Determination of fisheries refugia area for freshwater eels (Anguilla spp.) in Palabuhanratu bay, West Java, Indonesia

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Abstract. Freshwater eels (Anguilla spp.) are categorized as the order of Anguilliformes and have unique life cycle characters as a catadromous fish that migrate between freshwaters and sea waters. One of the concepts for fisheries management is fisheries refugia. Fisheries refugia is defined as sustainable use and not simply ‘no-take zones’. The concept focuses on links between critical habitats and fish life cycles. This study was aimed to determine fisheries refugia area for freshwater eels (Anguilla spp.) in Palabuhanratu bay, West Java, Indonesia. The research was conducted in several rivers that flow to Palabuhanratu bay. The study was organized from August 2014 to April 2015. Morphological identification, water quality, and habitat conditions as a basis for determination, hence, Cimandiri was carefully chosen as Fisheries Refugia area. The river composed with complete stadia, from glass eels to silver eels. Management recommendations with fisheries refugia concept included: prohibition of catching adult stadia in sizes above 49 cm; establishment of river areas as nursery ground protection in Sukaraja Sub-district; affirmation of prohibition electric and poison fishing methods (using); prohibition of glass eels fishing in January, February, March and December; and regulation of policy between cities or regencies.

Keywords: Anguilla, conservation, freshwater eels, protection, refugia

1. Introduction

Freshwater eels (Anguilla spp.) are categorized as the order of Anguilliformes and have unique life cycle characters as a catadromous fish. Catadromous fish is a fish that migrate between freshwaters and sea waters. The fish spawn in the deep sea, produce larvae (leptocephalus) and are carried by turbulent current towards the edge of ocean. Leptocephalus develops into glass eels which begin changing pigment of body, then grow into elvers and enter to river or estuary areas. Elvers mature into yellow eels and finally become silver eels to return to the sea for spawn and die (Aida et al 2003, Tesch et al 2003).

Freshwater eel (Anguilla spp.) is one of the fishery commodities with important economic value in the world. The decline of Anguilla Anguilla population in America and Europe and A. japonica in Japan make tropical eels for consumption target of the world's eel market (Arai 2014). Catching and cultivating activities from year to year tends to increase. One of the areas with freshwater eel resource
potential is Palabuhanratu bay (South Coast of Java Island) (Sriati 1998). The potential of freshwater eel fisheries in Palabuhanratu Bay significantly supports to fisheries activities for people income in Sukabumi Regency. However, freshwater culture is very determined by the availability of glass eels in the river (nature stock). There is another activity in around of this area can affect the internal factors of biological eel fish. In Palabuhanratu bay, there are not only freshwater eel resources but also crustacean resources were potential in this area (Wardiatno et al 2016a, b, c, Wahyudin et al 2017). The threats of overfishing and habitat degradation occur in Palabuhanratu bay and need for management resources.

Fisheries refugia is defined as marine or coastal areas where specific management measures are implemented to sustain important species (fisheries resources) during the critical phase of their life cycle, for sustainable use (UNEP 2005). The concept of fisheries refugia is constructed by identification and design with priority areas for integrated fisheries and habitat management (Paterson et al 2013). Protection area of freshwater eel with of fisheries refugia concept focuses on natural habitat condition and critical life cycles of fish in Palabuhanratu Bay. Morphological, water quality and habitat conditions are used to determine species protection areas with the concept of fisheries refugia.

The protection areas needed to be informed to stakeholders about the dangers of over-exploitation, especially in certain locations which are reproduction pathways. So, the process of fish recruitment is not disturbed. The guarantees of the spawning migration will ensure the existence of fish stocks in nature (Affandi 2005). This study was aimed to determine fisheries refugia area of freshwater eels (Anguilla spp.) in Palabuhanratu Bay, West Java.

2. Materials and methods

2.1. Time and location
The research was conducted in Cimandiri watershed include Sukabumi Regency, Cianjur Regency, and Sukabumi City (figure 1). Data were collected from December 2014 to April 2015.

