall not be used as bait.
R06	Flyingfish must be cooked by boiling method only; roasting or deep frying are prohibited before "flyingfish daytime feasting festival" (around May).	In Tao myth, a person who eats roasted fish will grow sores on their body. Following the "flyingfish daytime feasting festival" is the month of <i>Peypilapila</i> (a month based on Tao's calendar system when the "flyingfish storage festival" will be held; this occurs around June and most flyingfish taboos end at that time). According to tradition, the most skillful person at fishing or someone who caught a mahi-mahi fish ( <i>Coryphaena hippurus</i> ) will slaughter a pig as a sacrifice to the sea god, telling the god that they will roast the fish; only then they can start roasting the fish.
R07	Sea water must be used to cook flyingfish and the pot must not be covered until all flyingfish are in the pot. When the water boils, a dry reed must be lit as illumination.	Seawater symbolizes a blessing. The fish are not edible if they are not cooked with the <i>ataw</i> (seawater from the nearby beach, which is also a means to season the food). The ash from the wood fire is considered unlucky, so must be exorcized with a dry reed.
R08	Flyingfish are not allowed to be cooked with other foods (non-staple food like shellfish or pork) and must be cooked and served in their specific cooking ware and dinner ware.	The flyingfish is recognized as a sacred fish; cooking and mixing it with other foods will cause disease.
R09	Leftover flyingfish will be cooked with taro (staple food).	Taro can only be harvested once per year, so is a precious food source for the tribe, and is often served as a staple food with flyingfish and other big fish.
R10	Flyingfish must be hung properly and never dropped on the floor; rocks must not be thrown toward the fish rack.	No disrespectful behavior toward flyingfish.
R11	During the "ceremony to mark the end of catching flyingfish" (around July), the fins of flyingfish and other big fish are removed and left on the rocks of the right-hand side of the harbor, allowing them to be flushed back to the sea.	Symbolizing a revival ritual of flyingfish and other big fish.
L01	People are not allowed to speak, rock the boat, or yell when they sight flyingfish during nighttime fishing.	Yelling flyingfish are sighted will draw evil spirits to the boat. The tribe does not mention anything if they are going for fishing, because the evil spirit will affect their fishing conditions.
L02	It is best to catch an odd number of fish on the flyingfish season. A chicken can be brought on the boat if fish are not caught.	Traditionally, odd numbers are considered good luck. The ideal number of fish caught is three, followed by one, five, seven, and nine. They believe the clucking of a chicken will attract the fish.
L03	When carrying fish back to their house, fishers must walk a specific route and avoid walking past neighbors' houses.	When someone walks past a neighbor's house carrying flyingfish, it will affect the neighbor's fishing luck.
L04	All fishing boats have to depart before sunrise on "small boats daytime fishing festival" (around May).	This may relate to the foraging time of big fish, which usually starts around 3–4 am.
L05	Trespassing by other families to the flyingfish festival is forbidden.	The fishing luck will be "stolen" by others.

Table A1. Cont.

Code	Taboos and Norms	Plausible Motives or Interpretation
L06	It is prohibited for people from other tribes to fish in a tribe's territorial waters, eat fish caught by the tribe, or trespass into the tribe's area.	The fishing luck will be stolen by the people of other tribes if they enter the territory of the tribe.
L07	In <i>Kasiyaman</i> and <i>Paneneb</i> (a calendar system used by Tao people, in which the beginning of the flyingfish season is around February to March), the fish harvested during nighttime must be left overnight in the boat until the following morning. The fish can only be taken directly back home at <i>Pokokaod</i> (when the fishing group of big-boats is disbanded, around April).	The fish will leave overnight in the boat to avoid being noticed by the evil spirit. The roaming dogs and pigs on the island will steal the fish in the boat, so the tribe will stay and guard their fish.
L08	Orange and Indian Barringtonia ( <i>Barringtonia asiatica</i> ) are two taboo things in Tao culture. Do not mention the two things and do not bring orange to the ship or give as a treat. Eating snails and ginger is also prohibited during fishing.	One tribesperson said that Indian Barringtonia is known as an unholy plant because it often grows near graveyards; others said that the pronunciation of Indian Barringtonia is similar to "medicine" in the language of the Ivatan (a nearby tribe in Philippines), and the pronunciation of oranges is similar to "no fish" in the Tao language.
L09	The drying fish rack must be surrounded by a bamboo wall and no one is allowed to enter, especially pregnant women or midwives.	The bamboo wall will guard the fishing luck; the luck will be "stolen" if others get too close.
L10	Flyingfish must be served whole; cutting in into pieces is not allowed.	Eating flyingfish in pieces will bring bad luck to fishing.
L11	During the "boat festival," all boats must be parked at the right-hand side. The first flyingfish caught from the left-hand side must be pulled out from the right-hand side. Flyingfish must be cook on the right-hand side of the house.	"Right" symbolizes big and precious, and "left" symbolizes small and common. "Right" actually means the direction of the sunrise and left/right is relative to the direction facing the sea; for example, in Yuren village, when facing the sea, the sun will rise on the left-hand side, so villagers build their stoves at their left-hand side; however, for the Yeyin village, on the other side of the mountain, villagers build their stoves in the opposite direction.
L12	Housework, such as weeding, house building, or boat building, is prohibited when the members of a fishing group are living together.	There are many things to do during flyingfish season. It is considered taboo if housework is performed instead of focusing on fishing, and tribespeople will not catch any fish.
L13	Weaving by women is prohibited during the flyingfish season, because it will cause bad luck for their husband's fishing trip.	Women have to help with the cropping work and preparing of the fish. Weaving is considered a task during their spare time, so if they are; thus, weaving indicates they have nothing to do, thereby bringing bad luck to their husband's fishing trip.
L14	Women are not allowed to touch men's fishing gear, approach the shore, or participate in the flyingfish festival. Intimate acts between husband and wife are forbidden when members of the fishing group are living together.	Men believe that they will fail to catch fish or even lose their offspring if their boat is touched by women. Intimate acts are forbidden probably because they wish to focus on fishing.
L15	Women, especially pregnant women, are considered taboo to fishing activities. For example, a fisherman will fail to catch any big fish if his wife is pregnant. Cooking and collecting of dry flyingfish must be done by men, and women can only help with fish cleaning and gutting.	Tribal tradition states that if a pregnant woman turns over a reef rock, it will cause a tsunami. Others say the belly of pregnant women are round; round things roll, so the fish will roll away and escape. Thus, pregnant women are only allowed to eat fish caught by her own family and no one else, otherwise the fishing luck will be affected. Furthermore, all flyingfish related work is mostly done by men.