Figure 1. Map of Cimandiri River, West Java (— = Cimandiri River).
2.2. Research procedure
Data were collected to involve primary and secondary data. Primary data was obtained through river tracking and interviews. Before river tracking and interviews, one river was chosen first for fisheries refugia area based on information obtained from several references in generally eel research and specifically eel research in Palabuhanratu bay. Rivers that have been designated as refugia fisheries areas were reviewed through river tracking to observe habitat conditions, fishery and other activities around the watershed. In addition, interviews were conducted to discuss points considered important in the life cycle of eel fish. In addition, interviews were conducted with fishermen or local people around the river to find out the stage, location, and activity of catching eels.

2.3. Data analysis
All biological and social information were analyzed spatially in the map form of the utilization and protection area for freshwater eel fisheries resources. Maps were made by including certain areas that should not be used or protection spots and certain areas that can be exploited or catching points. Spatial analysis was performed using ArcGIS 9.3 software. Determination of the grass eels number or quota that must be protected was based on several assumptions with each value. The assumptions were several values of fecundity, hatching rates, and survival rates. This assumption had been adjusted to the conditions of Cimandiri River waters. Furthermore, the potential of glass eels in the Cimandiri River was estimated from the collectors.

3. Results and discussion
One of fisheries management was protection areas for important habitats in critical stadia of the life cycle of freshwater eel to maintain stock availability in nature. The protection area was determined based on biological and ecological information. In addition, the determination of the protected area must be adjusted to the social conditions in the community around Palabuhanratu Bay. Therefore, the concept of protection area needed understanding of all aspects (biology, ecology, and social). One of the concepts for fisheries management is fisheries refugia. The concept of fisheries refugia emphasized the protection of certain locations that become habitats in the critical life cycle, not prohibit total capture based on zoning area (Paterson et al. 2013). However, fisheries refugia provided areas for protection (spawning and nursery ground) to be closed for the critical life cycle (UNEP 2006). Freshwater eels in the original habitat would be preserved at important times for the life cycle, thus reducing growth overfishing and overfishing recruitment. Fisheries refugia were focused on areas that are very important for the life cycle of fish.

3.1. Establishment of the Cimandiri River as a fisheries refugia area
Fisheries refugia area was determined based on the characteristics of freshwater eel fisheries resources with several parameters. The parameters as a basis for determining the fisheries area include morphological identification, water quality, and habitat conditions in some rivers. The main parameter to choose one river from several rivers is water quality and habitat condition in each river.

Morphological identification showed that freshwater eels from some rivers have 3 species; there were A. bicolor, A. nebulosa nebulosa, and A. marmorata (Hakim et al. 2015). According to Arai (2014), A. bicolor in South of Java waters was thought to spawn in Mentawai waters. Larvae were carried by turbulence and currents towards the edge of the ocean. Larva developed into glass eels which begin and entered to river or estuary areas. It was suspected that there was connectivity of species in each river because it had the same spawning area. So, the determination of fisheries refugia area based on morphological information could be selected in any river. Determination of the area was emphasized on other parameters (water quality and habitat conditions).
Based on information about water quality and habitat conditions, there were several rivers that were eligible to be selected as freshwater eel protection areas. However, the Cimandiri River is considered appropriate to be chosen as a fisheries refugia area. The Cimandiri River has pollution index status in the category of mild polluted to medium polluted. The water quality index was unpolluted category and has a good status in fishery feasibility (Vamellia 2014). The other reason was Cimandiri River which was the largest river in Sukabumi Regency, so it had great potential for eel fisheries resources. The criteria of selected area based on UNEP (2005) were the importance of the life cycle of imperative economic species and the possibility of increasing stock. Good environmental conditions could maintain stock availability and increase stock.

3.2. Management of eel fisheries based on the concept of fisheries refugia

Fisheries refugia focused on the critical stages of species in the life cycle and sustainability for long time. Management was prioritized for small-scale fishermen. According to UNEP (2005), fisheries refugia did not simply zone determination that was not allowed to catch, but have a sustainable use purpose for present and future interests. The recommendations of the management plan were based on the characteristics of freshwater eel. Biological, ecological, and social aspects played an important role to formulate the utilization and protection of resources. Recommended for management strategies as follows:

3.2.1. Prohibition of catching adult stadia in sizes above 49 cm. Freshwater eels were catadromous fish where the preservation of populations was very dependent on migration successfully. In addition, eel fish cultivation activities still depend on the availability of glass eels in nature. There was no technology to help freshwater eels for spawning. Freshwater eel (Anguilla bicolor) spawned in deep-sea waters and the freshwater eel from Palabuhanratu Bay were estimated to have spawning areas in Mentawai waters (Arai 2014). The success of spawning was very needed for sustainable for freshwater eel fisheries.

A. bicolor bicolor has a size of silver eels at 49.7 cm to 63.6 cm with 4 to 6 years old (Arai et al 2011). Catching adult eels in the upstream area was a threat because the methods that used were not environmental friendly (used poisons). Though adult stadia were a critical stage for eels who needed to be protected hence spawning occurs. Freshwater eels migrated back into deep-sea waters for spawning. The adult fish in all parts of the Cimandiri River (upstream, midstream, and downstream) with sizes above 49 cm were forbidden to be caught.

3.2.2. Establishment of river areas as nursery ground protection. Freshwater eels migrated to search spawning and enlargement areas. The fish entered the river for exploration the enlargement area in upstream and migrated back to the sea for spawning. Distribution based on life stages showed that eel fish spread to all parts of the river. In the Cimandiri River, freshwater eels were found from the mouth of river until order one in upstream. The eel found in order one included adult category. The silver eel stage (adult eels) would return to the sea waters. Meanwhile, the yellow eel stage was experiencing growth. According to Deelder (1984), the yellow eel stage was more sedentary because fish conduct activities to fatten the body.

There were 56 parts of the Cimandiri River with river order 1. River with river order 1 was the upstream part where habitat and water conditions were still good. There was not much waste input from public activities. The area was suspected to be the habitat of yellow eels that needed to be protected area. Therefore, it was necessary to protect the river order 1, but not all river parts must be protected. General requirements that must be fulfilled were water resources must always be there. This meant that the part of the river to be protected was a permanent river with river order 1. Sukaraja Subdistrict was considered appropriate to be chosen as the protection area. Sukaraja Subdistrict has 7
permanent rivers with river order 1. The Cimandiri River on river 1 in Sukaraja subdistrict was shown in figure 2 which was a green part of the river.

From seven parts of the permanent river with river order 1 in the Sukaraja subdistrict, would be re-elected as protection area (not all from seven parts). The area must have been a supportive habitat for survival as the availability “lubuk” for stay and hide. In addition, we also needed to know about community activities with potential to throw waste into the waters. Therefore, the part of river that will be chosen was not or little community activities.

The concept of fisheries refugia was more emphasized in closing areas where fish was spawned or enlarged based on the season (Saikliang 2014). Fisheries refugia did not close an area to be permanently closed (Paterson et al 2013), but fisheries refugia were highlighted on providing areas that were very important in the life cycle such as spawning and broadening (UNEP 2006). The concept of fisheries refugia in Vietnam has established 2 pilot sites as areas that would be protected as a spawning ground and nursery ground for several important species managed by local communities (Long and Tuan 2014). The nursery area needed to be protected to prevent growth overfishing; the management steps were similar to the management of spawning areas (Siriraksophon 2014). The concept of fisheries refugia was applied to marine fisheries. This study recommended Sukaraja Subdistrict as a pilot site for eel protection in the Cimandiri River. Management steps needed to be reformulated between the Sukaraja Subdistrict community and the government of the two regencies and one city.

Figure 2. Areas of utilization and protection of freshwater eel fisheries in Cimandiri River ( = protection area; = Cimandiri river; = sub-district boundary; = grass eel area).

3.2.3. Prohibition of electric fishing and fishing methods (using poison). Electric fishing was a fishing method using electric tools. This fishing gear could turn off all types of biota in various sizes, so it was very harmful to other non-target fish. In addition, this tool is not environmental friendly. The use of electric fishing gear has been banned from fisheries communities in the lower stream (glass eels fishing grounds). However, there was still the use of electric fishing gear in the middle stream. In addition, there were fishing activities using unsuitable methods. In the upper stream, some people caught adult eels using poison or cyanide. This was very dangerous for all types of biota. Therefore, there needed to be confirmed regarding the prohibition using electric fishing and poison or cyanide.
3.2.4. **Prohibition of glass eels fishing in January, February, March, and December.** Glass eel fisheries were the main fishing activity in the Cimandiri River. This location had seen very high fishing activities. The fishing activity was carried out along 5 km from the river mouth (Hakim et al 2019). Every distance of about 10 meters along 5 km was almost found by fishermen on riverside during the peak season. Most of these fishermen were not main fishermen. The catches were very large and exceed the capacity of the collectors, so all catches were not utilized properly. In addition, it was feared reduce the probability of adult fish to live. However, if it was not used, glass eels would death naturally. Therefore, it was necessary to set the time and number of captures on glass eels stage.