Table A1. Cont.

Code	Taboos and Norms	Plausible Motives or Interpretation
E01	Tao people will spread charcoal ash inside their boat during nighttime fishing.	Charcoal ash symbolizes "destroy," similar to salt or shellfish ash, and is often used in the exorcism of evil spirits.
E02	The people will place a cross made of dry reeds on the boat if any fish are caught during the flyingfish season.	A cross made of dry reeds will stop and prevent haunting by evil spirits.
E03	Wives and children must stay home if their husband/father are still on the shore and not yet fishing.	To avoid notice of evil spirits and preventing the husband/father from going fishing, or let the husband/father ensure the safety of their family and keep their focus on the fishing trip.
E04	Harvesting of common phytia ( <i>Pythia scarabaeus</i> or <i>namisil</i> in Tao language) are prohibited.	The reef rock needs to be pried open to harvest the common phytia. According to tribal tradition, the gesture of "pry open" will cause the boat to turn over.
E05	Flyingfish caught by a fishing group must be eaten within a day or a week. Every family member of a fisherman must eat the fish before noon. <i>Jianachan</i> (unfinished fish in the morning) will be discarded after 1–2 pm and a new batch of dried flyingfish will be cooked afterward; however, this fish will also be discarded if not finished before sunset.	Stocking of flyingfish is prohibited during the start of flyingfish season. The fish must be eaten or given away as gift. Any leftover flyingfish is considered unlucky; an evil spirit will come and share the flyingfish.
E06	All harvested flyingfish must be processed before sunset (before 3 pm).	The daytime and direction of sunrise is considered good luck. Tradition says that evil spirits will come out and share the flyingfish after sunset.
E07	If one tribesperson passes away, the whole tribe will stop fishing, hunting, or farming activities for 3–7 days to mourn their death (in the present day, the mourning period is reduced to 1 day due to the increase in tourism demand); the family of the deceased must rest for one month before resuming fishing and are not allowed to participated in the "flyingfish summoning ritual".	Tao people believe that one will turn into an evil spirit after death. If someone dies, the deceased will be buried in a cemetery and no praying or funeral will be held, and the local tribe will place bamboo or a wooden board in front of the door to prevent being haunted by the evil spirit. The family of the deceased will not participate in festivals and the name of the deceased will not be mentioned to ease their grief.
O01	Adult men should get their hair cut at the beginning of flyingfish season.	A haircut symbolizes a fresh start. According to tradition, if one does not get a haircut, he will be considered an orphan and will be mocked and made fun of by others.
O02	Flyingfish caught by a fishing group must be shared equally among members; selling or taking more than they need is prohibited.	Tao people share not only their harvested fish, but everything that can be shared. They claim that sharing united the Tao people and it is the feature of their culture about which they are the proudest.
O03	Only one fishing trip per day is allowed during the flyingfish season.	To prevent competition and overfishing.
O04	The drying process of flyingfish can only be undertaken by adult men. Flyingfish will be placed horizontally in the daytime and hang vertically during nighttime.	The flyingfish is mostly placed horizontally during early times; the fish is hung vertically when there are more fish harvested to save hanging space. The fish head must point inside the house when placed horizontally, meaning more fish are welcomed into the house; the fish head is only allowed to point toward the sea after the "small boats daytime fishing festival". In the present day, only Hongtou and Yuren villages place their flyingfish horizontally; other villages hang their fish vertically.
O05	The eyeball of the flyingfish must be eaten raw, before any other part; however, women are not allowed to eat the eyeball.	The fish eyeball is considered to be good for health, so has to be eaten in its freshest state (raw). Women are not allowed to approach the shore. The eyeball will no longer be fresh when taken home, so women are not allowed to eat the eyeball. To prevent the eyeball from rotting, it must be removed first during the drying process. In early times, the fish eyeball was taken as breakfast due to a shortage of food.

Table A1. Cont.

Code	Taboos and Norms	Plausible Motives or Interpretation
O06	Any preserved or stored fish at home should finished first before flyingfish is eaten.	To prevent food being wasted.
O07	All flyingfish must be finished or discarded before <i>manoyotoyon</i> (ceremony marking the end of flyingfish consumption, around October); following this ceremony, Tao people are not allowed to eat flyingfish until the next season starts.	Tao people believed that any leftover flyingfish in the home will bring bad luck to their family. Due to a lack of food preservation methods in early times, this is believed to be associated with health and sanitation considerations.
O08	Edible fish species are divided into three groups: "elder's fish", "man's fish", and "women's fish". Women are not allowed to eat "man's fish".	Generally, "women's fish" are difficult to catch but have the best quality, and are edible for both women and men. "Men's fish" are easier to catch but have lower quality, and may only be eaten by adult men. Unusual or ferocious looking fish, or those with the lowest quality fish, are classified as "elder's fish," and mainly eaten by experienced elders. Flyingfish is edible for all people.

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