Glass eel potential must be calculated to determine glass eel capture limits. The potential calculation was done by making several assumptions. The assumptions about eels in general were:

a. There were several values of fecundity, hatching rates, and survival rates in general that had been adjusted to the conditions of Cimandiri River waters.
   - Fecundity of eel based on Tesch et al (2003) was 1.3 million to 1.5 million eggs.
   - Hatching rates from eel eggs by 80% based on research by Chang et al (2004).
   - The preleptocephalus to glass eels phase had a survival rate of 1%. This was based on the distance of eel migration from the spawning site to freshwater (river mouth).
   - Survival rates of glass eels to elvers was 20% and survival rates of elvers to yellow eels was 40-60% by Tesch et al (2003).
   - Survival rates from yellow eels to silver eels were 90%. It was assumed that in this phase the eel did not remote migration and was not a critical phase.
   - Survival rates of silver eels (inland water) to a maturity stage and ready to spawn was 10%. It was assumed that silver eels must migrate far from river waters into the deep sea.

b. Glass eels capture was 50% of the glass eel potential in the Cimandiri River.
   The potential of glass eels in the Cimandiri River was estimated from the collectors. In the Cimandiri River, there were several glass eel collectors; one of them was Mr. Engkan. He was a collecting fisherman who controls 30% of the total catch in the Cimandiri River with an average production amount of 300 kg/year; so that the total average catches production in the Cimandiri River was 1,000 kg/year. Based on the production, with assumption of catches was 50% from glass eel potential. It could be assessed that the glass eel fishery potential in the Cimandiri River was 2,000 kg/year.

Based on the previous assumption, 2,000 kilograms of glass eels with a total of 12,000,000 individuals produced by the parent (silver eels) as many as 1000 individuals. Based on the assumption, the number of glass eels by capturing was 1000 kilograms with a total of 6,000,000 individuals. The fish would grow to silver eels as many as 432,000 individuals. For sustainable glass eels stock, it was necessary to limit the capture of 11.57% of the total catch.

PT JSI was one of the largest cultivation companies in Palabuhanratu that received most of the glass eels from the Cimandiri River. The data of PT JSI was assumed to describe the availability of glass eels on the Cimandiri River. The total of glass eel receives in 2013 was 580,927 kilograms (JSI 2013 in Widyasari 2013) with monthly production as shown in figure 3. When fishing restrictions were 11.55% of total catches, it was reducing glass eel revenue by 67 kilograms. Sixty-seven kilograms was the number of glass eels from January to March and December.

The fourth month had a number of glass eels of 11.55% from the total glass eels received by PT JSI. These months had relatively few numbers. This illustrated the catches in the Cimandiri River with a relatively lower compared to other months. If fishing in those months would result low catches. January, February, March, and December were not recommended for glass eels fishing.
Figure 3. The month of prohibited (red color) and allowed (blue color) for glass eels fishing in Cimandiri River.

c. Regulation of policy between cities or regencies

Cimandiri River was a river that passes through Sukabumi and Cianjur. The current regulations only focus on each regency, there was no integrated regulation from all authority in Cimandiri River. For example, Sukabumi focuses on glass eels capture fisheries, but there is no regulation regarding fishing activities from upstream to downstream. Community activities around Cimandiri River in Cianjur Regency and Sukabumi City would have an impact on the condition of the river in Sukabumi Regency. Therefore, it is necessary to have relevant policy regulations between the regencies or cities for integrated management both utilization and protection properly.

4. Conclusions

Fisheries refugia concept is recommended to include prohibition of catching adult stadia in size above 49 cm; establishment of river areas as nursery ground protection in Sukaraja Sub-district; affirmation of prohibition electric and poison fishing methods; prohibition of glass eels fishing in January, February, March and December; and regulation of policy between cities/regencies.

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